Emotional Spaces in Virtual Reality: Applications for Healthcare & Wellbeing

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This thesis is dedicated to my beloved family; Mrs Reem, Eng Abdallah, Omar, Sa'ad and Hamzeh Tabbaa, without you, I could not have achieved this

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Abstract

Despite the abundance of research that supports the efficacy of Virtual Reality (VR) in applications for healthcare and wellbeing, the process of designing VR as an emotional space that fosters the appropriate therapeutic milieu is rarely discussed. Furthermore, current approaches for VR design tend to be lone one-off controlled experiments, rather than extensions to advance knowledge of best practices that considers the real-world deployment contexts. In this research thesis, a series of studies were carried out to investigate the effects of emotional experiences in VR within healthcare contexts, and how to design emotional spaces in VR, in a way that meets the needs of key stakeholders such as clinicians, patients and the deployment setting. First, the psychological and physiological effects of VR was explored. This study investigated the emotional effects of engaging in 360-degree video-based experiences in VR and the use of eye-tracking in VR to predict emotional elicitation. The study also explored the potential of eye-tracking in VR as a tool for emotional assessment in healthcare and wellbeing. The second study investigated the use of VR as an emotional space in a healthcare setting by presenting VR as a non-pharmacological intervention for people living with moderate to severe dementia residing in a locked psychiatric hospital. The study concluded that by "bringing the outside in" VR was cognitively stimulating, sustained attention, promoted wellbeing among the patients, reduced behaviour that challenges, and offered a unique medium for caregivers and patients to build therapeutic rapport. Finally, the last study analysed the co-design, iterative prototyping and evaluation of four user-centred psychological, cognitive and behavioural VR interventions. This study aimed to understand the design elements of effective, meaningful and enriched VR interventions.

The findings are drawn in this thesis, and the implications of these findings extend the theoretical and practical knowledge in designing emotional spaces within VR in a way that fosters the appropriate therapeutic medium for healthcare and wellbeing contexts.

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List of Acronyms

360-VEs	360° Video-Based Virtual Environments
ACT	Acceptance & Commitment Therapy
IADS	Affective Digital Sounds System
API	Application Program Interfaces
CG	Caregivers
CAVE	Cave Automatic Virtual Environment
CMA	Circumplex Model of Effects
CBM-I	Cognitive Bias Modification of Interpretations
DEAP	Database for Emotion Analysis using Physiological signals
ADHD	Deficit Hyperactivity Disorder
ED	Eating Disorders
ECG	Electrocardiogram
EEG	Electroencephalogram
ET	Exposure Therapy
GSR	Galvanic Skin Response
GDS	Global Deterioration Scale
HMD	Head Mounted Displays
HCI	Human-Computer Interaction
IMU	Inertial Measurement Units
IAPS	International Affective Picutres System
MMORPG	Massive Multiplayer Online Role-Playing Games
MET	Mirror Exposure Therapy
NHS	National Health Service
OERS	Observed Emotion Rating Scale
OAS-MNR	Overt Aggression Scale-Modified for Neurorehabilitation
PWD	People with Dementia
PT	Play Therapy
PTSD	Post-Traumatic Stress Disorder
PQ	Presence Questionnaire
PC&B	Psychological, Cognitive & Behavioural
QOL	Quality of Life
SAM	Self-Assessment Manikin
SASBA	St Andrews Sexual Behaviour Assessment
3D-VEs	Three-Dimensional Computer-Generated Virtual Environments
UI	User Interface
UX	User-Experience
VIF	Variance Inflation Factor
VE	Virtual Environment
VR	Virtual Reality
VRET	Virtual Reality Exposure Therapy
VWs	Virtual Worlds
VAS	Visual Analog Scale
WHO	World Health Organization

Chapter 1: Introduction

1.1 Background

According to the World Health Organization (WHO), as of 2016, it is estimated that globally, nearly one in 10 (676 million) people suffer from a form of a mental disorder. In addition, mental health problems are one of the leading causes of overall disease burden and disability worldwide (Vos *et al.* 2015).

Due to the recent advances in technologies, in particular in Human-Computer Interaction (HCI), research has gained its momentum in developing novel technologies that support the mental healthcare and wellbeing field in general and the Psychological, Cognitive & Behavioural (PC&B) domains in specific (see section 2.3). Decades of research have shown the efficacy of technology-based interventions within this domain to cater to diagnoses and assessment (Bankole *et al.* 2012; Cushman, Stein and Duffy 2008; Mendez, Joshi and Jimenez 2015), treatment (Emmelkamp *et al.* 2001; Kip *et al.* 2018), training and rehabilitation (Bortone *et al.* 2018; Didehbani *et al.* 2016; Kandalaft *et al.* 2013) and other forms of support such as self-management (Ristau, Yang and White 2013; Schroeder *et al.* 2018).

Virtual Reality (VR) is a technological platform that has received substantial attention in healthcare research. VR refers to the combination of hardware and software that allows users to be completely isolated from the real world by surrounding them with a digitally created or captured Virtual Environment (VE) visible in every direction (see section 2.1.2 for a concrete definition). Users can explore and interact with VR content in a variety of ways such as by looking around, walking through, manipulating objects or performing actions. Nowadays, VR headsets are readily available in the consumer market with a variety of interaction modalities and working mechanisms (see section 2.1.3).

In the past two decades, researchers have utilised VR as a tool to facilitate therapies (Beidel *et al.* 2019; Bouchard *et al.* 2017; Freeman *et al.* 2018; Sekhavat and Nomani 2017; Wiederhold, Riva and Gutiérrez-Maldonado

2016), diagnoses and assessments (Gorini *et al.* 2010; Renaud *et al.* 2009; Trottier *et al.* 2014; Zakzanis *et al.* 2009), training and rehabilitation (Bortone *et al.* 2018; Hoffman *et al.* 2000, 2001; du Sert *et al.* 2018; White and Moussavi 2016) and other forms of support within PC&B domains. Research has explored the use of VR in the context of dementia (Hodge *et al.* 2018; Pettersson *et al.* 2018; White and Moussavi 2016; Zakzanis *et al.* 2009), eating disorders (Gorini *et al.* 2010; Marco, Perpiñá and Botella 2013), anxiety disorders (Bouchard *et al.* 2017; Freeman *et al.* 2018; Maples-Keller *et al.* 2017; Miloff *et al.* 2019; Sekhavat and Nomani 2017), autism (Boyd *et al.* 2018; Strickland 1997) and schizophrenia (Freeman 2008; du Sert *et al.* 2018), just to mention a few (see section 2.3).

Researchers outlined many features about VR that make it unique and attractive to use within the context of mental healthcare and wellbeing. Such features include the ability to systematically control the stimuli and provide progressive exposure suitable to the patient's pace and simulate different situations safely in comparison to the unpredictable nature of the real-world circumstances (Bush 2008; Weiss *et al.* 2006). This also compensates for some treatment-specific locations, circumstances, or situations that may be time-consuming, costly and inaccessible (Bush 2008; Rothbaum *et al.* 2000).

1.2 Problem Statement

Despite the emerging research that supports the efficacy of VR in applications for mental healthcare and wellbeing in general and PC&B domains in particular, many areas that relate to designing such VR interventions are rarely addressed.

Many PC&B disorders stem from individuals' excessive, insufficient or inappropriate emotional responses to the situations or circumstances they experience or face (Sheppes, Suri and Gross 2015). Therefore, many PC&B interventions focus on enhancing the ability to process and regulate emotions to support personal and social functioning and, ultimately, support people's quality of life to lead meaningful and stable lives (Gross 2002; World Health

Organization 2005). As such, many PC&B-VR interventions –especially therapy and rehabilitation-related interventions– have utilised VR as an emotional space, a therapeutic medium where users "step into" and emotionally engage in the therapy through VR (see sections 2.2.2 and 2.3). Such emotional spaces in VR have been used to induce emotional responses that are therapeutically meaningful such as inducing anxiety and fear for treating phobias (Bouchard *et al.* 2017; Freeman *et al.* 2018; Garcia-Palacios *et al.* 2002) and reducing emotional distress (Hoffman *et al.* 2000; Niki *et al.* 2019) (more details in sections 2.2.2). Despite the breadth of literature exploring the efficacy of VR as an emotional space in PC&B contexts, the design knowledge in this domain is still scarce. Such design knowledge is required to ensure that the VEs and the user experience as a whole in VR are designed to elicit the desired emotional responses and, most critically, meets the clinical aims of therapies.

Furthermore, users within mental healthcare and wellbeing may present with specific design requirements when designing user-friendly and effective experiences, mainly due to the variability in users' cognitive, sensory and physical abilities in this domain. For instance, people with cognitive disorders including autism, dementia and intellectual developmental disorder experience challenges in navigating technology platforms, memory recall to execute the appropriate sequence of tasks/activities, eye/hand coordination when using input devices and cope with potential information overload (Britto and Pizzolato 2016; Kalimullah and Sushmitha 2017; Kascak, Rebola and Sanford 2014; Slatin and Rush 2003). In the context of VR in general and VR for PC&B applications in particular, design guidelines, accessibility guidelines, and design framework for designing VR interventions that cater to the critical needs of users and patients are still scarce. This is particularly challenging in VR because the technology has been originally designed for gaming and entertainment purposes; as such, end-users in healthcare such as patients and clinicians may not be familiar with such interaction modalities.

In addition, technology-based interventions, including VR, typically rely on the translation of traditional clinical and therapeutic interventions rather than the design of an entirely novel intervention paradigm (Kraft and Yardley, 2009). Thus, it is vital to understand the conventional practices and processes in such therapies when adopting the therapy to VR. However, considering VR has a unique interaction modality and features, translating such conventional practices directly to VR may not be possible. As such, it is unclear what design elements need to be considered and how they can be designed to allow such an effective translation from conventional intervention to VR intervention.

Finally, much research in healthcare VR has been done in a controlled experimental setting. Although such research is valuable to demonstrate the efficacy and potential of VR, the real-world healthcare context may present with challenges to the deployment of such PC&B-VR interventions. Deployment in the context of this thesis refers to enabling technology such as VR to be ready for effective and efficient use by designing VR interventions that consider all stakeholders' needs (patients, management and security, physical environment, etc.) within a particular real-world healthcare environment. For example, it is unclear how the spatial constraints within clinics, hospitals or care homes affect the deployability of VR in these environments and how to adapt the design of the PC&B-VR intervention to cope with such constraints and hence, make VR more realistically deployable. Additionally, it is unclear whether VR can be deployed in more restricted healthcare settings such as locked, low secure, medium secure or high secure services. As such, there is a need to understand the real-world deployment contexts within mental healthcare and wellbeing and share such best-case practices to consistently design successful PC&B-VR interventions which attend to the needs of relevant stakeholders, match their design requirements and consider the real-world healthcare contexts.

1.3 Aim & Research Questions

This thesis aims to investigate the design and deployment issues and challenges of VR in mental healthcare and wellbeing in general, and in particular, PC&B domains. Addressing such a substantial research problem requires wider collective efforts beyond the scope of a single PhD thesis. Therefore, the research work done in this thesis aims to address specific literature gaps that are under the umbrella of the research problem. Specifically, this thesis aims to address the following research questions:

- **RQ 1: Can VR be used as an emotional space, a tool for emotional elicitation? What are its potentials within PC&B contexts?**
  This research question, addressed in Chapter 3, investigates the psychological and physiological effects of engaging in 360° Video-Based Environments (360-VEs) using VR. In this study, healthy participants engaged with a range of 360-VEs using VR, while eye-gaze behaviour was recorded using eye-tracking. The study findings demonstrated that VR could elicit a range of emotions effectively. The analysis of eye-gaze behaviours is promising, suggesting that eye-tracking in VR has strong potential in predicting various emotional states. Finally, the potential of VR in general and eye-tracking VR in particular as a tool for emotional assessment in PC&B contexts is discussed.
- **RQ 2: What is the potential of VR as an emotional space within a real-world healthcare setting?**
  Building on the previous study's findings, this research question (addressed in Chapter 4) aimed to understand how emotional elicitation in VR could be designed and deployed to fit a real-world healthcare setting's needs and requirements. Specifically, the study investigated emotional elicitation in VR as a non-pharmacological intervention for people living with moderate to severe dementia residing in a locked psychiatric hospital. This study was planned to follow the same methodology as the study in Chapter 3, including the use of eye-tracking VR as a tool to measure emotional elicitation;

however, several barriers were met. These barriers mainly relate to the feasibility of eye-tracking for people with moderate to severe dementia and the security and safety considerations for deploying a wired VR headset -that incorporates eye-tracking- within a locked psychiatric hospital environment (see section 4.2.6 for further details). As such, parts of the methodology were adapted to fit this deployment context. The study found that VR is feasible and deployable in restricted healthcare settings, such as a locked psychiatric hospital. VR was well-accepted by people living with moderate to severe dementia; the study concluded that emotional spaces in VR could promote positive mood, cognitive stimulation, and general wellbeing.

RQ 3: What are the design elements that are required for meaningful, deployable and effective PC&B-VR experiences? What are the current needs, opportunities and challenges within these design elements?

The final research question, addressed in Chapter 5, aimed to gain a broader understanding of the design and deployment of emotional spaces in VR within PC&B contexts. In this chapter, the design and deployment processes of a total of four user-centred VR-based PC&B interventions were examined (including the study examined in Chapter 4). The study aimed to identify design elements required for effective, meaningful and enriched VR interventions within PC&B contexts. Critical design elements of these interventions were identified and examined on how they were translated and adapted into VR, including the incorporation of the needs of users, clinicians, and the context of the real-world healthcare setting. Afterwards, the thematic analysis results discussing the design needs, opportunities and challenges for designing meaningful and effective PC&B-VR interventions were presented.

1.4 Scope

This thesis is concerned with extending knowledge on the design and deployment of VR in the mental healthcare and wellbeing domain.

First of all, only low-cost fully-immersive VR systems are considered in this thesis. Immersion is concerned with the objective description of the technology and its technical capabilities to isolate the user from the real world (see section 2.1.2 for a concrete definition). Given the spatial and monetary constraints that semi-immersive systems present with (see section 2.1.2), only fully-immersive systems like VR are considered in this thesis. Furthermore, given that one of the thesis aims is to explore deployable solutions that attend to the real-world constraints within healthcare, technologies that are significantly expensive or only available for scientific experimental labs are not considered in this thesis.

Secondly, the healthcare and wellbeing field is a wide domain to examine in one thesis. This thesis is concerned with VR applications in PC&B domains within mental healthcare and wellbeing, such as treatment and assessment (see section 2.3). Furthermore, the thesis does not focus on physical rehabilitation. However, studies that are concerned with enhancing physical rehabilitation outcomes through psychologically supporting the patients by enabling them to achieve their physical rehabilitation goals are included.

1.5 Contribution

The contribution of this thesis is to shed light on how VR can be designed and deployed to deliver emotional, enriched and therapeutically meaningful experiences that best fit PC&B applications. This thesis offers considerable theoretical and practical contributions to the topic. The overall key contributions from this thesis could be summarised as follows:

- Extending the understanding of the effects of VR as a space for emotional elicitation within mental healthcare and wellbeing contexts (Chapters 3, 4 and 5)
- Extending the understanding of VR intervention design for effective and meaningful interventions that cater to the needs of key stakeholders (Chapters 5)

- Extending the understanding related to the deployment of VR in mental healthcare and wellbeing (Chapters 4 and 5)

The findings from these studies were published in a number of peer-reviewed journals and conferences to extend the existing knowledge in the research community by contributing to the overall understanding of designing VR for mental healthcare and well-being. Table 1.1 summarises the publications which have arisen directly from this thesis work.

Table 1.1: Publications list arising directly from this PhD thesis

Chapter	Journal/ Conference	Title	Status	Citation
Three	IEEE Transactions on Affective Computing	Understanding Emotional Elicitation in VR Through Eye-Gaze Behaviour. VR Eyes: Emotions Dataset (VREED)	Preparing to submit	-
Four	2019 CHI Conference on Human Factors in Computing Systems (CHI'19)	Bring the Outside In: Providing Accessible Experiences Through VR for People with Dementia in Locked Psychiatric Hospitals	Published	(Tabbaa *et al.* 2019)
Four	Dementia Journal	Bringing the Outside In: The Feasibility of Virtual Reality with Individuals Living with Dementia in a Locked Psychiatric Hospital	Published	(Rose *et al.* 2019)
Five	International Journal of Human-Computer Interaction	A Reflection on Virtual Reality Design for Psychological, Cognitive & Behavioral Interventions: Design Needs, Opportunities & Challenges	Published	(Tabbaa *et al.* 2020)

Furthermore, the data collected in the study described in Chapter 3 is ready to be published as a publicly available dataset. The dataset is part of a larger collaboration, which includes the psychological and physiological responses of engaging in 360-VEs using VR, including self-reported questionnaires, subjective ratings, eye-tracking data, Electrocardiogram (ECG) data and Galvanic Skin Response (GSR) data.

In addition, the following table presents work that has been completed during the research period and has been used in the research in this PhD thesis but is not directly produced from studies carried under this thesis.

Table 1.2: Publications list of collaborations used in this PhD thesis but not directly emerged from it

Chapter	Conference	Title	Status	Citation
Five	IFIP Conference on Human-Computer Interaction (INTERACT'2017)	How Real is Unreal? Virtual Reality and the Impact of Visual Imagery on the Experience of Exercise-Induced Pain	Published	(Matsangidou *et al.* 2017)

1.6 Structure

The structure of this thesis is as follows:

- In Chapter 2, a review of the literature focused on topics related to this thesis is presented. First, an introduction to the VR technology and VEs are presented. Second, user interaction and behaviour when engaging in VR experiences are explored. Then, a review of previous literature on the efficacy of VR in the mental healthcare and wellbeing domain is examined. Finally, design approaches and challenges in designing PC&B-VR interventions are investigated.
- Chapter 3 presents the results of an exploratory study that examined the potential of eye-tracking in VR as a tool for emotional assessment when engaging in 360-VEs. Data from thirty-four participants whom each engaged in twelve 360-VEs was collected, analysed, and presented. In addition, the data collected in this study are collated to be made a publicly available dataset.
- Chapter 4 describes a study that explored the feasibility, design and deployment of 360-VEs in healthcare settings. Specifically, eight individuals living with moderate to severe dementia residing in a locked psychiatric hospital were offered five 360-VEs to explore while being supported by sixteen caregivers. The results of the study were

organised in themes to discuss in depth the appeal of using VR for people with moderate to severe dementia and the observed impact of such interaction, as well as the design considerations for meaningful VR experiences and successful deployment in a healthcare setting.

- Chapter 5 illustrates the results of an analysis that included the co-design, iterative prototyping and evaluation of four user-centred PC&B-VR interventions. In the aims of understanding the needs, opportunities and challenges in designing effective and deployable VR interventions, the study explored the process of which conventional therapies were translated into VR, the design needs of critical stakeholders such as clinicians and users and the real-world healthcare setting and how it affects the design of the VR intervention.
- Finally, in Chapter 6, the overall findings, implications, and limitations of the three studies which have been carried out are discussed then followed by potential future work opportunities derived from the work done in this thesis. The results from chapters 3, 4 and 5 have been synthesised to provide an in-depth discussion on how emotional spaces in VR could be designed to carry out experiences that attend to the critical needs of stakeholders such as clinicians and patients and how the understanding of healthcare contexts contribute to the VR intervention design and deployment.

Chapter 2: Literature Review

The literature review chapter focuses on a range of topics related to the key research components in this thesis. First, the literature that relates to Virtual Reality (VR) and Virtual Environments (VEs) was reviewed (section 2.1); this includes a discussion around the current state of the art of VR and some related terms such as immersion. Then, user interaction and behaviour within VR was investigated (section 2.2), aiming to understand how VR experiences affect users psychologically and physiologically and the role of presence in emotional elicitation. Afterwards, a review was conducted to examine the scholarly work that has been done to utilise VR in the context of mental healthcare and wellbeing in general and Psychological, Cognitive and Behavioural domains (PC&B) in specific (section 2.3); including examples of studies which examined the efficacy of VR in assessments, therapies and other modalities of support in this field. Finally, the literature related to understanding the VR design framework for mental healthcare and wellbeing was explored to understand how to produce effective, meaningful and deployable PC&B-VR interventions (section 2.4).

2.1 Virtual Reality & Virtual Environments

This section focuses on defining digitally created or captured environments such as VEs and the difference between VEs and other similar terms such as virtual worlds. Furthermore, the types of VEs and methods to acquire such content are discussed. Afterwards, the term immersion and the range of immersive technologies are presented, with an emphasis on fully-immersive technologies such as Head Mounted Displays (HMD) or what is also known as VR, accompanied with a brief review of the state of the art of VR technology.

2.1.1 **Virtual Environments**

A VE is defined as *"the synthetic, interactive, illusory environment perceived when a user wears or inhabits appropriate apparatus, providing a coordinated presentation of sensory information mimicking that of a physical environment"* (Ellis 1994, p. 17). Other researchers added that the display is required to cover a substantial field-of-view (Boman 1995). VEs are also known by other terms such as "immersive environments" or "immersive virtual environments". In this sense, the term VE is suitable to describe environments that users "step into" when using VR (discussed in section 2.1.2). Specifically, the stereoscopic view in VR allows users to view a wide field-of-view (often ~100-110 degrees). In addition, the camera from which users view the VE is in the first-person view. Finally, the software of VR updates the user's view as they look around, hence, providing a coordinated presentation in a way that mimics how users view the physical world.

Terms like Virtual Worlds (VWs) or what can also be called "synthetic worlds" or "simulated worlds" may seem to be adjacent terms for VEs at first glance; however, when taking a closer look, subtle differences can be identified. A VW is defined as *"the synchronous, persistent network of people, represented as avatars, facilitated by networked computers"* (Bell 2008, p. 2). This definition seems to be agreed upon in the literature body, with stress points over specific elements described within the definition. For example, some researchers stressed the importance of having virtual characters known as avatars to mediate the interaction between players (Norris 2009), while others stressed the importance of having multi-player, multi-user or a "community" within a VW (Bell 2008). From the above, it is prevalent that it does not matter whether the technology is immersive or not in order for the simulated environment to be described as a VW and that the multi-user aspect is what separates VWs from other virtual spaces.

For the purpose of this thesis, the term VEs will be used to describe all VR visual content as it is a more relevant term to semi-immersive and fully-immersive technologies (discussed in section 2.1.2). Furthermore, considering that VEs may or may not have a multi-user or multi-player element, the term VWs cannot be inclusive to all VEs discussed in this thesis.

Generally, there are two types of VEs, Three-Dimensional Computer-Generated Virtual Environments (3D-VEs) and 360° Video-Based Virtual Environments (360-VEs). 3D-VEs are VEs designed using 3D graphics (see

Figure 2.1) and sometimes complemented with some two-dimensional elements such as menus and buttons. Generating 3D graphics require extensive and specialist experience. Depending on the complexity of the content of the 3D-VE, modelling artists, texturing artists, rigging technical developers, animators, lighting artists, and game programmers and developers with specialist experience in VR development may be required. Depending on the programmed complexity, users can view-only or interact with elements within the 3D-VE. Typically, such interactions are mediated using technology-specific handheld controllers or tracking systems that can track the physical movement of the user and reflect such movement in the VE.

Figure 2.1: Example of a 3D-VE (Everybody's Golf VR by Playstation[1])

On the other hand, 360-VEs (see Figure 2.2) are VEs recorded using omnidirectional cameras, a technology that allows several cameras to record in every direction all at the same time. The recorded videos are then stitched together to simulate a 360˚ view. The most popular 360˚ cameras that are used to acquire 360-VEs consists of two 180˚ cameras, such as Insta360 Evo[2] and Fusion from GoPro[3]. Furthermore, more professional 360˚ cameras such as GoPro Odyssey and MoooVR[4] offer higher resolution quality and synchronisation to the pixel between the cameras. Unlike generating 3D-VEs, generating 360-VEs at a basic level do not require extensive technical skills;

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[1] https://www.playstation.com/games/everybodys-golf-vr-ps4
[2] https://www.insta360.com
[3] https://gopro.com
[4] http://mooovr.com

instead, filmmakers can simply record and share the 360-VEs on online platforms like Facebook and YouTube.

Figure 2.2: Example of a 360-VE (Barcelona by TwoReality[5])

2.1.2 Immersion & Immersive Technologies

The term "immersion" is a common term when discussing VR and other forms of immersive media. There have been attempts in the literature to define the term "immersion" and distinguish it from other relevant terms such as presence (discussed in section 2.2.1). Slater and Sanchez-Vives (2016) defined immersion as the objective description of the technology and its technical capabilities. In a similar sense, Kalawsky (2000) defined immersion as the physical extent of the sensory information, which is a functionality that is provided by the enabling technology. Therefore, the sense of immersion critically relies on the features and capabilities of the technology.

Several factors affect the sense and intensity of immersion, such as the ability of the technology to surround the user with the VE, the ability of the technology to correspond to the user's movement and behaviour, the latency in displaying correspondence to user movements, the quality of the display resolution and the wideness of the field-of-view. All of such technical factors play a crucial role in determining how natural and close-to-real-life the VR experience is to the user and hence how immersed they feel in the VE (Slater, Usoh and Steed 1994). To this end, there are three levels of immersive

[5] https://www.tworeality.com/360-video-production

technologies: non-immersive, semi-immersive, and fully-immersive technologies.

Non-immersive technologies are technologies that display VEs on a monitor. In non-immersive technologies, the user is not surrounded by the VE; instead, the user is distant and views the VE as an outsider rather being "in" the VE. Non-immersive technologies include PCs and game consoles such as Nintendo[6] and PlayStation[7]. In PC-based VEs, users view the VE using the PC monitor and can interact with the VE using a mouse, keyboard, or a peripheral that can be connected to a PC such as a joystick. In gaming consoles, users view the VE using a monitor and interact with the console-specific gaming controllers such as the DUALSHOCK-4 wireless controller and the Mini Wired Gamepad available for the Playstation console.

Semi-immersive technologies are spatially immersive installations, including the Cave Automatic Virtual Environment (CAVE) such as Visbox[8]. The CAVE system (see Figure 2.3) projects sections of the VE onto the walls and floor, where the collation of all sections compiles the VE. The CAVE system requires a specifically dedicated room for the CAVE projection and utilises a projector that is mounted on the ceiling (Cruz-Neira, Sandin and DeFanti 1993). One advantage of using the CAVE is that it allows more than one user to view the VE at the same time. Nonetheless, there are many downsides to the deployment and use of this technology. One major disadvantage of the CAVE is the physical space requirements for the installation; the room needs to be in specific dimensions where typically it is a 3-meter cubed room (Slater and Sanchez-Vives 2016), which may not be feasible in all spaces where the application of the CAVE may take place, in addition to the substantial cost of setting up the projection room. The second disadvantage of the CAVE is the cost of equipment; both the projector and the computer with high-end specifications that are required to process the simulated VE are costly. For all

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[6] https://www.nintendo.com
[7] https://www.playstation.com
[8] http://www.visbox.com/products/cave

the above reasons, the CAVE is unfeasible for many end-users; therefore, the deployment of the CAVE in the consumer market can be very challenging.

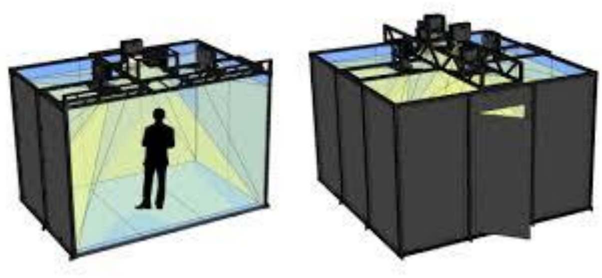

Figure 2.3: Example of a CAVE System (Visbox)

Fully-immersive technologies refer to technologies such as Head Mounted Displays (HMDs), where a display with stereoscopic lenses is fitted onto the user's head, and the user becomes completely isolated from the real-world environment. Virtual Reality (VR) is a term used to describe the interactive VE that surrounds the user from every direction and feels adjacent to the real world (Witmer, Jerome and Singer 2005). Other literature work has defined VR as a "reality" that is "virtual" (Slater and Sanchez-Vives 2016). VR HMDs track the orientation of the user's head, feed the information to the computer or processing unit and correspond to the user's head orientation by displaying the relevant parts of the VE. Depending on the programmed complexity, the user can explore and interact with the environment; the user can immerse in the VE by looking around, walking through, manipulating objects or performing actions.

There are several practical reasons why VR has become more popular nowadays. VR has a higher production value in comparison to semi-immersive technologies; VR can be deployed to end-users more easily because it is significantly cheaper and does not have the spatial constraints that semi-immersive technologies have. This explains the recent surge in the production and use of VR HMDs in comparison to semi-immersive technologies in the past decade (Anthes *et al.* 2016). Given that one of the aims of this thesis is to offer deployable solutions that attend to the real-world constraints within the healthcare and well-being domain, the scope of this thesis solely considers the use of fully-immersive VR technology.

2.1.3 The State of the Art of Virtual Reality

The concept of an immersive simulation using an HMD can be traced as far back as the sixties of the last century. The earliest HMD prototype found was the "Stereoscopic Television Apparatus for Individual Use" proposed by Heilig (1960), where the use of dual optical lens units to simulate an immersive stereoscopic experience was introduced. It appears that the general shape of the proposed apparatus (see Figure 2.4) looks close to the HMD design available nowadays.

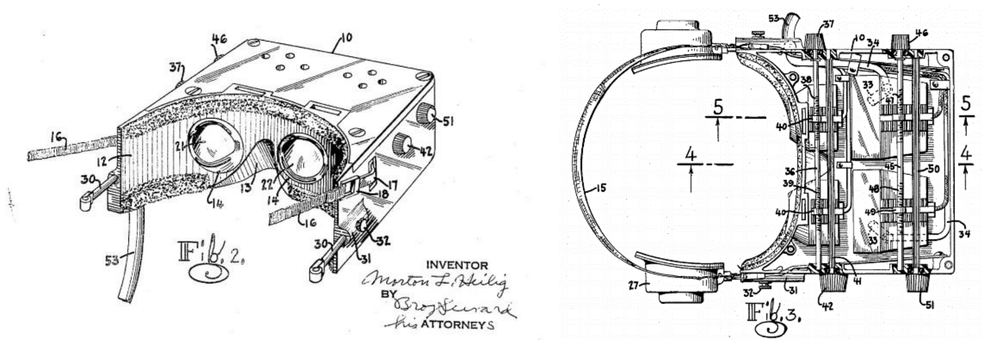

Figure 2.4: Heilig's sketch of the "Stereoscopic Television Apparatus for Individual Use" (Heilig 1960)

Another pioneering vision of the VR HMD was proposed by Sutherland in "The Ultimate Display" in 1965. Sutherland has introduced key concepts of immersive HMDs such as the concept of 3D sight and sound that are perceived adjacent to the real world by the observer, enhanced by including sensory input devices to manipulate, interact with, and "feel" 3D objects in VR; which is the underlying infrastructure to the current VR HMDs (Sutherland 1965). Years later, in 1990, the NASA Ames' Aerospace Human Factors Research Division introduced the Virtual Interface Environment Workstation (VIEW) (NASA 1999). The VIEW (see Figure 2.5) was a stereoscopic HMD system in which the user could "step into" the VE and interact with it using the "DataGlove" as an input modality.

Figure 2.5: The VIEW VR HMD (NASA 1999)

Following the advances in technology, including advances in the gaming industry as well as advances in graphical and computational processing powers, VR has evolved immensely in the past twenty years. Currently, there exist a wide variety of VR HMDs available in the consumer market, in which each varies in its features, ergonomic design, operating platform, and price. Currently available VR HMDs can be split into two main categories: System-Dependant and Portable HMDs.

For the purpose of this thesis, an exhaustive comparison between HMD models will not be discussed; this section aims to briefly introduce the type of HMDs in each of the categories to gain a broad understanding of the difference between System-Dependant and Portable VR HMDs. However, there exist work in the literature where a comprehensive taxonomy to the current state of the art of VR technology is offered (Anthes *et al.* 2016). Finally, considering that one aim of this thesis is to provide deployable VR experiences in the mental healthcare and wellbeing domain, examples of HMDs that are only available for scientific experimental labs or come at a significant price (£2,000+) are excluded.

System-Dependant VR HMDs are wire-connected to a PC, laptop, or a gaming console such as PS VR from PlayStation[9]. The VR system entirely relies on the PC, laptop or console's processing powers to render the VE in real-time; therefore, it is required for the machine to have high-end specifications in order for it to be able to cope with real-time rendering. System-Dependant VR HMDs contain a display screen as part of the hardware model, where the processing machine treats the HMD as an additional monitor. Most HMD models have headphones as part of the HMD design to stream audial feedback. In addition, interaction peripherals are often included, such as handheld controllers and tracking kits that would track the physical position and movement of the user's body. Also, some HMD models such as HTC Vive Pro Eye[10] and FOVE-0[11] are equipped with other features such as eye-tracking. The most popular HMDs available in the market come from two leading manufacturers: Oculus[12] and HTC Vive[13]. In addition to the cost of a System-Dependant HMD, which is considerably costly at the moment (£600-£1,200), the system could not run without the processing machine (i.e. PC, laptop or console) that incorporates necessary high technical requirements, which adds on to the cost of the VR system as a whole.

Portable VR headsets do not have a display as part of the headset's hardware design and do not need to be connected to a processing unit via wires; instead, Portable VR relies on the use of mobile smartphones to process the visual and audial streaming of the VR content and uses the headset's lenses to transform the smartphone's screen display to stereoscopic view. Considering the widespread use of smartphones, owning a Portable VR system only requires the purchase of the HMD itself with no other extra cost; hence, Portable VR is far less expensive than System-Dependant VR.

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[9] https://www.playstation.com/en-gb/explore/playstation-vr
[10] https://www.vive.com/uk/product/vive-pro-eye
[11] https://www.getfove.com
[12] https://www.oculus.com
[13] https://www.vive.com

However, with the absence of the PC's powerful processing powers, and the reliance on the smartphone's limited processing capabilities, some Portable VR HMDs struggle to process heavy real-time rendering. There are several types of Portable VR headsets, to which the materials used, features, and price varies considerably.

Simple Portable VR headsets have a primitive look and features, and often use simple and light materials such as Google Cardboard[14], which can come with or without a head strap and come at a low price(~£6-£9). These type of headsets do not typically come with face padding; meaning, they may not be comfortable for constant use. In addition, since the padding is not available, fitting the headset to fit the face fully could be uncomfortable and allow for external light leakage. Furthermore, such HMDs do not have handheld controllers; instead, a cardboard button that physically taps onto the screen is used, which can limit its functionality to the minimum.

Other mobile headsets use more sophisticated material such as plastic, often have face padding and sometimes include extra handheld controllers depending on the model. There are generic Portable VR HMDs that are compatible with multiple smartphone platforms (i.e. Android and iOS) such as MERGE[15] and VR SHINECON[16], while others are made for a specific range of smartphone models or operating platform such as Samsung Gear VR[17] and Google Daydream View[18]. Such headsets vary in price (£15-£60). The features of these mobile VR headsets can vary in terms of comfortability of the padding, weight of the HMD, additional controllers and the ergonomic design of these controllers.

Until recently, Standalone or "All-in-One" VR HMDs have been introduced in the market such as Oculus Go and Oculus Quest. Such HMDs come with an

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[14] https://arvr.google.com/cardboard
[15] https://mergeedu.com/headset
[16] http://www.shinecon.com/vr-glasses
[17] https://www.samsung.com/global/galaxy/gear-vr
[18] https://arvr.google.com/daydream

embedded processor where no PC, laptop or smartphone is required. These Portable HMDs are considered a "hybrid" between mobile-based HMDs and System-dependant HMDs in many aspects such as resolution quality, ergonomic design, and price (~£190).

2.2 Studies of User Interaction & Behaviour in Virtual Reality

The next section investigated in this literature review relates to user interaction, behaviours and responses to engaging in VR experiences.

2.2.1 **Sensing Presence in Virtual Reality**

Earlier in the literature, Slater (2003) pointed out the confusion in the research field between the terms "presence" and "immersion" and called for the need to distinguish the two terminologies. Later, Slater and other researchers defined the difference between presence and immersion and the relationship between them. While immersion describes the objective description of the technology and its technical capabilities (as discussed in section 2.1.2), the sense of presence is defined as the perception of *"being there"*; which can be triggered when the user looks around, and the VE responds to such movement (Baños *et al.* 2004; Slater and Sanchez-Vives 2016).

Nonetheless, the relationship between presence and immersion is close. Presence is thought of as a subjective correlate of immersion; when the technology is immersive, the user can suspend their sense of awareness of the real world and feels like "being there" in the virtual space (Slater and Sanchez-Vives 2016). Other researchers have concluded that fully immersive VR experiences result in a higher and more sustained sense of presence in comparison to non-immersive experiences (Baños *et al.* 2004, 2005). It has also been seen that the sense of presence as the outcome of immersion, however, it does not have a one-to-one relationship, as other factors affect the sense of presence (Schubert, Friedmann and Regenbrecht 2001).

Specifically, there are two categories of factors that determines and affects the user's sense of presence:

- Objective (internal) factors are related to the technical features of the VR technology (Slater, Usoh and Steed 1994). The term "media characteristics" has also been used in the body of literature to describe these factors (Ijsselsteijn and Riva 2003). Objective factors include a variety of technical features within VR, such as the degree of interactivity, adoption of interactivity mechanics, self-representation within the VE and the behaviour of objects within the VE.
- Subjective (external) factors are related to the person-to-person differences (Slater, Usoh and Steed 1994). The term "user characteristics" has also been used in the body of literature to describe these factors (Ijsselsteijn and Riva 2003). Subjective factors like age, gender and variables related to cognitive and physical abilities (Baños *et al.* 2004) are identified to affect users' sense of presence. Furthermore, researchers found certain personality traits that empower or dampen the user's sense of presence, such as impulsive tendencies, empathy, absorption, mental imagination, perspective-taking, and immersive tendencies (Kober and Neuper 2013; Witmer, Jerome and Singer 2005).

2.2.2 **Emotional Elicitation in Virtual Reality**

Emotions can be described as subjective experiences that involve psychological and physiological reactions and responses (Hockenbury and Hockenbury 2010). Emotions are a crucial aspect of our lives; they constitute an essential part in decision-making, social interaction, perception, memory, learning and creativity (Tripathi *et al.* 2017; Zhang, Liu and Lai 2015). In the context of psychology in general and mental healthcare and wellbeing in specific, the importance of understanding and dealing with one's emotions cannot be understated. The World Health Organization (WHO) concludes that emotional wellbeing is a fundamental parameter to peoples' quality of life; it enables people to live meaningful, social, peaceful and stable lives (World

Health Organization 2005). Furthermore, in the context of mental healthcare and wellbeing, the ability to process and regulate emotions is vital for personal and social functioning (Gross 2002). The body of research suggests that many psychological disorders stem from individuals' excessive, insufficient or inappropriate emotional responses to the situations or circumstances they experience or face (Sheppes, Suri and Gross 2015).

To this end, emotional elicitation and modulation have received significant research interests within the Human-Computer Interaction (HCI) community, especially within VR research. The sense of presence in VR can enable users to engage emotionally in affective stimuli more deeply and profoundly than non-immersive or semi-immersive mediums (see section 2.2.2). However, the relationship between presence and emotions has been under debate; some researchers regard presence as the carrier or mediator that allows real emotions to be activated in VR (Parsons and Rizzo 2008), while others concluded that the relationship between presence and emotions is mutually dependant (Diemer *et al.* 2015). Nonetheless, regardless of how the relationship between emotions and presence is articulated, it is consistent through the literature that the sense of presence is greater when users are fully emotionally engaged in VR; where emotional (affective) VEs triggers a higher sense of presence than neutral (non-affective) VEs (Baños *et al.* 2004; Bouchard *et al.* 2011; Riva *et al.* 2007).

In the mental healthcare and wellbeing domain, the body of literature has explored the use of VR as an emotional space for therapy, a therapeutic medium where users "step into" the emotionally eliciting VE and engage in therapy through VR (see section 2.3.1). For instance, VR has been used to induce anxiety as part of the therapy, for example, in treating different anxiety disorders and phobias (Mishkind *et al.* 2017). In such treatments, VR was used to provide an immersive stimulus to help the patient induce the anxiety-related phobia as they would feel in the actual situation whilst being supported by the therapist in a safe physical environment. On the other hand, VR has also been used to induce calmness and relaxation (Anderson *et al.* 2017; Navarro-Haro *et al.* 2017).

At the other end of the spectrum, instead of using VR to trigger and arouse emotions as part of the therapy, VR has been used as a tool to modulate emotional responses. VR has been effective in providing alternative imagery to help users modulate emotional distress caused by the physical reality that the user is experiencing. For example, VR has been used to alleviate physical pain experienced during painful procedures such as wound care for burn patients (Hoffman *et al.* 2000) and painful oncology-related procedure for cancer patients (Niki *et al.* 2019) (further details in section 2.3.2).

Considering that VR can simulate a real response, emotions elicited during VR are equally real (Slater and Sanchez-Vives 2016). In addition to the psychological influence of emotional elicitation in VR, researchers found that emotional stimuli in VR also influence users physiologically, such as blood pressure and heart rate (Gorini *et al.* 2010; Macedonio *et al.* 2007), skin conductance response (Gorini *et al.* 2010), brain activity (Kosunen *et al.* 2016), eye-gaze behaviour (Pettersson *et al.* 2018; Renaud *et al.* 2002; Trottier *et al.* 2014), head movement (Li *et al.* 2017), and physical sexual arousal (Renaud *et al.* 2014; Trottier *et al.* 2014). To which, the body of research has explored the use of measuring physiological responses in mental healthcare and wellbeing context. For example, one study combined the use of Electroencephalogram (EEG) with natural VEs in VR to create a neuroadaptive meditation system that induces user-centred deeper levels of relaxation (Kosunen *et al.* 2016). In addition, VR has been used to assess sexual arousal in paraphilia within forensic settings for offenders through measuring penile blood flow that measures sexual arousal to detect sexual deviant interests (Renaud et al., 2014).

Furthermore, the study conducted in Chapter 3 explored the use of eye-tracking within VR as a tool to assess emotional elicitation when engaging in 360-VEs. Therefore, a more comprehensive literature review in this area will be presented in the chapter. Specifically, literature that relates to the structure of emotions and how emotions can be measured is explored. In addition, the literature and potential of eye-tracking within VR for mental healthcare and wellbeing was investigated.

2.2.3 **Side Effects of Virtual Reality**

Adverse side effects of using VR are not uncommon; all VR HMD manufacturers have documented potential adverse side effects of using VR as well as safety recommendations for safe use of VR that minimises such adverse side effects and preserves the safety of users. Side effects of VR can be divided into the following clusters: i) oculomotor side effects such as eye strain, double or blurred vision, ii) disorientation side effects such as vertigo, impaired balance and light-headedness, iii) dizziness-related side effects such as nausea, vomiting or symptoms similar to motion sickness (Bouchard *et al.* 2011).

While such side effects are critical to recognise as they stand, it also affects other components of the VR experience, such as the sense of presence. Research has shown a negative correlation between the sense of presence and the adverse effects of VR, such as motion sickness (Witmer, Jerome and Singer 2005). Furthermore, adverse effects of VR have been defined as one of the four factors that measure the sense of presence, where this factor negatively correlates with the intensity of the sense of presence (Lessiter *et al.* 2001). The reason for such a negative correlation is that when users experience adverse effects, they tend to shift their focus away from the VE and attend to their physiological wellbeing (Witmer, Jerome and Singer 2005).

To this end, three factors have an impact on the existence and intensity of dizziness-related adverse effects such as motion sickness (Bouchard *et al.* 2011):

- User characteristics such as age and health condition(s): For example, considering that the HMD and controller(s) may contain magnets or components that emit radio waves –which could affect the operation of nearby electronics–, those who use/have medical devices such as cardiac pacemakers, hearing aids and defibrillators should not use VR.

Furthermore, women who are pregnant are advised to consult with their physician before using VR. In addition, children under 13 should not be using VR[19].

- System characteristics: Such as the brightness, the spatial resolution of the HMD, the temporal delay or mismatch between head movements and the corresponding camera update.
- Task characteristics: Such as the speed of movements and length of immersion time.

With paying attention to the second and third factors, research has shown that adverse effects of VR, including motion-sickness can be minimised through following some design guidelines (both hardware-related and software-related) as well as recommendations for when using VR. Examples of VE design-related guidelines include avoiding high acceleration or jumping movements within the VE, allowing the user to have a degree of control as unanticipated movements generate motion sickness, and having an avatar that foreshadows camera movements, as it helps anticipation and preparation for the visual motion (Porcino *et al.* 2017). Examples of recommendations that relate to the capabilities of the hardware include using an appropriate field of view and avoid latency in real-time rendering (Porcino *et al.* 2017). Finally, examples of behaviour-related guidelines include taking at least 10-15 minute breaks every 30 minutes when using VR, not using VR under the influence of alcohol, drugs and not using VR in a moving vehicle[20].

2.3 Virtual Reality in Mental Healthcare & Wellbeing

According to the WHO, as of 2016, it is estimated that globally, nearly one in 10 (676 million) people suffer from a form of a mental disorder such as anxiety-related disorders (~28-300 million), depression (~264-300 million) and eating disorders (~16 million) (Ritchie and Roser 2018; World Health

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[19] https://www.oculus.com/legal/health-and-safety-warnings
[20] https://developer.oculus.com/design

Organization 2016). In addition, mental health problems are one of the leading causes of overall disease burden and disability worldwide (Vos *et al.* 2015). Furthermore, the WHO ranks Major Depressive Disorder as the 4th leading cause of disability worldwide and this disorder is projected to be the second leading cause by 2020 (World Health Organization 2016).

In England, one in six adults suffers from a mental health problem (McManus *et al.* 2009). The financial costs of the adverse effects of mental illness on people's quality of life are estimated at £41.8 billion per year in England alone (Sainsbury Centre for Mental Health 2003), and the cost of treating mental health problems are projected to increase by 45% by 2026 (McCrone *et al.* 2008).

Similarly, 18.9% (46.6 million) of adults in the United States suffer from a mental disorder, and additional 4.5% (11.2 million) adults are diagnosed with a serious mental illness where institutionalisation and/or pharmacological interventions are required (*National Institute of Mental Health* 2017). Furthermore, treating and supporting mental health disorders is the 6th highest healthcare cost in the United States; as of 2013, $187.8 billion was spent on caring for individuals with mental health disorders, and $71 billion was the amount spent to treat depressive disorders alone (Dieleman *et al.* 2016).

Although there is an abundance of empirical evidence supporting the efficacy of therapies, many people, for a variety of reasons (i.e. due to stigma, lack of access), do not pursue them, and for those who do, adherence is often low (Corrigan 2004). As such, to address this "last mile" problem, there has been emerging interests in identifying innovative ways to offer access and encourage people to actively take part in assessments, treatments, training and other forms of support related to mental healthcare and wellbeing.

In the HCI community, in particular, there has been a growing body of research over the use of digital technologies to support therapies and interventions over the past few decades. Such interventions have used an array of digital platforms such as web (Allam *et al.* 2015), games (Lu and Kharrazi 2018), mobile (Baig, GholamHosseini and Connolly 2015), augmented reality (Baranowski and Lyons 2020), and VR (Niki *et al.* 2019) in a variety of forms from diagnoses and assessment (Mendez, Joshi and Jimenez 2015), treatment (Emmelkamp *et al.* 2001), rehabilitation (Bortone *et al.* 2018) to self-management (Schroeder *et al.* 2018).

VR is a technological platform that has received significant attention in healthcare and wellbeing in general and PC&B domains in particular. In the past twenty years, researchers have explored the efficacy of VR, how it can be beneficial to the target users and what distinctive VR features that conventional interventions may not be able to offer. Herein, the body of literature was explored, aiming to understand how VR was used to cater to various forms of support within mental healthcare and wellbeing.

2.3.1 **Virtual Reality for Therapy & Treatment**

Decades of research demonstrate the efficacy of VR in supporting therapies and treatments in several mental healthcare and wellbeing domains. For instance, VR has been used to facilitate Exposure Therapy (ET). ET is a well-established treatment for addressing psychological trauma, stress and anxiety disorders, where the patient repeatedly confronts the trauma-related cues, frightening events or circumstances that cause them to react as if they were in immediate danger when they do not appear to be (Rothbaum and Schwartz 2002). The rationale behind ET is that by continuing to expose oneself to such stimuli or cues, the patient can decouple the “fight or flight” response when danger is not present (Mowrer 1960). Virtual Reality Exposure Therapy (VRET) has become a well-known term since the early 2000s, where VR is used to facilitate ET by recreating the environment or circumstances that trigger the trauma or anxiety in patients (Difede, Hoffman and Jaysinghe 2002).

VRET has been used to treat a variety of phobias such as arachnophobia (i.e. fear of spiders; see Figure 2.6) (Garcia-Palacios *et al.* 2002; Miloff *et al.* 2016, 2019), aviophobia (i.e. fear of flying) (Rothbaum *et al.* 2000; Wiederhold and Wiederhold 2003), acrophobia (i.e. fear of heights) (Coelho *et al.* 2006;

Freeman *et al.* 2018) and social phobia (see Figure 2.7) (Bouchard *et al.* 2017; Sekhavat and Nomani 2017). See a summary in Maples-Keller et al. (2017).

Figure 2.6: Example of a 3D-VE for the treatment of arachnophobia in VR (Miloff 2016)

Figure 2.7: Example of a 3D-VE for the treatment of social anxiety in VR (Sekhavat and Nomani 2017)

In VRET, patients "step into" the VE aiming to confront the feared stimuli in a therapeutic manner. Patients then engage in the process of habituation and extinction to learn how to see such stimuli less threatening. VRET has offered several distinctive features for therapy, including the ability to control the stimuli and provide progressive exposure suitable to the patient's pace (Weiss *et al.* 2006). Another feature VRET offers is the ability to expose users to different situations safely in comparison to the unpredictable nature of the real-world circumstances; VR provides an immersive stimulus to help the patient feel the same anxiety as they would feel in the actual situation whilst being supported by the therapist in a safe physical environment (Bush 2008; Weiss *et al.* 2006). Furthermore, VR can compensate for some phobia-related locations, circumstances, or situations that may be time-consuming, costly or inaccessible. For example, in the case of aviophobia, accessing an aeroplane to simulate take-off and landing can be costly and inaccessible (Bush 2008; Rothbaum *et al.* 2000). Some studies also described VR as an attractive treatment technique; VRET has been reported to have a low drop-out rate, which could motivate more people with phobias to engage in and complete treatment (Garcia-Palacios *et al.* 2002).

Another related area VRET has been used is in the treatment for the anxiety and stress that occurs because of a specific traumatic event, or what is clinically known as Post-Traumatic Stress Disorder (PTSD). VRET has been used (see a summary in Gonçalves et al. (2012)) with patients who had developed PTSD after the World Trade Centre attacks (Difede *et al.* 2007; Difede, Hoffman and Jaysinghe 2002), motor vehicle accidents (Beck *et al.* 2007) and combat-related PTSD for veterans (Beidel *et al.* 2019; Ready *et al.* 2006; Rothbaum *et al.* 2001). VRET for PTSD offers a unique benefit for patients, especially those who experience the symptoms of avoidance (Gonçalves *et al.* 2012). Avoidance of reminders of the trauma (i.e. thoughts, emotions, locations) is one well-established symptom of PTSD. Hence, many patients with PTSD struggle to engage their emotions and senses in the treatment despite their efforts and willingness to engage. Therefore, VRET can offer a medium to facilitate emotional processing of memories of the trauma (Difede *et al.* 2007; Difede, Hoffman and Jaysinghe 2002; Gonçalves *et al.* 2012).

Another area of research related to VR therapy that has received significant attention is in the treatment of eating and weight disorders (Riva *et al.* 2004; Wiederhold, Riva and Gutiérrez-Maldonado 2016), including anorexia nervosa (Marco, Perpiñá and Botella 2013; Riva *et al.* 1999), bulimia nervosa (Marco, Perpiñá and Botella 2013) and binge eating disorder (Riva *et al.* 2000, 2002). In a case study that examined the treatment of anorexia nervosa using VR, the study yielded positive results; significant reductions were reported in the patient's bodily dissatisfaction and avoidance behaviours. Furthermore, the patient presented with a high degree of motivation to change (Riva *et al.* 1999).

Another successful study explored the use of VR with 57 women diagnosed with image-related disturbances in obesity and binge eating disorders (Riva *et al.* 2000). The study found that using VR, all patients improved in bodily satisfaction and had a significant reduction in problematic eating and social behaviours. VR was also found effective when delivered as part of a therapy protocol. One study compared the effectiveness of cognitive behavioural therapy with cognitive behavioural therapy combined with VR throughout 15 sessions for 34 patients with different eating disorder diagnoses (Marco, Perpiñá and Botella 2013). Interestingly, the study concluded that cognitive behavioural training was more effective when combined with VR than when delivered on its own. The study found that immersing in VR using body image-related scenarios boosted the efficiency of treatment and accelerated the treatment process and therefore gained more significant improvement.

2.3.2 Virtual Reality for Rehabilitation

Rehabilitation in the context of mental healthcare and wellbeing is an umbrella term for activities and approaches that aims to enable individuals with mental health conditions to develop or maintain skills needed in their daily living, aiming to help them lead independent and meaningful lives for as much as possible, for as long as possible (Luo *et al.* 2018).

For example, psychiatric rehabilitation refers to interventions that aim towards individuals with persistent and serious mental illnesses such as schizophrenia to cope with their condition as well as develop emotional, social and intellectual skills needed to support their daily living (Rössler 2006). In this context, VR has been used as a method for reducing auditory verbal hallucinations experienced by persons with schizophrenia and the depressive symptoms and the distress that comes with it by visualising “the other” as a virtual avatar. Specifically, patients created an avatar that best resembled the most dominant and distressing person (i.e. “the other”) or entity believed to be the source of the malevolent voice (du Sert *et al.* 2018). Interestingly, the study found significant improvements in reducing auditory verbal hallucinations, distress and depressive symptoms and overall quality of life that lasted at the 3-month-follow-up period.

Another area that comes under the umbrella of rehabilitation is psychological rehabilitation in coping with and reducing pain. Psychological rehabilitation in the context of pain focuses on non-pharmacological approaches to eliminate or reduce chronic or unavoidable pain, and therefore, promote wellbeing (Altmaier *et al.* 1992). In this context, the body of research has explored the use of VR as a non-pharmacological intervention to reduce pain levels during wound care for burn victims. Users were immersed in VR while their severe burn wounds were getting cared for (Hoffman *et al.* 2000, 2001). Specifically, in the case of two adolescent patients with deep flame/flash burn wounds covering 5% and 33.5% of their total body surface area, VR was dramatically more effective than non-immersive video games in reducing sensed pain (30%- 80%), bothersomeness (39%-86%) and anxiety (22%-58%) during wound care and staple removal procedures (Hoffman *et al.* 2000). The study highlighted that the immersion component of VR, where patients' attention can be captured away from the painful real-world, majorly contributed to patients' significant reduction in pain and anxiety. These results were also replicated in caring for cancer patients; VR was found to be effective in reducing pain and anxiety during a painful oncology procedure (Wolitzky *et al.* 2005). Interestingly, not only patients' ratings of distress were significantly lower in VR in comparison to no distraction (control), but also the heart rate of those using VR was significantly lower; meaning, physically, patients did not experience as much pain and distress in VR as those in the control group.

Psychological rehabilitation also extends to enhancing the outcomes of physical rehabilitation through psychologically supporting the patients by enabling them to achieve their physical rehabilitation goals. For example, one study explored the use of VR in physical therapy of burnt body parts in seven patients (Hoffman *et al.* 2001). Using VR, the results showed statistically significant lower ratings of pain for when patients exercised in VR from when patients did not use VR (control). Another example is in a study that examined the use of VR and wearable haptics to train children with neuromotor impairments such as cerebral palsy (see Figure 2.8) (Bortone *et al.* 2018). The serious-game-based VR intervention yielded positive results and offered a new medium for such user group to engage in training that can be tailored to each own physical abilities and limitations, making physiological rehabilitation more motivational.

Figure 2.8: VR combined with wearable haptics to enhance physiological rehabilitation outcomes (Bortone 2018)

Other forms of rehabilitation include maintaining and enhancing the quality of life through training skills that tend to decline due to the course of the illness or disorder. In this context, one case study successfully demonstrated the potential of VR as a cognition training tool to enhance spatial navigation skills for an individual with dementia (White and Moussavi 2016). Not only that the individual with dementia achieved the desired targets of the navigational training, but also, their primary caregiver indicated that the training yielded positive outcomes in the patients' daily living, such as enhanced navigation skills when driving their vehicle. Another example is when researchers explored the use of VR to go "to a memorable place" or "return home" for cancer patients in palliative care. Using Google Earth VR[21], patients "travelled" virtually to places that piqued their interest. As a result, patients' pain,

[21] https://arvr.google.com/earth

tiredness, drowsiness, depression, anxiety and wellbeing improved significantly (Niki *et al.* 2019).

Other researchers have utilised VR as a tool for psychosocial rehabilitation to train individuals with autism on skills they typically find challenging, such as social communication (Boyd *et al.* 2018; Strickland 1997). The body of research outlined several distinctive attributes which highlight the value of VR for this user-group. For instance, the capability to tailor VR to the abilities of individuals is vital. Furthermore, unlike the multi-sensory high-stimuli unpredictable real-world environment, VR can break down the stimuli for as little as needed. This is especially unique for users on the autism spectrum, as VR offers a safer and less hazardous environment for training. In addition, individuals on the autism spectrum often find social interaction highly complex; therefore, face-to-face interactions with the teacher can be so disruptive that learning is not possible, to which, a VR environment can provide a contact-free form of learning.

2.3.3 **Virtual Reality for Assessment**

Several researchers have utilised VR as a tool for assessing several PC&B disorders. For example, VR was explored as a tool for the assessment of eating disorders by engaging patients in VEs (i.e. restaurant) and VE elements (i.e. high-calorie food) that induce body-image-related anxiety (see Figure 2.9) (Gorini *et al.* 2010). The study compared patients' stress and anxiety levels when exposed to real food, photos of food and food in VR. Interestingly, the research work found that VR provided clinicians with a more close-to-real-life reaction from patients; VR elicited higher anxiety levels than the conventional assessment method (i.e. photos of food). In fact, VR induced an equally stressful and anxiousness response to when patients were exposed to real food. These findings were also confirmed with physiological responses; food in VR and real food conditions induced significantly higher heart rate and galvanic skin responses in comparison to photos of food. The study concluded that the role presence (whether in front of real food or VR) is vital to facilitate emotional processes. Specifically, by engaging patients in VR, patients were no longer passively observing food (like in photos); instead, they were engaged in the process of exploring the food and going through the anxiety-inducing VE (i.e. restaurant) as they would in real life.

Figure 2.9: 3D-VE for the assessment of eating disorders (Gorini 2010)

VR was also used to detect cognitive skills that tend to degenerate as a result of dementia, such as spatial navigational deficits. One study explored the difference between young and older adults in completing game-based spatial navigation tasks in VR (Zakzanis *et al.* 2009). The results show that younger adults are faster to learn and memorise navigational paths than adults. Furthermore, healthy adults were able to name, memorise and complete tasks better than adults with a dementia diagnosis. Specifically, the time to complete the navigation tasks, the number of wrong turns and the ability to name cities, objects and buildings were the main items where adults with dementia presented with deficits.

VR has received significant interest in the field of forensic psychiatry. VR has been used to assess and detect sexual arousal for paraphilia. Paraphilia and sexual violence are very challenging to assess and rehabilitate amongst the various psychopathologies that have to be dealt with in clinical forensic practices, mainly because offenders can be quite reluctant to disclose their sexual deviant interests (Kalmus and Beech 2005; Renaud *et al.* 2009). To exacerbate the matter, many sex offenders tend to exert voluntary control over sexual arousal during assessments by deliberately distracting themselves from the sexually arousing stimuli (Golde, Strassberg and Turner 2000). Furthermore, traditional approaches tend to utilise resources from real people (i.e. pictures or voices of real people) to prompt sexual arousal in offenders and therefore assess their deviant interests. However, picture-based and audio recordings stimuli lack plasticity and vividness and may not faithful enough to the reality of the offenders. This is in addition to the ethical and legal concerns against using pictures of real people, for example, in the case of paedophilia, where pictures of real children are used (Laws and Gress 2004). Many researchers explored the usability and efficacy of VR to assist in overcoming these challenges. First, researchers used photo-realistic 3D models in VR and especially child-like models to overcome the ethical problems of using real child models to induce sexual arousal when assessing paedophilic offenders (Renaud *et al.* 2002, 2009). Second, researchers were able to tailor 3D models to specific sexual interests, therefore, evoked a significant sexual response, and hence, provided a better assessment modality (Renaud *et al.* 2014). Thirdly, through eye-tracking within VR, clinicians were able to detect faking attempts by offenders through controlling or avoiding sexual arousal (Renaud *et al.* 2009; Trottier *et al.* 2014).

2.4 Designing Virtual Reality for Mental Healthcare & Wellbeing

Despite the abundance of research presented in section 2.3 that supports the efficacy of VR in mental healthcare and wellbeing in general and PC&B domains in particular, there are major barriers when it comes to designing, developing and deploying VR interventions.

Technology-based interventions typically rely on the translation of traditional clinical and therapeutic interventions rather than the design of an entirely novel intervention paradigm (Kraft and Yardley 2009). Thus, it is important to understand the conventional practices and processes in the therapies when developing technology-based interventions and embedding this in-depth understanding in the design of the VR intervention. Such an understanding would enable VR to achieve its intended purpose effectively, hence, increase the deployability of VR in real-world healthcare settings.

However, when designers translate conventional therapies into VR, very fundamental design questions arise related to visual and interaction aspects of the VR intervention. Even though design frameworks, best-case practices or "cookbooks" have been explored by the body of the HCI research community for other technology platforms, such as those related to games (Fanfarelli, McDaniel and Crossley 2018; Siriaraya *et al.* 2018; de Vette, Tabak and Vollenbroek-Hutten 2018), web (Britto and Pizzolato 2016) and mobile health (mHealth) (van Dooren *et al.* 2019; Miller, Cafazzo and Seto 2016) for mental healthcare and wellbeing applications, little is known about the best-case practices in VR design in this domain.

When exploring the literature for design frameworks, guidelines or best practices in VR design for mental healthcare and wellbeing, only some practical guidelines[22] were found that addressed clinicians on how to manage the VR equipment (i.e. making sure that the headset is safely mounted, sterilising the headset, earphones and controllers after each use, etc.). In addition, there are some recommendations on what clinicians should wary of when administering the VR technology, including monitoring additional measures on top of the therapy outcome measures that are related to VR use, such as monitoring the levels of dizziness or nausea when using VR (Mishkind *et al.* 2017).

Currently, there exist some generic design guidelines, such as the guidelines laid out on the Oculus[23] developer's website, which are generic for developing any VR application. However, such guidelines, although helpful, may not attend to the unique design requirements when designing user-friendly and effective experiences in mental healthcare and wellbeing, mainly due to the

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[22] https://painstudieslab.com/vr-guidelines
[23] https://developer.oculus.com/design

variability in the specific design needs of each user group, such as the variability in cognitive, sensory and physical abilities.

For instance, people with cognitive disorders, including autism and intellectual developmental disorder, experience barriers in using mainstream web platforms due to difficulties in recognising the correct navigational path, have less eye/hand coordination when using input devices (i.e. mouse) and have a lower threshold for information overload (Slatin and Rush 2003). This is why many researchers have explored technology design for users with specific mental and physical needs, such as the design of mobile applications for older adults (Kalimullah and Sushmitha 2017; Kascak, Rebola and Sanford 2014), websites for people on the autism spectrum (Britto and Pizzolato 2016) and augmented reality for people with visual impairment (Choo, Balan and Lee 2019). Given these unique design requirements, designing VR experiences requires being sensitive to the needs of the clinical population for user-friendly and highly engaging yet clinically relevant VR experiences. Such understanding of design enables technologies, including VR, to be efficient, effective, user-friendly and safe to use by its intended users; hence, realistically deployable within healthcare settings.

Such lack of ability to produce a VR design framework may be due to the lack of studies describing the design process of VR and how the co-design process addressed the critical needs of stakeholders in the design. Only very few studies were found that described the design process of developing their VR interventions for PWD (Hodge *et al.* 2018), anxiety disorders (Lindner *et al.* 2017) and forensic mental healthcare (Kip, Kelders and Van Gemert-Pijnen 2019).

Another barrier to consider is the current approaches to the development pipeline of VR interventions. Developing VR applications requires the specialised technical expertise of programmers and developers specialising in VR or 3D game-based application. In addition to software development, VR intervention design also involves digital artists (2D and/or 3D) to create the User-Interface (UI) assets (i.e. menus and buttons) and visual elements within the VE (character(s) and surrounding 3D environment). Finally, User-Experience (UX) designers are often required for more sophisticated game-design paradigms in translating traditional interventions into VR so that the intervention is effective, deployable and usable by key stakeholders such as patients and clinicians. Such development pipeline is both costly and lengthy in time; the resources required for medical research institutions or healthcare services who wish to develop their own VR applications could be substantial and may not necessarily be available in-house.

2.5 Summary

The body of research presents a plethora of literature that explored and validated the efficacy of VR in mental healthcare and wellbeing to deliver therapies, treatments, training, assessments and other forms of support within this domain. Nonetheless, best practices and design framework are still scarce. The knowledge on how VR can be designed as an emotional space, a therapeutic medium where users "step into" and emotionally engage in the therapy through VR, is lacking. Furthermore, knowledge on how VR can be designed in a way that caters to the critical needs of key stakeholders such as therapists and users is limited. In addition, it is unclear how to effectively translate the critical therapy elements from conventional mediums to VR. Finally, considering that much research in VR and healthcare have been done in a controlled experimental setting, it is unclear how the real-world healthcare context may present with challenges to the deployment of VR.

Herein, this thesis aims to investigate the design and deployment issues and challenges of VR in mental healthcare and wellbeing in general and PC&B domains in specific. This thesis presents three studies, of which each aims to address specific literature gaps that are under the umbrella of the research problem. Since the studies are of an independent nature, hence, chapter-specific literature may be presented to clarify the study-specific literature gaps and research questions. Specifically, the studies aimed to investigate the effects of engaging in emotional experiences in VR, the feasibility, design and deployability of VR in a healthcare setting and the design elements required for meaningful, efficient and effective PC&B-VR experiences.

The three studies are summarised as below:

- The first study in Chapter 3 explored the potential of eye-tracking in VR as a tool to assess emotional elicitation. The chapter aims to understand whether eye-gaze behaviour in VR could predict emotional responses when engaging in 360-VEs, then discusses the potential applications of eye-tracking VR in the context of mental healthcare and wellbeing.
- The study in Chapter 4 explored the feasibility and deployment of VR in a locked psychiatric hospital for people with moderate to severe dementia. The study explored how VR could be beneficial to this target group and how VR can be designed to support these benefits. In addition, practical and deployment considerations were explored to inform the deployability requirements of VR in a healthcare setting.
- Finally, Chapter 5 explored the co-design processes of four user-centred PC&B-VR interventions, aiming to draw the design needs, opportunities and challenges of designing VR experiences for mental healthcare and wellbeing. Specifically, the study explored the design challenges when translating conventional therapies into VR, the design elements for meaningful PC&B experiences and how they adapt to meet stakeholders' sensitive requirements and the deployment context as a whole.

Chapter 3: Exploring the Potential of Eye-Tracking Virtual Reality in Assessing Emotional Elicitation Using 360° Video-Based Environments

3.1 Introduction

In the previous chapter, emotions and emotional elicitation have been briefly introduced (see section 2.2.2), including the significance of emotions and how they affect many aspects of our lives. In particular, the ability to process and regulate emotions is vital for personal and social functioning (Gross 2002); many psychological disorders stem from individuals' excessive, insufficient or inappropriate emotional responses to the situations or circumstances they experience or face (Sheppes, Suri and Gross 2015). In addition, the use of VR for emotional elicitation was briefly introduced, summarising that VR can elicit real psychological and physiological emotional responses, mainly due to the immersion aspect of VR, which allows VR to deliver virtual experiences similar to the real world (Macedonio *et al.* 2007).

The importance of understanding the physiological aspect of emotional and social experiences in the context of mental healthcare and wellbeing in general and Psychological, Cognitive and Behavioural (PC&B) domains in specific cannot be understated. Many researchers have used a variety of physiological and behavioural measures to understand and assess users' emotional responses within this field. Eye-Tracking (gaze behaviour and pupillary response) have gained popularity in PC&B domains as a modality of assessment, as it gives researchers and practitioners a window into the user's visual and cognitive processes (Salvucci and Goldberg 2000). For instance, eye-tracking has been utilised to assess mental fatigue (Yamada and Kobayashi 2018), distress intolerance (Macatee *et al.* 2018) and impaired attention (Gehrer *et al.* 2019).

It is only until recently, VR Head Mounted Displays (HMDs) such as FOVE-0[24] and HTC Vive Pro Eye Series[25], which come with embedded eye-tracking sensors, have become easily accessible in the consumer market. As such, research in eye-tracking VR in PC&B is still scarce. Despite the great potential and efficacy VR have demonstrated in treatment, rehabilitation, assessment and other forms of support (see section 2.3), eye-tracking in VR for mental healthcare and wellbeing is still an untapped research area with high potentials.

Herein, the study in this chapter aimed to explore eye-gaze behaviour to detect emotional elicitation in 360-VEs using VR as well as its potential applications in mental healthcare and wellbeing. Specifically, this study aimed to address the following research questions:

- Can emotional 360-VE content delivered via a VR headset elicit a range of emotions that may be useful for applications in mental healthcare and wellbeing?
- Can eye-tracking VR be used to assess emotional elicitation within 360-VEs through eye-gaze behaviour?
- And ultimately, what are the potentials of using low-cost eye-tracking VR technology as a tool to measure emotional responses for mental healthcare and wellbeing?

This study is part of a broader collaboration that combined the efforts of a team of researchers within the School of Engineering & Digital Arts, University of Kent, the United Kingdom, and BBC Research & Development, the United Kingdom. The collaborative work aimed to produce a publicly available dataset that includes the psychological and physiological responses of engaging in 360-VEs using VR, including self-reported questionnaires, subjective ratings, eye-tracking data, Electrocardiogram (ECG) data and

[24] https://www.getfove.com
[25] https://www.vive.com/uk/product/vive-pro-eye

Galvanic Skin Response (GSR) data. Currently, this dataset is ready to be published as the relevant scholarly paper is under preparation for submission.

The author of this thesis led the study design, ethics approval process, data collection for all data signals, data labelling and data organisation for publication. The behavioural and physiological data (eye-tracking, ECG and GSR) were pre-processed, and features were extracted by other collaborators in the project. The author of the thesis conducted the statistical analysis of the psychological measures and eye-tracking data.

Considering the specific research questions this study examined, the next section presents a chapter-specific literature review related to the structure of emotions, measuring emotional elicitation and eye-tracking VR for mental healthcare and wellbeing. Afterwards, the stimuli selection process of the affective 360-VEs used in this study is presented, followed by the research methodology, describing the participant selection process and experimental setup. Finally, the results section is presented, then followed by a discussion.

3.2 Literature Review

3.2.1 **Emotion Models**

As discussed in section 2.2.2, emotions are thought to be a psychological and physiological response triggered by conscious or unconscious perceptions of people, objects or situations. Despite the vital role that emotions play in one's behaviour, response and opinions, it is one of the least understood aspects of human experiences (Riva *et al.* 2007). In order to study emotions and emotional elicitation, it is crucial to understand the underlying structure of emotions and how they are intercorrelated.

An extensive body of research has explored how emotions can be categorised, in which research can quantify and describe emotions. One of the most popularly used models is the Circumplex Model of Effects (CMA) (see Figure 3.1) (Russell and Mehrabian 1977). This widely used model characterises emotions in regards to response tendencies and interprets the underlying emotional affects as a continuum of highly interrelated states.

The CMA is a bidimensional model, where emotions are distributed on Cartesian coordinates; each coordinate represents a neurophysiological pathway by which emotion is being processed. Specifically, the CMA presents with two dimensions on a grid; valence as the horizontal axis, which ranges from pleasant or positive (i.e. happy, relaxed) to unpleasant or negative (i.e. nervous, sad) and arousal as the vertical axis, which ranges from deactivation or low arousal (i.e. calm, depressed) to activation or high arousal (i.e. tense, excited) (see Figure 3.1). In the CMA, each emotion is seen as a linear combination of valence and arousal. Furthermore, as shown in Figure 3.1, the bipolar descriptors are exact opposites; for example, the exact opposite of "excited" is "bored", and the exact opposite of "stressed" is "relaxed". Figure 3.2 shows the CMA with more comprehensive emotion descriptors and how they relate to each other across and within quadrants. For example, the descriptors "sad", "gloomy", and "depressed" are clustered closely together in the low arousal negative quadrant; meaning they induce close levels of valence and arousal, and they are more negatively arousing than other emotion descriptors within the low arousal negative quadrant such as "tired" and "droopy".

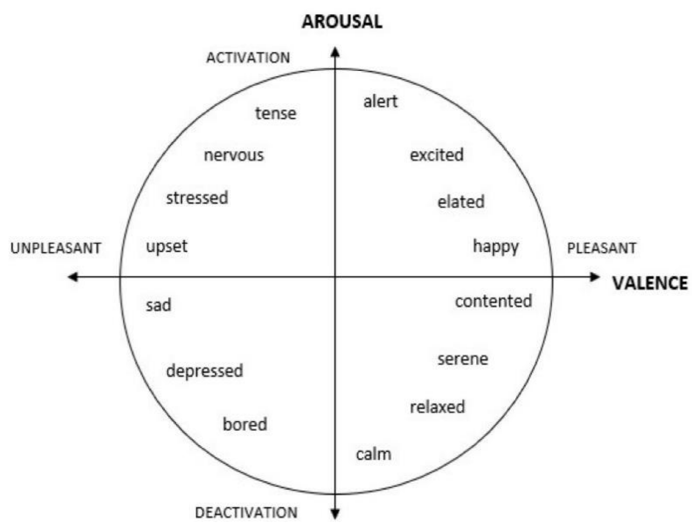


Figure 3.1: Graphical representation of the CMA (Russell & Mehrabian 1980)

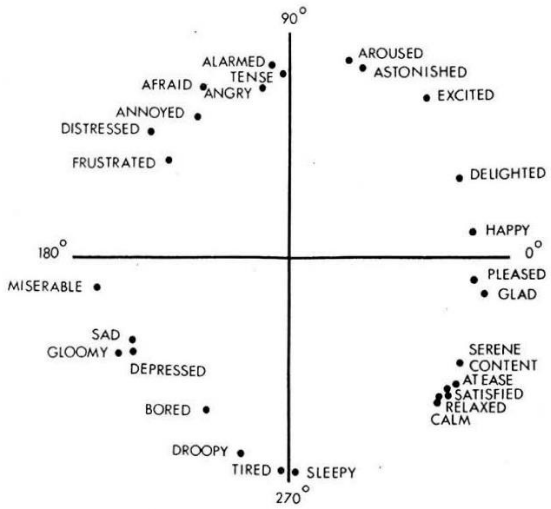


Figure 3.2: Graphical representation of the CMA for 28 Emotions (Russell & Mehrabian 1980)

Russel and Mehrabian had also developed a third dimension called dominance. The dominance dimension is connected to feelings of control over a situation and restrictions caused by physical or social barriers. The dominance dimension ranges from submissiveness to dominance. The literature deemed this dimension questionable, as it is not clear on whether dominance is regarded as affective, cognitive or neither (Bakker *et al.* 2014). Secondly, unlike valence and arousal, which accounted for a large proportion of variance, dominance showed a small percentage of explained variance (Russell 1980). As such, many researchers do not pay attention to the dominance dimension (Bakker *et al.* 2014). In this study, only the valence and arousal dimensions will be used to categorise emotional elicitation in 360-VEs.

3.2.2 **Measuring Emotional Elicitation**

The body of literature has explored various resources of stimuli to elicit emotional responses such as images (Valenza, Lanata and Scilingo 2012), sounds (Nardelli *et al.* 2015), film (Fernández *et al.* 2012), television video commercials (Micu and Plummer 2010) and VR (Li *et al.* 2017; Maples-Keller *et al.* 2017). In addition to measuring emotional elicitation through verbal reportings, i.e. subjective ratings, many researchers have examined the use of various physiological and behavioural markers to understand and assess emotional responses during exposure to affective stimuli. Such physiological measures include the use of ECG for heart rate, respiratory rate and blood volume pressure (Fernández *et al.* 2012; Nardelli *et al.* 2015; Valenza, Lanata and Scilingo 2012; Zhang, Liu and Lai 2015), GSR for skin sweat activity (Anderson *et al.* 2017; Macedonio *et al.* 2007; Valenza, Lanata and Scilingo 2012; Zhang, Liu and Lai 2015), Electroencephalogram (EEG) for brain activity (Jalilifard, Pizzolato and Islam 2016; Kosunen *et al.* 2016; Tripathi *et al.* 2017), eye-tracking (Salvucci and Goldberg 2000) and head movement (Li *et al.* 2017).

In the context of mental healthcare and wellbeing in general and PC&B domains in specific, the evaluation of physiological and behavioural responses to understand emotional elicitation and regulation is of substantial importance within the research community. Understanding emotional responses physiologically may provide researchers with a critical lens to understand users further, assess and design better therapies for users within the PC&B domains. For instance, an interesting study explored the use of GSR to predict the probability of developing Post-Traumatic Stress Disorder (PTSD) following a traumatic experience (Hinrichs *et al.* 2019). The study collected GSR data within hours of the traumatic event at a hospital and then correlated the GSR levels with PTSD diagnosis and severity at the 1-, 3-, 6- and 12-month post-trauma marks. The study concluded that GSR is a robust biomarker for developing PTSD symptoms. Similarly, another study found that the severity of symptoms of PTSD in patients positively correlated with increased brain activity when processing non-trauma-related information (Shin, Rauch and Pitman 2006). Another study found that adolescents and young adult with PTSD after child abuse had blunted, i.e. less pronounced, cardiac reactions (using ECG) when exposed to physically threatening stimuli than healthy controls, which is connected to symptoms of PTSD such as numbness and de-activation (Iffland *et al.* 2020).

Eye-tracking, in particular, has received significant research interests in the past years for PC&B applications. The research concluded that many PC&B disorders are related to impairments or dysfunction in the neural system that affects emotional processing and empathic responses, directly influencing eye-behaviour and pupillary response (Puviani, Rama and Vitetta 2016). For instance, one study compared the pupillary response towards emotional stimuli (photographs of people expressing emotional expressions) between typically developing children and children with autism (Nuske *et al.* 2014). The study presented with fundamental differences in emotion processing in autism; the pupillary response of children with autism revealed significantly less reactivity to facial expressions, hence, deficits in social and communication skills.

In addition to the pupillary response, eye gaze-behaviour has been examined in this context. Eye-gaze metrics include blinking, fixation (when the eye temporarily remains still over time, typically over informative regions of interest and occur during visual and cognitive processing), saccade (the rapid motion of the eye from one fixation to another) and micro-saccade (an intra-fixational eye-movement feature where the eye jitters during a fixation) (see section 3.4.7) (Holmqvist *et al.* 2011). For example, one study explored the use of eye-tracking to detect mental fatigue before and after a cognitively stressful mental activity in young and older adults (Yamada and Kobayashi 2018). The results showed a 91% accuracy in detecting mental fatigue through eye-gaze behaviours such as saccade velocity, blinking and pupillary dilation. Another study explored the use of eye-tracking for assessing impaired attention in psychopathic offenders (Gehrer *et al.* 2019). The study found that psychopathic offenders fixated and dwelled more on the stimuli (photographs of people expressing emotional expressions) in comparison to non-psychopathic offenders.

Nonetheless, despite the advantages of utilising physiological and behavioural measures in diagnostics, assessment and therapies, the body of research has regarded many of these tools as invasive, time-consuming, expensive, requiring specialists who may not be accessible and, therefore, unsustainable. As such, more research work is directed towards developing and designing solutions that can measure physiological responses with increased ease-of-use and accessibility and decreased cost (Puviani, Rama and Vitetta 2016).

3.2.3 **Eye-Tracking in Virtual Reality**

Using VR, it has been shown that 3D-VEs can trigger or elicit a range of emotions, including fear (see a review in Diemer et al. (2015), anxiety (see reviews in Diemer et al. (2015) and Parsons and Rizzo (2015)), as well as relaxation (Kosunen *et al.* 2016; Navarro-Haro *et al.* 2017; Riva *et al.* 2007). 360-VEs in VR were also found to be emotionally engaging by eliciting a range of emotions such as anger (Macedonio *et al.* 2007), relaxation (Anderson *et al.* 2017; Li *et al.* 2017), sadness, anxiety and fear (Li *et al.* 2017) in users.

Considering that eye-tracking in VR is relatively new, especially when it comes to the accessibility of such technology in the consumer market, little research was found that examined the use of eye-tracking in VR in PC&B domains. For instance, one study reproduced a VR version of a well-known cognitive task used for cognitive ability evaluation using eye-tracking VR (Pettersson *et al.* 2018). As shown in Figure 3.3, the study projected the task elements onto a wall in a 3D room in VR, then, gaze-behaviours were collected; as a result, the heatmap shows fixation points and duration of fixations.

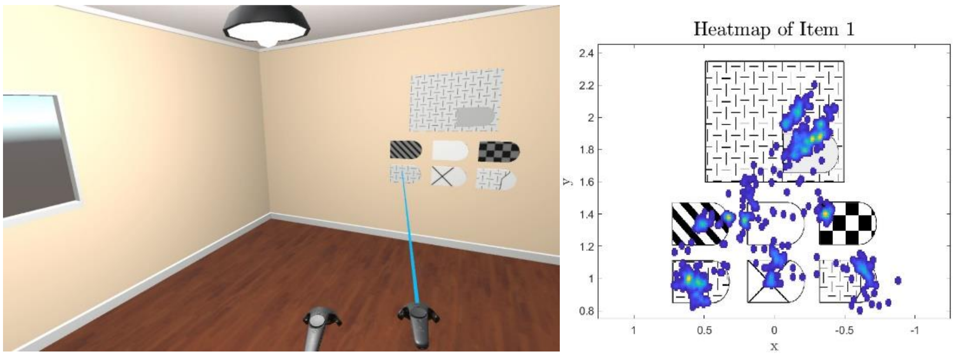


Figure 3.3: Cognitive task evaluation in VR and its corresponding user's eye-gaze heatmap (Pettersson 2018)

Another example that has been discussed in section 2.3.3 is the use of eye-tracking in VR for the assessment of sexual deviancy (Trottier *et al.* 2014). The results show that 3D naked life-like characters can be perceived as sexually arousing and that using eye-gaze heat-maps projected onto the 3D characters can reveal where offenders fixated at and for how long. Furthermore, the study also found that eye-tracking VR can detect faking attempts in controlling sexual arousal; therefore, eye-tracking VR could enhance the validity of the assessment of offenders.

In both presented cases, 3D-VEs were used, where eye-tracking data was captured by projecting the data onto 3D objects. Considering that 360-VEs are relatively new in the consumer market, only until recently, research started to look at eye-tracking in 360-VEs using VR. One study examined gaze-guided adaptive narratives for tourism-related VEs, where the relevant text-based and audio-based information appear depending on the user's gaze at pre-defined points of interest (Kwok *et al.* 2019). Another study explored emotional elicitation in 360-VEs and explored the correlation between head movement in VR and emotional elicitation, finding that head yaw positively correlated with valence and head pitch with arousal (Li *et al.* 2017).

As such, the area of eye-tracking in VR is understudied; it is unclear how 360-VEs can provide a range of emotional responses that could be of use in the PC&B domains, how eye-gaze behaviour could infer emotional elicitation, and ultimately, the potential of eye-tracking VR in PC&B domains is yet to be explored. Therefore, this study aimed to evaluate emotional responses in 360-VEs over a range of emotional categories based on the CMA, explore the validity of eye-gaze behaviour in VR to predict emotional elicitation and discuss the potential of eye-tracking in VR within mental healthcare and wellbeing.

3.3 Stimuli Selection Process

The selection of effective emotional stimuli is essential for measuring affective responses; therefore, the selection process underwent several stages. The study aimed to employ three 360-VEs within each quadrant of the CMA. The final 360-VEs (n=12) used in the study were a result of rigorous discussions and a pilot trial; each explained in the following subsections.

3.3.1 Initial Stimuli Exclusion Criteria

Using YouTube online platform, the author of this thesis attempted to harvest potential 360-VEs using the filter "360" (which refers to 360-VEs). Six researchers (four researchers in HCI, including the author of this thesis, an expert in user-experience design and an expert in behavioural psychology) engaged in three sessions to identify suitable VEs. As a result, the following exclusion criteria evolved to the selection of the 360-VEs:

- VEs that are purely or partially computer-generated; for the consistency of the selection.
- Monochrome 360-VEs; for the consistency of the colour scheme.
- Blurring, moving, shaking, unstable cameras; that is to avoid inducing adverse effects of VR such as motion sickness.
- Bad stitching techniques; that is to avoid unwanted distraction or annoyance.
- Resolution less than 2K (2048×1080); that is to avoid compromising content resolution quality.
- Audial content with low recording quality such as scratching, unclear, too low, or white/ambient noise to avoid annoyance.
- 360-VEs that were less than one minute long were to be excluded; that is to keep minimal engagement time consistent. As for 360-VEs that are more than three minutes long were to be capped at the three-minute mark; since the participants are expected to engage in twelve 360-VEs, prolonged sessions may cause exhaustion or aggravate adverse effects.

After applying the exclusion criteria, researchers identified the initial selection list (n=81). Then, researchers excluded VEs (n=38) that were perceived as neutral or received highly confusing ratings where researchers could not agree on what emotional category the VE elicited. Finally, for the remaining VEs (n=43), to ensure a diverse selection of the 360-VEs, the research team voted for the most emotionally intense 360-VEs among VEs that shared highly similar content. For example, only one 360-VE was selected among VEs containing baby animals such as puppies and kittens. As such, 22 VEs were excluded. As a result, the pilot trial included the final list of VEs (n=21).

3.3.2 **Volunteer Rating Tools**

Volunteers rated each 360-VE using the following tools:

- Self-Assessment Manikin (SAM) is a well-established affective state measurement using a cartoon-like manikin on a Likert scale to plot the basic CMA dimensions. The valence scale (Figure 3.4) ranges from 1="sad" to 9="happy", while the arousal scale (Figure 3.5) ranges from 1="calm" to 9="excited" (Bradley and Lang 1994).

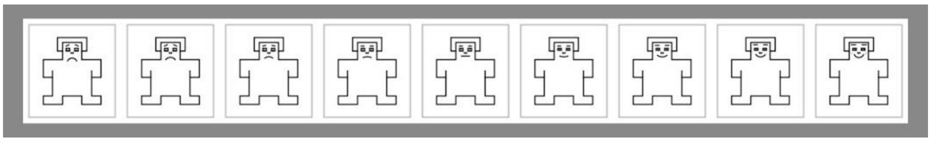


Figure 3.4: SAM Valence Scale (Bradley and Lang 1994)

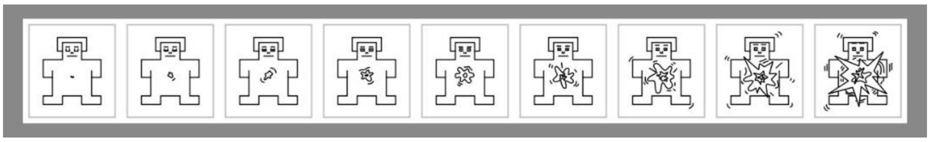


Figure 3.5: SAM Arousal Scale (Bradley and Lang 1994)

- The Visual Analog Scale (VAS) (Hawker *et al.* 2011) is a horizontal scale ranging across a continuum from 0 to 100, anchored by two verbal descriptors at each end (Figure 3.6). Using VAS, volunteers rated how they felt while engaging in 360-VEs using over, joy, happiness, calmness, relaxation, anger, disgust, fear, anxiousness and sadness.

To what extent do you feel *fearful* right now?	
Not fearful at all	As fearful as I can be

Figure 3.6: Example of VAS

3.3.3 **Pilot Trial**

Twelve volunteers (six females and six males) aged between 19 and 33 (*M*= 24.17, *SD*= 4.19) engaged in and rated the selected 360-VEs (n=21). The volunteers watched the 360-VEs in a randomised order. Table 3.1 shows the rated valence and arousal results (Mean (M) and Standard Deviation (SD)) of all 360-VEs. See Appendix–A for YouTube links of the final 360-VEs included in the study).

Table 3.1: Pilot trial volunteers' ratings results

CMA	ID	Title	Rated Valence		Rated Arousal		Included in the Study?
			M	SD	M	SD	
High Arousal Positive	125	Walk the Rope	6.42	1.38	7.17	1.34	**Yes**
	006	Music Video	7.33	1.50	4.42	2.50	No
	110	The Lion King	7.83	1.11	4.58	2.57	No
	030	Elephants in the mud	7.17	1.34	4.83	2.62	No
	029	Elephants in the field	7.33	1.21	4.83	2.40	No
	012	Brazilian Dance	6.83	1.60	6.00	2.45	**Yes**
	024	Dancing with Stars	6.67	1.51	6.00	1.26	**Yes**
	074	Pole Dancing	6.50	1.76	4.83	1.83	No
Low Arousal Positive	117	Beautiful Resorts	7.83	1.59	3.83	2.55	No
	051	Calm Pond in Forest	7.08	1.44	3.58	2.68	**Yes**
	013	Cute Bunnies	7.42	1.68	3.50	2.58	**Yes**
	120	Around the World	8.50	0.84	5.33	3.50	**Yes**
High Arousal Negative	108	The Exorcist	3.75	2.18	6.75	1.86	**Yes**
	109	Alone in Forest Tent	3.83	2.21	6.50	2.39	**Yes**
	115	Zombies Coming Close	4.83	3.60	8.00	1.26	No
	116	Zombies Eating Flesh	3.33	2.39	6.33	2.39	**Yes**
Low Arousal Negative	076	Post Terror Attacks	3.25	1.96	3.42	2.19	**Yes**
	095	Solitary Confinement	3.17	3.25	5.50	3.02	No
	113	Iraqi Refugee Story	3.33	2.73	3.33	1.97	No
	075	Refugee Story Collection	2.75	1.76	3.50	2.02	**Yes**
	080	Refugee Rescue Boats	2.17	1.80	3.83	2.44	**Yes**

High Arousal Positive: 360-VEs in this quadrant were expected to receive high valence (positive) and high arousal ratings. All VEs in this quadrant were perceived as positive (>5.0). As for arousal, only V125, V012 and V024 were perceived as highly arousing; hence, included in the final selection for the study.

Low Arousal Positive: 360-VEs in this quadrant were expected to receive high valence (positive) and low arousal ratings. All VEs in this quadrant were perceived as positive. As for arousal, V120 was perceived as highly arousing;

therefore, dropped from the study. V117, V051 and V013 were perceived as low arousing; therefore, included in the final selection for the study.

High Arousal Negative: 360-VEs in this quadrant were expected to receive low valence (negative) and high arousal ratings. All VEs in this quadrant were perceived as negative and highly arousing. Since V115 received borderline high valence ratings (M=4.83), only V108, V109 and V116 were included in the final selection for the study.

Low Arousal Negative: The 360-VEs in this quadrant were expected to receive low valence (negative) and low arousal ratings. All VEs in this quadrant were perceived as negative. As for arousal, all VEs were perceived as low arousing except for V095; therefore, dropped from the study. Considering the aim was to employ three VEs per quadrant, V076, V075 and V080 were included in the study, while V113 was dropped as it received the highest ratings of valence.

3.4 Methodology

3.4.1 **Participant Screening Criteria**

An invitation was sent to various mailing lists within the Canterbury campus at the University of Kent – the United Kingdom. The email contained a blurb and a link to a survey which described participation information and an eligibility checker which was a series of exclusion criteria questions to check whether interested individuals could participate.

Specifically, individuals who reported they have or have had a seizure(s), seizure disorder, epilepsy, heart condition(s), heart arrhythmias or hypertension were excluded from participation. Furthermore, individuals who reported to have or have had a vestibular disorder, any medical condition(s) affecting balance, frequent headaches, light-headedness, or dizziness, visual or hearing impairment, head injury, neurological disease(s), learning disability, psychological disorders or clinical depression were also excluded. In addition, individuals who have a perfect or close-to-perfect vision with the assistance of glasses were excluded from participation due to the rigidity of the HMD model.

Finally, individuals who rated six or higher on a Likert scale on "how easily do you get motion or carsick?" where 1="never been motion sick" and 7="get motion sick very easily" were excluded considering that participants are expected to engage in VR for an extended period.

3.4.2 **Ethics**

All participants signed a consent form prior to the study. All procedures conformed to the Declaration of Helsinki. The study was approved by the University of Kent School of Psychology Research Ethics Committee (Ref.ID201715000228084504).

3.4.3 **Participants**

Thirty-four individuals (17 female and 17 male) aged between 18 and 61 years (M=25.00, SD=7.65) volunteered to take part in this study. 55.9% of participants (n=19) reported having used VR before; of which, none have reported feeling motion sick amid or post exposure to VR. On a Likert scale from one to seven on "how easily do you get motion or carsick?" participants reported they do not easily get motion sick (M=1.350, SD=1.12).

3.4.4 **Apparatus & Setup**

The FOVE-0 HMD and a set of headphones were wire-connected to a dedicated computer to stream the visual and audial content. The FOVE-0 is a hands-free HMD secured with its 3-point harness adjustable Velcro head straps. The HMD has a WQHD OLED display (2560x1440 pixels) and renders at a frame rate of 70 fps with a field of view up to 100 degrees. The head orientation tracking system uses Inertial Measurement Units (IMU), and the eye-tracking system uses infrared-based technology on each eye with tracking accuracy less than 1 degree at 120 fps and running at a sampling frequency of 60 Hz. In addition, headphones were used for streaming audial content, and an 11" Macbook Pro laptop and mouse were used to fill all self-reported questionnaires.

3.4.5 **Experimental Procedure**

A verbal instructions protocol (see Appendix–G) was used to ensure that instructions are held constant for all participants. At first, potential participants were provided information about the study details (see Appendix–B) then signed consent (see Appendix–C). Afterwards, participants filled the "Participant's Profile & Pre-Exposure" questionnaire (see Appendix–E). Once completed, participants were introduced to the use of the VR; they were told on how the HMD can be fitted using the adjustment straps and how to navigate VEs by rotating their head and upper body whilst seated. As every participant has unique physiological properties, eye-gaze calibration was required; therefore, participants had their eyes calibrated using the standard FOVE-0 calibration program where they were asked to look and follow a green dot. Afterwards, participants wore the headphones and HMD then were asked to engage in the 360-VE from beginning to end. Once the duration of the 360-VE has ended, participants filled the "Post-Exposure" questionnaire (see Appendix–F) then had a two-minute cool-down period before the next 360-VE, where they were asked to relax and sit quietly. This procedure was repeated until participants engaged in all 360-VEs. The order of the quadrants and the 360-VEs within the quadrants were randomised using the Latin Square design to avoid order effects on emotional elicitation. In the end, participants were fully debriefed (see Appendix–D) about the study aims and received a 10 pounds Amazon voucher as a token of appreciation for their participation. Each session lasted approximately two hours.

3.4.6 Psychological Measures

Participants completed the following self-reported measures:

- As part of the "Participant's Profile & Pre-Exposure" questionnaire (see Appendix–E), participants were asked to report demographic information such as age, sex, sexual orientation, ethnicity, dominant hand, and English proficiency[26].

[26] In this Chapter, demographic information were only used to describe the sample of participants (see section 4.3.4). Considering this dataset is designed to be made publicly available, demographic data were collected as an effort to provide useful information that could be utilised further in analyses by other researchers.

- As part of the “Post-Exposure” questionnaire, participants were asked to complete the Presence Questionnaire (PQ) (Witmer and Singer 1998) immediately after engaging in each 360-VE experience. The PQ is composed of eight questions related to feelings of presence rated on a 7-point Likert scale.
- The SAM and VAS (see section 3.3.2) were used at the beginning of the session as a pre-exposure baseline measure. The questions were adapted to ask participants how they felt “right now, at this moment”.
- The SAM and VAS (see section 3.3.2) were used immediately after engaging in each 360-VE, as part of the “Post-Exposure” questionnaire. The questions were adapted to ask participants how they felt “whilst watching the video”.
- Using VAS, participants were asked to rate how dizzy they felt, once at the beginning of the session and once after exposure to each 360-VE, as part of the “Post-Exposure” questionnaire.

3.4.7 **Eye-Gaze Measures**

Eye-tracking data per participant were generated for each 360-VE from beginning to end, including data for the left eye, right eye, and head rotation, yielding a total of 408 trials (twelve 360-VEs * 34 participants). The raw data (per participant per 360-VE) included vector data of each eye independently (X, Y, Z), binary eye-closed/open for each eye independently, head orientation in degrees (X, Y, Z) and timestamp.

Preprocessing of raw data and extracting features was conducted by collaborators in the project. The GazeParser[27] library was used to extract eye-gaze features for analysis. The library produced four main eye-gaze features: fixation, micro-saccade, saccade and blink using the threshold values presented in Table 3.2 (Holmqvist *et al.* 2011; Otero-Millan *et al.* 2008). In preparation for feature extraction using GazeParser, eye-gaze and head-movement data were combined to produce horizontal and vertical viewing

[27] http://gazeparser.sourceforge.net

angle (X, Y) data per eye. The feature extraction algorithm is based on velocity threshold method or what is also known as velocity-based identification; where the algorithm distinguishes fixations (low velocity) from saccades (high velocity) based on gaze point-to-point velocities (see full taxonomy of identifying fixations and eye-tracking protocols including velocity-based algorithms Salvucci and Goldberg (2000)). Finally, statistical calculations were carried for each feature. Considering the 360-VEs had slightly different time lengths, the count (number of instances) were normalised by length (number of instances/time). Table 3.2 describes the eye-tracking features that were extracted, brief description, threshold, and the statistical calculations carried on for each feature, including Normalised Count (NormCount), Mean (M), Maximum (Max), Standard Deviation (SD) and Skewness (Skew); a measure of asymmetry in a distribution.

Table 3.2: Summary of eye-tracking features, threshold and statistical metrics

Main Feature	Brief Description	Threshold	Statistical Metrics
Fixation	Temporal stillness in the eye movement over time	Fixation Minumum Duration=300ms	Number of Fixations (NormCount)
			First Fixation Duration
			Duration (M, Max, SD, Skew)
Micro-Saccade	Intra-fixational movement where the eye jitters during a fixation	Micro-Saccade Minimum Duration During a Fixation=400ms	Number of Micro-Saccades (NormCount)
			Peak Velocity (M, Max, SD, Skew)
			Direction (M, Max, SD, Skew)
			Horizontal Amplitude (M, Max, SD, Skew)
			Vertical Amplitude (M, Max, SD, Skew)
Saccade	Rapid motion of the eye from one fixation to another	• Saccade Velocity Threshold=35ms • Saccade Acceleration Threshold=400ms • Saccade Minumum Duration=30ms • Saccade Minimum Amplitude=5ms	Number of Saccades (NormCount)
			Duration (M, Max, SD, Skew)
			Direction (M, Max, SD, Skew)
Blink	Eye closed	Blink Minumum Duration =50ms	Number of Blinks (NormCount)
			Duration (M, Max, SD, Skew)

3.5 Results

The results are organised as follows. First, the categorisation of the 360-VEs over valence and arousal was validated using SAM. Then, using VAS ratings of emotions, further understanding of emotional elicitation in 360-VEs was explored. Afterwards, the results of presence ratings are presented, followed by an analysis of participants' ratings of dizziness. Finally, eye-tracking data were examined to evaluate whether eye-gaze behaviour could predict emotional elicitation over the arousal and valence dimensions. While this section will present the analysis results, a more detailed discussion about these findings and how they relate to research questions will follow in section 3.6.

The study included 34 participants engaging in twelve 360-VEs, yielding a total of 408 trials. One participant wished to stop using VR after engaging in four 360-VEs, commenting that the high arousal negative 360-VEs were very intense. Another participant wished to withdraw from engaging in one high arousal negative 360-VE after engaging in two 360-VEs in the same category, commenting that these 360-VEs were very intense to them. Finally, five trials were withdrawn from the eye-tracking analysis due to the poor quality of eye-gaze data recorded caused by technical problems of the HMD. Therefore, the final dataset included 394 trials.

All statistical analyses were carried by the author of the thesis using JASP[28] version 0.12.

3.5.1 **Validation of Affective 360-VEs (SAM)**

This analysis aimed to understand whether 360-VEs triggered the desired arousal and valence effects in participants. Table 3.3 describes the Mean (M) and Standard Deviation (SD) of valence and arousal ratings using SAM in each quadrant (also see Figure 3.7).

As for the valence dimension, negative VEs were perceived as negative (low arousal negative; M=2.46, high arousal negative; M=4.29), and positive VEs were perceived as positive (low arousal positive; M=6.48, high arousal positive; M=6.46). As for the arousal dimension, the intended low arousal VEs were perceived as low arousing (low arousal negative; M=3.52, low arousal positive; M=2.51). However, as for the intended high arousal VEs, only the intended high arousal negative VEs were perceived as high arousing (high arousal negative; M=6.00, high arousal positive; M=3.80).

[28] https://jasp-stats.org

Table 3.3: Ratings of valence and arousal per CMA quadrant

Intendent CMA Quadrant	Rated Arousal		Rated Valence	
	M	SD	M	SD
High Arousal Positive	3.80	1.97	6.46	0.77
Low Arousal Positive	2.51	1.12	6.48	1.00
High Arousal Negative	6.00	1.60	4.29	1.59
Low Arousal Negative	3.52	1.69	2.46	1.06

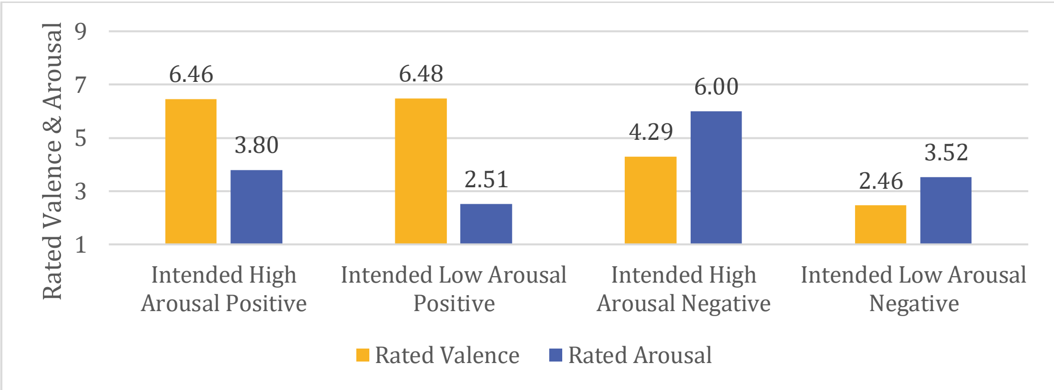


Figure 3.7: Ratings of valence and arousal per CMA quadrant

A two-way repeated-measures ANOVA was carried out to determine the significance of engaging in 360-VEs in the four CMA quadrants, followed by Tukey's HSD tests to examine the significance of the valence and arousal dimensions independently.

Rated Valence ANOVA: The rated valence significantly differed in the four quadrants of the CMA, $F(132, 2)=21.62$, $p<.001$. Tukey's HSD test indicated that the mean value of rated valence in negative VEs ($M=3.38$, $SD=1.63$) was significantly lower than positive VEs ($M=6.47$, $SD=0.89$), $t(132, 2)=-15.59$, $p<.001$. Interestingly, the mean value of rated valence in low arousal VEs ($M=4.44$, $SD=2.71$) was significantly lower than high arousal VEs ($M=5.36$, $SD=1.66$), $t(132, 2)=-4.55$, $p<.001$; meaning, participants rated high arousal VEs significantly more positively than low arousal VEs.

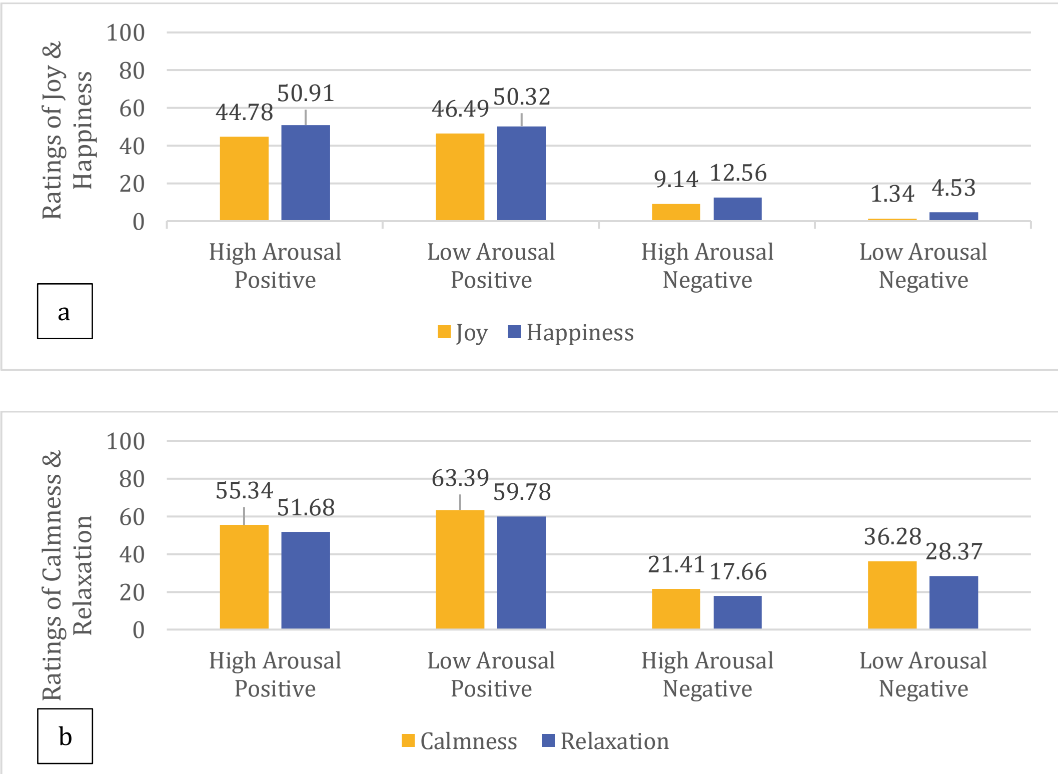
Rated Arousal ANOVA: The rated arousal significantly differed in the four quadrants of the CMA, $F(132, 2)=4.55$, $p=.035$. Tukey's HSD test indicated that the mean value of rated arousal in low arousal VEs ($M=3.02$, $SD=1.51$) was significantly lower than high arousal VEs ($M=4.92$, $SD=2.09$), $t(132, 2)=-6.71$,

p<.001. Interestingly, the mean value of rated arousal in negative VEs (M=4.76, SD=2.05) was significantly higher than positive VEs (M=3.16, SD=1.72), t(132, 2)=5.71, p<.001; meaning, negative VEs were perceived as significantly more arousing than positive VEs.

In summary, it is prevalent that participants experienced four distinct emotional states over the arousal dimension (high, low) and valence dimension (negative, positive). Even though participants perceived the high arousal positive 360-VEs as low arousing, the ratings of arousal in this quadrant were still significantly higher than low arousing 360-VEs.

3.5.2 **Emotional Elicitation (VAS)**

This analysis was aimed to evaluate the emotional effects of engaging in 360-VEs using nine VASs of emotions. To gain a general understanding of how participants rated 360-VEs in each quadrant, Figure 3.8 presents the participants' ratings mean values of each VAS emotion in each quadrant.



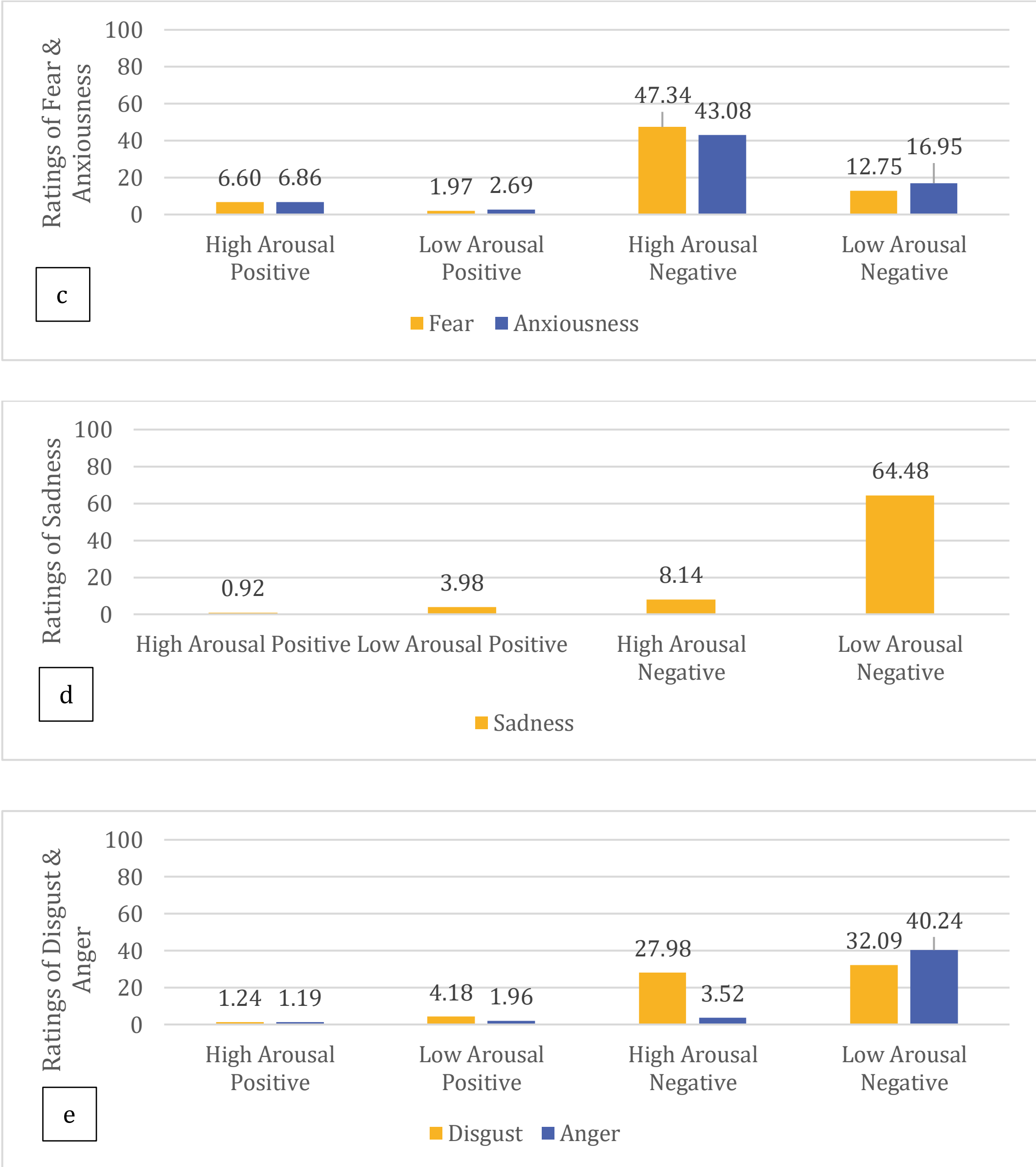


Figure 3.8: Mean values of VAS ratings over the four quadrants of the CMA – a: ratings of joy & happiness, b: ratings of calmness & relaxation, c: ratings of fear & anxiousness, d: ratings of sadness and e: ratings of disgust & anger

Two-way repeated-measures ANOVAs were carried out to determine the significance of engaging in 360-VEs in the four CMA quadrants per VAS emotion, followed by Tukey's HSD tests to examine the significance of each VAS emotion over the valence and arousal dimensions independently. The full results of each VAS emotion are described in Appendix–H. Table 3.4 summarises the results of the ANOVAs and Tukey's HSD tests for each VAS emotion, where significant *p* values are in bold.

Table 3.4: ANOVA and Tukey's test results for VAS ratings (A=Arousal, V=Valence, L=Low, H=High)

VAS	ANOVA				Tukey's HSD					
	df	*MS*	*F*	*p*	CMA		M	SD	*t*	*p*
Joy	2	757.53	2.70	0.10	A	L	23.58	27.97	-1.05	0.3
						H	26.69	24.69		
					V	L	5.24	10.52	-13.96	**<.001**
						H	45.64	21.53		
Happiness	2	463.71	1.72	0.19	A	L	27.08	26.53	-1.52	.13
						H	31.45	27.03		
					V	L	8.54	14.02	-14.85	**<.001**
						H	50.62	18.76		
Calmness	2	389.62	0.79	0.37	A	L	49.64	25.54	2.99	**0.003**
						H	38.12	28.21		
					V	L	28.85	23.11	-7.96	**<.001**
						H	59.37	22.54		
Relaxation	2	57.23	0.11	0.74	A	L	43.84	28.35	2.41	**.017**
						H	34.41	27.34		
					V	L	23.01	21.40	-8.37	**<.001**
						H	55.73	24.44		
Fear	2	7511.35	30.31	**<.001**	A	L	7.44	14.66	-7.21	**<.001**
						H	27.28	26.9		
					V	L	30.05	27.26	9.47	**<.001**
						H	4.29	6.93		
Anxiousness	2	4035.24	15.65	**<.001**	A	L	9.92	16.35	-5.46	**<.001**
						H	25.24	25		
					V	L	30.01	24.73	9.1	**<.001**
						H	4.77	8.25		
Sadness	2	23772.45	113.23	**<.001**	A	L	34.68	35.75	11.86	**<.001**
						H	4.58	8.78		
					V	L	36.31	34.44	13.52	**<.001**
						H	2.45	5.46		
						H	1.57	4.75		
Disgust	2	11.42	0.038	0.85	A	L	9.92	16.35	1.17	0.24
						H	25.24	25		
					V	L	30.01	24.73	9.1	**<.001**
						H	4.77	8.25		
Anger	2	10826.46	52.0.2	**<.001**	A	L	21.39	27.44	7.52	**<.001**
						H	2.37	5.52		
					V	L	21.88	26.91	8.15	**<.001**
						H	1.57	4.75		

Ratings of Joy & Happiness: The analyses show that the ratings significantly differed over valence; meaning, positive VEs received higher ratings of joy and happiness than negative VEs, regardless of arousal.

Ratings of Calmness & Relaxation: The analyses show that the ratings significantly differed over the arousal and valence dimensions. Meaning, low arousal VEs received higher ratings of calmness and relaxation than high arousal VEs and positive VEs received higher ratings of calmness relaxation than negative VEs.

Ratings of Fear & Anxiousness: The analyses show that the ratings significantly differed in the four quadrants of the CMA, meaning, participants experienced four distinct levels of fear and anxiousness. Over the arousal and valence dimensions, high arousal VEs received significantly higher ratings of fear and anxiousness than low arousal VEs, and negative VEs received significantly higher ratings of fear and anxiousness than positive VEs.

Ratings of Sadness: The analyses show that the ratings significantly differed in the four quadrants of the CMA; meaning, participants experienced four distinct levels of sadness. Over the arousal and valence dimensions, low arousal VEs received significantly higher ratings of sadness than high arousal VEs, and negative VEs received significantly higher ratings of sadness than positive VEs.

Ratings of Disgust: The analyses show that the ratings only significantly differed over valence; meaning, negative VEs received higher ratings of disgust than positive VEs, regardless of arousal.

Ratings of Anger: The analyses show that the ratings significantly differed in the four quadrants of the CMA; meaning, participants experienced four distinct levels of anger. Over the arousal and valence dimensions, low arousal VEs received significantly higher ratings of anger than high arousal VEs, and negative VEs received significantly higher ratings of anger than positive VEs.

Generally, the results show that participants successfully experienced the desired emotions in the relevant quadrants. A worth-noting observation is that it seems that positive emotions are valence-specific, regardless of arousal, while in contrast, negative emotions were more quadrant-specific. That means, high ratings of happiness, joy, calmness and relaxation were present in both high arousal and low arousal positive VEs, while in contrast, high ratings of fear and anxiousness were only present in the high arousal negative VEs, and high ratings of sadness were only present in low arousal negative VEs. As such, it could be that negative emotions are more strongly recognised and felt than positive emotions. A possible explanation for this observation could be due to a psychological phenomenon called negativity bias. Negativity bias refers to the asymmetry in the way people perceive positive versus negative information, situations, memories or stimuli where people attend to, recognise and remember negative information far more than positive information (Vaish, Grossmann and Woodward 2008). Some research work reported negativity bias in the way users perceive emotional stimuli. For instance, one study found that people are biased towards negative stimuli (word-based and picture-based) than positive stimuli (Yuan *et al.* 2019). Similarly, one study reported that the brain processes and recognises negative stimuli (pictures) more profoundly and much faster than positive stimuli (Ito *et al.* 1998).

According to Russell and Mehrabian, the emotion descriptors "anger" and "disgust" lie in the high arousal negative quadrant (Russell and Mehrabian 1977). However, according to the results, participants rated high disgust and anger responses in the low arousal negative quadrant. Researchers have outlined that many reasons may affect the meaning of emotion descriptors in the CMA, which may affect the evaluation of these emotion descriptors, such as cultural differences, language differences, and moral principles (Russell, Lewicka and Niit 1989). Specifically, research shows that condemn-related emotions such as anger and disgust are strongly associated with moral judgement (Hutcherson and Gross 2011). Considering the content presented in the low arousal negative quadrant (stories of Syrian and Iraqi refugee camps, an experience of fleeing war through refugee boats and a post-terrorist attack vigil in Paris), it could be argued that the ratings of disgust and anger were more related to moral judgement; where participants may have condoned or condemned the VE content.

3.5.3 **The Sense of Presence (PQ)**

Using a two-way repeated-measures ANOVA, the analysis aimed to understand the levels of presence when engaging in 360-VEs across quadrants, followed by Tukey's HSD tests to examine the significance of presence over the valence and arousal dimensions independently (see Figure 3.9).

The ANOVA results showed no significant interaction between valence and arousal over ratings of presence, $F(132, 2)=2.84$, $p=0.09$. Tukey's HSD test indicated that the mean value of presence over low arousal ($M=4.54$, $SD=$) did not significantly differ from high arousal ($M=4.4$, $SD=$), $t(132, 2)=1.13$, $p=0.26$. However, the mean value of presence over low valence (negative) ($M=4.67$, $SD=$) was significantly higher than high valence (positive) ($M=4.26$, $SD=$), $t(132, 2)=3.13$, $p=0.002$; meaning, participants felt more present in negative VEs than positive VEs.

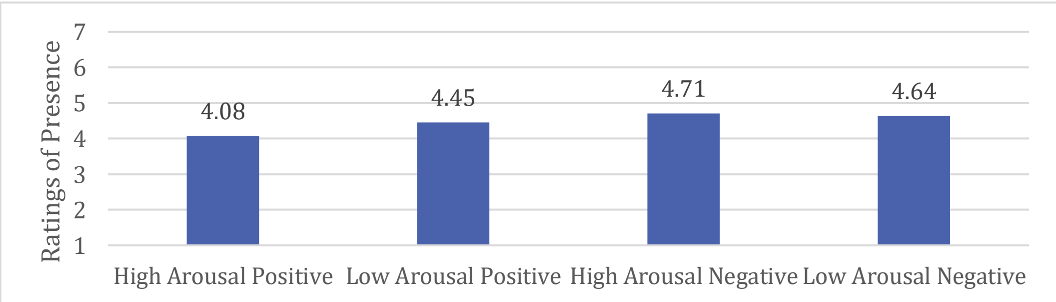


Figure 3.9: Mean ratings of presence per CMA quadrant

In summary, although participants felt present in all 360-VEs across all quadrants, participants felt more present in negative 360-VEs than positive ones. These results support the results found in the previous section, where negative emotions were more profoundly pronounced than positive emotions. These findings are consistent with previous literature, which concluded that the sense of presence is heightened when sensed emotions are more intense (Baños et al., 2004; Riva et al., 2007; Bouchard et al., 2011).

3.5.4 **Levels of Dizziness (VAS)**

This analysis was aimed to assess the ratings of dizziness throughout the session. Figure 3.10 presents the mean ratings of dizziness before the session (baseline) and twelve post-exposure ratings after engaging in each 360-VE. Given the lack of variance in the twelve post-exposure ratings, the mean of all post-exposure ratings was calculated to explore the pre-post effect of exposure to VR. A paired-samples t-test revealed there was no significant difference between the baseline ratings of dizziness (M=3.53, SD=9.56) and the post-exposure ratings of dizziness (M=2.44, SD=1.22); $t(33)$=.68, p=.50.

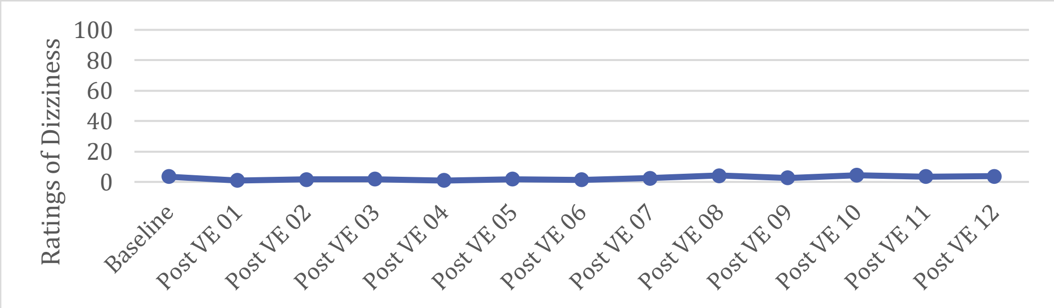


Figure 3.10: Mean ratings of dizziness (pre-exposure and repeated post-exposure)

3.5.5 **Prediction of Emotional Elicitation Using Eye-Gaze**

This section aimed to understand whether eye-gaze behaviour could be used to predict emotional elicitation in VR when engaging in 360-VEs. Binomial logistic regression was used for this analysis. Multicollinearity is a well-known issue when using regression analyses over highly correlated predictors (Vatcheva *et al.* 2016). Having predictors with high collinearity in the regression model results in problematic and biased standard errors and p-values; therefore, it could result in unrealistic and unsound interpretations. The most common tools for multicollinearity diagnostics in regression models in general and logistic regression in specific are pairwise correlation coefficients between predictors (where the cutoff is 0.80) (Berry, Feldman and Stanley Feldman 1985) as well as Variance Inflation Factor (VIF) (where the cutoff is 5) (Midi, Sarkar and Rana 2010; Vatcheva *et al.* 2016). In this study, first, pairwise correlations (using Spearman's 2-tailed tests) were conducted to eliminate highly correlating predictors. Afterwards, VIF diagnostics were then carried to detect any remaining multi-collinearities between predictors. As a result, the NormCount of saccades, SDs and Maxs of fixation, saccade and blink durations, SDs of micro-saccade horizontal and vertical amplitudes, M and Max of micro-saccade peak velocity and Skew of micro-saccade direction were all discarded from proceeding to the regression models. Table 3.5 describes the final variables that were used in the regression models. The results of the regression analyses are presented per CMA dimension.

Table 3.5: Statistical variables used in the regression analyses

Main Feature	Brief Description	Statistical Metrics
Fixation	Temporal stillness in the eye movement over time	Number of Fixations (NormCount)
		First Fixation Duration
		Duration (M, Skew)
Micro-Saccade	Intra-fixational movement where the eye jitters during a fixation	Number of Micro-Saccades (NormCount)
		Peak Velocity (SD, Skew)
		Direction (M, Max, SD)
		Horizontal Amplitude (M, Max, Skew)
		Vertical Amplitude (M, Max, Skew)
Saccade	Rapid motion of the eye from one fixation to another	Duration (M, Skew)
		Direction (M, Max, SD, Skew)
Blink	Eye closed	Number of Blinks (NormCount)
		Duration (M, Skew)

3.5.5.1 Predictors of Arousal

A binomial logistic regression analysis was used to predict emotional elicitation in VR based on the arousal dimension using eye-gaze features. The logistic regression model was statistically significant, $\chi^2(25)=173.43$, $p<.001$. The model explained 51.4% (Nagelkerke R^2) of the variance in arousal and correctly classified 79.5% of the cases. Meaning, 51.4% of the variation in the eye-gaze features over arousal can be explained by the regression model, while 79.5% of the cases were correctly classified. Sensitivity was 76.3%, in which, the regression model correctly predicted low arousal (i.e. true negatives), and specificity was 82.5%, in which the regression model correctly predicted high arousal (i.e. true positives).

Predictors' contribution to the model is summarised in Table 3.6, where significant predictors' *p* values are in bold.

Table 3.6: Predictors of emotional elicitation over the arousal dimension

Predictor	*B*	S.E.	Wald	*df*	*p*	Exp(B)	95% CI	
							Lower	Upper
Fix NormCount	-8.759	2.118	17.10	1	**.000**	0.000	0.000	0.010
Fix Duration M	-0.001	0.000	18.99	1	**.000**	0.999	0.999	1.000
Fix Duration Skew	-0.400	0.175	5.21	1	**.023**	0.670	0.475	0.945
1st Fix Duration	0.000	0.000	0.05	1	.82	1.000	1.000	1.000
Mic-Sac NormCount	-1.472	0.573	6.61	1	**.010**	0.230	0.075	0.705
Mic-Sac Peak-Vel SD	-0.003	0.005	0.48	1	.49	0.997	0.988	1.006
Mic-Sac Peak-Vel Skew	0.477	0.249	3.66	1	.06	1.610	0.989	2.623
Mic-Sac Direction M	-0.009	0.014	0.46	1	.50	0.991	0.964	1.018
Mic-Sac Direction SD	0.100	0.032	9.45	1	**.002**	1.105	1.037	1.177
Mic-Sac Direction Max	-1.245	0.423	8.67	1	**.003**	0.288	0.126	0.660
Mic-Sac H-Amp M	0.261	0.145	3.25	1	.07	1.298	0.977	1.725
Mic-Sac H-Amp Skew	-0.035	0.079	0.20	1	.65	0.965	0.827	1.126
Mic-Sac H-Amp Max	-0.009	0.004	6.34	1	**.012**	0.991	0.984	0.998
Mic-Sac V-Amp M	-0.165	0.556	0.09	1	.77	0.848	0.285	2.521
Mic-Sac V-Amp Skew	0.342	0.079	18.52	1	**.000**	1.408	1.205	1.645
Mic-Sac V-Amp Max	-0.019	0.009	4.51	1	**.034**	0.981	0.964	0.999
Sac Duration M	-0.003	0.001	4.87	1	**.027**	0.997	0.994	1.000
Sac Duration Skew	-0.578	0.227	6.51	1	**.011**	0.561	0.360	0.875
Sac Direction M	0.300	0.733	0.17	1	.68	1.349	0.321	5.680
Sac Direction SD	-0.622	0.948	0.43	1	.51	0.537	0.084	3.439
Sac Direction Skew	0.163	1.617	0.01	1	.92	1.177	0.049	28.027
Sac Direction Max	-3.518	1.498	5.52	1	**.019**	0.030	0.002	0.558
Blink NormCount	-2.150	1.107	3.77	1	.05	0.117	0.013	1.021
Blink Duration M	0.009	0.003	11.57	1	**.001**	1.009	1.004	1.015
Blink Duration Skew	-0.338	0.162	4.36	1	**.037**	0.713	0.519	0.980
Note: Low Arousal=0, High Arousal=1								

Fixations: The fixation (NormCount) and duration (M and Skew) were significant predictors of arousal. The results show that lower fixation count, shorter mean durations and negatively skewed durations all predicted engagement in high arousal VEs, while higher count, longer and positively skewed durations predicted engagement in low arousal VEs.

Micro-Saccades: The micro-saccade (NormCount), direction (SD and Max), horizontal amplitude (Max), and vertical amplitude (Skew and Max) were significant predictors of arousal. The results show that a lower micro-saccade count predicted engagement in high arousal VEs, while a higher count predicted engagement in low arousal VEs. Furthermore, the low variance in the micro-saccade direction predicted engagement in low arousal VEs, while high variance predicted engagement in high arousal VEs. In addition, smaller values of maximum saccade direction predicted engagement in high arousal VEs, while larger values predicted engagement in low arousal VEs. Furthermore, smaller values of maximum micro-saccade horizontal and vertical amplitude predicted engagement in high arousal VEs, while larger values predicted engagement in low arousal VEs. Finally, negative skewness of micro-saccade vertical amplitude predicted engagement in low arousal VEs, while positive skewness predicted engagement in high arousal VEs.

Saccades: The saccade duration (M and Skew) and direction (Max) were significant predictors of arousal. The results show that shorter mean durations, negatively skewed saccade durations and smaller values of maximum saccade direction predicted engagement in high arousal VEs, while longer and positively skewed durations, as well as larger maximum saccade direction values, predicted engagement in low arousal VEs.

Blinks: The blink duration (M and Skew) was a significant predictor of arousal. The results show that shorter blink mean durations predicted engagement in low arousal VEs, while longer durations predicted engagement in high arousal VEs. Negatively skewed blink durations predicted engagement in high arousal VEs, while positively skewed blink durations predicted engagement in low arousal VEs.

3.5.5.2 Predictors of Valence

A binomial logistic regression analysis was used to predict emotional elicitation in VR based on the valence dimension using eye-gaze features. The logistic regression model was statistically significant, $\chi^2(25)=122.16$, $p<.001$. The model explained 38.7% (Nagelkerke R^2) of the variance in arousal and correctly classified 75.3% of the cases. Meaning, 38.7% of the variation in the eye-gaze features over valence can be explained by the regression model, while 75.3% of the cases were correctly classified. Sensitivity was 80.4%, in which the regression model correctly predicted low valence (i.e. true negatives), and specificity was 70.1%, in which the regression model correctly predicted high valence (i.e. true positives).

Predictors' contribution to the model is summarised in Table 3.7, where significant predictors' *p* values are in bold.

Table 3.7: Predictors of emotional elicitation over the valence dimension

Predictor	*B*	S.E.	Wald	*df*	*p*	Exp(B)	95% CI	
							Lower	Upper
Fix NormCount	-3.540	1.641	4.65	1	**.031**	0.029	0.001	0.724
Fix Duration M	0.000	0.000	1.67	1	.2	1.000	1.000	1.000
Fix Duration Skew	-0.087	0.154	0.32	1	.57	0.916	0.677	1.240
1st Fix Duration	0.000	0.000	0.26	1	.61	1.000	1.000	1.000
Mic-Sac NormCount	-3.242	0.600	29.17	1	**.000**	0.039	0.012	0.127
Mic-Sac Peak-Vel SD	-0.003	0.001	4.77	1	**.029**	0.997	0.994	1.000
Mic-Sac Peak-Vel Skew	-0.080	0.201	0.16	1	.69	0.924	0.623	1.370
Mic-Sac Direction M	0.011	0.012	0.85	1	.36	1.012	0.987	1.037
Mic-Sac Direction SD	0.032	0.029	1.23	1	.27	1.032	0.976	1.092
Mic-Sac Direction Max	1.244	0.371	11.22	1	**.001**	3.469	1.675	7.182
Mic-Sac H-Amp M	0.185	0.132	1.98	1	.16	1.203	0.930	1.557
Mic-Sac H-Amp Skew	-0.066	0.074	0.79	1	.37	0.936	0.811	1.082
Mic-Sac H-Amp Max	0.008	0.003	5.19	1	**.023**	1.008	1.001	1.014
Mic-Sac V-Amp M	-0.058	0.424	0.02	1	.89	0.944	0.411	2.165
Mic-Sac V-Amp Skew	0.013	0.064	0.04	1	.83	1.013	0.894	1.149
Mic-Sac V-Amp Max	0.007	0.008	0.73	1	.39	1.007	0.991	1.023
Sac Duration M	-0.003	0.001	5.07	1	**.024**	0.997	0.995	1.000
Sac Duration Skew	0.136	0.194	0.49	1	.48	1.146	0.783	1.676
Sac Direction M	-0.069	0.627	0.01	1	.91	0.933	0.273	3.188
Sac Direction SD	-3.396	0.894	14.43	1	**.000**	0.033	0.006	0.193
Sac Direction Skew	-0.131	1.345	0.01	1	.92	0.877	0.063	12.240
Sac Direction Max	0.037	0.779	0.00	1	.96	1.037	0.225	4.776
Blink NormCount	-2.889	1.035	7.79	1	**.005**	0.056	0.007	0.423
Blink Duration M	-0.004	0.002	6.16	1	**.013**	0.996	0.993	0.999
Blink Duration Skew	-0.107	0.144	0.56	1	.46	0.898	0.678	1.190
Note: Low Valence(negative)=0, High Valence(positive)=1								

Fixations: The fixation (NormCount) was a significant predictor of valence; where lower fixation count predicted engagement in positive VEs, while higher count predicted engagement in negative VEs.

Micro-Saccades: The micro-saccade (NormCount), micro-saccade peak velocity (SD), micro-saccade direction (Max) and micro-saccade horizontal amplitude (Max) were all significant predictors of valence. The results show that lower micro-saccade count and variance in peak velocity predicted engagement in positive VEs, while higher count and variance predicted engagement in negative VEs. In addition, smaller values of maximum micro-saccade direction and horizontal amplitude predicted engagement in negative VEs, while larger values predicted engagement in positive VEs.

Saccades: The saccade duration (M) and direction (SD) were significant predictors of valence, where shorter saccade mean durations and smaller variance in saccade direction predicted engagement in positive VEs, while longer durations and higher variance predicted engagement in negative VEs.

Blinks: The blink (NormCount) and duration (M) were significant predictors of valence, where lower blink count and shorter mean durations predicted engagement in positive VEs, while higher count and longer durations predicted engagement in negative VEs.

3.5.5.3 Summary of Regression Analyses

Overall, the results of the regression analyses yielded promising results; it is clear that eye-gaze behaviour can predict emotional elicitation across the arousal and valence dimensions when users are engaging in 360-VEs using VR. In particular, the fixation, micro-saccade and blink count have shown to be significant predictors of arousal and/or valence. Furthermore, the durations (mean) of fixations, saccades, and blinks have also shown to be significant predictors of arousal and/or valence. Finally, the direction of saccades and micro-saccades has shown to be significant predictors of arousal and/or valence as well. The table below highlights the key results of the eye-gaze regression analysis.

Table 3.8: Summary of regression analyses

	Variable	Summary of Prediction
Fixation	NormCount – *predicted both Arousal & Valence*	Low fixation count predicted engagement in high arousal VEs and positive VEs.
	Duration (M & Skew) – *predicted Arousal only*	Short and negatively skewed fixation durations predicted engagement in high arousal VEs.
Micro-Saccades	NormCount – *predicted both Arousal & Valence*	Low micro-saccade count predicted engagement in high arousal VEs and positive VEs.
	Direction – *predicted both Arousal & Valence*	Small values of maximum micro-saccade direction predicted engagement in high arousal VEs and negative VEs. Small variance in the micro-saccade direction predicted engagement in low arousal VEs.
	Horizontal and Vertical Amplitudes – *predicted both Arousal & Valence*	Small values of maximum micro-saccade horizontal amplitude predicted engagement in high arousal VEs and negative VEs. Small values of maximum micro-saccade vertical amplitude predicted engagement in high arousal VEs.
Saccades	Duration – *predicted both Arousal & Valence*	Short saccade durations predicted engagement in high arousal VEs and positive VEs.
	Direction – *predicted both Arousal & Valence*	Small values of maximum saccade direction predicted engagement in high arousal VEs. Small variance in saccade direction predicted engagement in positive VEs.
Blinks	NormCount – *predicted Valence only*	Low blink count predicted engagement in positive VEs.
	Duration – *predicted both Arousal & Valence*	Short blink mean durations predicted engagement in low arousal VEs and positive VEs.

3.6 Discussion

The present study examined emotional responses in 360-VEs over the four quadrants of the CMA; high arousal positive, low arousal positive, high arousal negative and low arousal negative. The study also explored whether eye-gaze behaviour could infer emotional elicitation when engaging in 360-VEs using VR and what potentials eye-tracking in VR could hold within PC&B contexts. The discussion section is organised to discuss the potential of 360-VEs in VR as a medium for emotional elicitation in PC&B domains as well as the potential of eye-tracking VR as an assessment tool for emotional elicitation in mental healthcare and wellbeing.

3.6.1 Potential of Emotional Elicitation Using 360-VEs in Virtual Reality for Mental Healthcare & Wellbeing

Emotional elicitation and/or modulation is central to many PC&B interventions; hence, research within the HCI community, including VR research, has taken tremendous interests in developing interventions to elicit, modulate and assess emotional responses (see section 2.2.2). VR, in particular, has shown great potential by providing a novel emotional space for therapy, where users "step into" the emotionally eliciting VE and engage in therapy.

Herein, the first research question in this study was to explore whether 360-VEs could elicit emotional responses that might be useful in PC&B contexts. Throughout the study, it was prevalent that participants experienced four distinct emotional states over the arousal dimension (high, low) and valence dimension (negative, positive) when engaging in 360-VEs using VR. In addition, the VAS results further explained participant's emotional responses using nine emotion descriptors. The results of the VAS showed that participants experienced the desired emotional responses in 360-VEs.

In the past two decades of VR research in mental healthcare and wellbeing (see sections 2.3 and 3.2.3), most PC&B-VR interventions have utilised 3D-VEs to elicit emotional responses. Although 3D-VEs have been effective in this context, the expertise it requires to develop such VEs, development time and cost are recognised pitfalls in the literature (Hodge *et al.* 2018; Riva 2005; Siriaraya and Ang 2014). Only until recently, technologies that allow for the making of 360-VEs (such as 360˚ cameras) have become available in the consumer market at low cost (see section 2.1.1). In PC&B contexts, only one study was found that utilised 360-VEs in VR; Google Earth VR[29] was used as a non-pharmacological palliative care intervention to "take" terminal cancer patients to "go to a memorable place" or "return home" (Niki *et al.* 2019).

[29] https://arvr.google.com/earth

The study presented in this chapter has demonstrated the potential of utilising 360-VEs in eliciting emotional responses. Specifically, the results in this study show that 360-VEs can induce intense negative responses (i.e. anxiety and fear) with high levels of presence when engaging in negative 360-VEs. Previous research in PC&B contexts has utilised 3D-VEs in VR to elicit negative responses for therapeutic purposes such as fear and anxiousness for the treatment of phobia and anxiety disorders (see section 2.3). Since 360-VEs could be easily captured or readily available on online platforms, 360-VEs could have great potential in delivering similar types of treatments. Many 360-VEs available on online platforms contain experiences that potentially may be used for aviophobia (i.e. aeroplane experiences), arachnophobia (i.e. VEs with spiders), acrophobia (i.e. high height experiences such as the top of buildings, towers, mountains) or social phobia (i.e. large crowds).

At the other end of the spectrum, the use of positive 360-VEs may also have great potential in PC&B-VR applications. The body of research has used a variety of positive 3D-VEs to modulate psychological and physiological distress (Hoffman *et al.* 2000, 2001; Wolitzky *et al.* 2005). In which positive 3D-VE experiences were offered to patients as a distraction from physiological distress caused by painful procedures. In these studies, the elements 3D-VEs included are animals (i.e. zoo), water elements (i.e. waterfall, river) and snow elements (i.e. igloo, snowman, snowballs). Furthermore, positive 3D-VEs were also used to induce calmness and relaxation using natural elements such as mountains and rivers (Navarro-Haro *et al.* 2017). The 3D elements that were used in all of these examples can be easily found in readily available 360-VEs. For instance, several positive 360-VEs that were selected in this study contained natural elements and animals. To which, the results indicated that these 360-VEs significantly induced calmness, relaxation, joy and happiness.

Nonetheless, the results indicated that negative 360-VEs significantly induced higher levels of presence in comparison to positive 360-VEs. In addition, negative emotions were more intensely felt and recognised than positive emotions. Furthermore, low arousal and high arousal 360-VEs were both perceived as calming, relaxing, joyful and happy. Hence, when considering the deployment of 360-VE experiences, more efforts are required to induce significantly high levels of presence in positive experiences. Furthermore, more effort is required to induce distinctive low arousal and high arousal positive responses. In addition to audial and visual feedback, Mulsemedia or multiple-sensorial media are receiving increasing interests in HCI research in general and VR research in specific . Mulsemedia is related to the optimisation of experiences, including VR, by incorporating some or many sensory modalities such as haptics, olfactory and airflow sensing to increase immersion and engagement levels (Covaci *et al.* 2019). One path which could be investigated is to incorporate Mulsemedia in positive experiences.

3.6.2 Eye-Tracking in Virtual Reality as a Tool to Predict Emotional Elicitation

The second research question in this study aimed to address the efficacy of eye-tracking VR in predicting emotional elicitation when engaging in 360-VEs. The regression analyses showed that eye-tracking data successfully predicted affective states over the arousal and valence dimensions, demonstrating the efficacy of eye-tracking in VR for affect assessment when engaging in 360-VEs.

Direct comparisons with the literature work must be proceeded with caution due to the differences in experimental setups, apparatus, conditions and feature extraction and analysis methodologies. Furthermore, eye-tracking research examining affect using eye-gaze in VR is scarce. However, some similarities with studies which examined eye-gaze for affect in non-immersive mediums can be observed.

For instance, in this study, fixation duration was a significant predictor of arousal; where shorter fixation durations predicted engagement in high arousal VEs and longer durations predicted engagement in low arousal VEs, which is consistent with previous studies (Alhargan, Cooke and Binjammaz 2017; Simola *et al.* 2015). Furthermore, research shows that shorter fixation durations are associated with engagement with positive stimuli (i.e. games, movie clips), where longer fixation durations were associated with negative stimuli (Alhargan, Cooke and Binjammaz 2017; Lu *et al.* 2015). In this study, the relationship is consistent with these findings; shorter fixation durations were associated with engagement in positive VEs, and longer durations were associated with engagement in negative VEs; however, fixation duration only significantly contributed to the regression model over the arousal dimension. It is important to note that in some research, the level of arousal of the positive and negative stimuli was not clarified; therefore, a direct comparison is challenging (Lu *et al.* 2015).

In addition, it was found that fixation count was a significant predictor over both the arousal and valence dimensions; where low fixation count predicted engagement in high arousal VEs and positive VEs, and high count predicted engagement in low arousal VEs and negative VEs, which is also consistent with previous findings which examined the fixation count over valence and arousal using images (Simola *et al.* 2015).

Furthermore, Alhargan, Cooke and Binjammaz found that low blink count was associated with engagement in high arousal games, and the high count was associated with engagement in low arousal games (Alhargan, Cooke and Binjammaz 2017). In this study, although the blink count did not significantly contribute to the regression model, the relationship of blink count over the arousal dimension is consistent; low blink count was associated with engagement in high arousal 360-VEs, and the high count was associated with engagement in low arousal 360-VEs.

The area of research in eye-tracking using VR is still understudied; this could be because HMDs equipped with eye-tracking hardware and software have only become available in the consumer market until recently. Furthermore, of the few studies that have examined eye-tracking in VR, most have examined their hypotheses using pre-defined areas of interest, where fixation-related data is projected onto the 3D elements of interest (Kwok *et al.* 2019; Pettersson *et al.* 2018). The results in this study show that the use of eye-gaze behaviour (with no pre-defined areas of interest) is also an effective approach in detecting emotional elicitation when engaging in 360-VEs.

3.6.3 Potential of Eye-Tracking Virtual Reality in Mental Healthcare and Wellbeing

The third research question in this study aimed to explore the potential of eye-tracking VR in PC&B contexts. All four eye-gaze features that were explored in this study (fixations, micro-saccades, saccades and blinks) have been investigated by previous literature in PC&B contexts non-immersive mediums. For example, many saccade-related features revealed attentional biases for emotional stimuli in patients with anxiety and depression disorders (see a review in Armstrong and Olatunji (2012)). One study found that increased saccade duration around the area of interest (pictures of emotionally expressive faces) significantly correlated with social anxiety, indicating that people with social anxiety find difficulty in disengaging attention towards facial expressions (Schofield *et al.* 2012). In this study, high arousal VEs were predicted by short saccade durations and small maximum values of saccade direction. Furthermore, high variance in saccade direction predicted engagement in negative VEs. One interesting future direction could be to explore whether these saccadic features could predict anxiety-related emotions using VR.

The body of research has explored micro-saccadic behaviour predominantly in concentration-related mental healthcare and wellbeing applications. For example, micro-saccade amplitudes have been found to define concentration levels, where increased micro-saccade amplitude correlated with a low level of concentration (Buettner, Baumgartl and Sauter 2019). One study identified micro-saccadic behaviour as a biomarker of Attention Deficit Hyperactivity Disorder (ADHD), where people with ADHD presented with a significantly high number of micro-saccade instances in comparison to the non-clinical sample (Panagiotidi, Overton and Stafford 2017). Micro-saccadic behaviour has been explored in this study; the micro-saccade frequency and maximum values of micro-saccade direction were significant predictors for both arousal and valence. In addition, horizontal and vertical micro-saccade amplitudes significantly predicted both arousal and valence. The research community could capitalise on miro-saccadic features in VR to investigate concentration capabilities and its applications in mental healthcare and wellbeing.

Fixation is perhaps the most explored eye-gaze feature in the body of literature in mental healthcare and wellbeing. For example, one study found that fixation behaviours could detect arachnophobia in users (Pflugshaupt *et al.* 2005). The study concluded that phobic patients detected (initial fixation) spiders faster than non-phobic controls and also presented with avoidance, avoiding looking at the stimuli (short fixation durations over high arousal negative stimuli, i.e. spiders). In this study, the first fixation duration was not a significant predictor of arousal; however, low fixation count predicted engagement in high arousal 360-VEs. Another interesting study utilised fixation features to assess the effect of placebo treatments in arachnophobic patients (Gremsl *et al.* 2018). The study revealed that patients under placebo treatment fixated more over the pictures of spiders in comparison to non-placebo treatment, indicating that patients experienced reduced symptoms of avoidance when in placebo treatment. In this study, higher fixation count predicted engagement in low arousal 360-VEs. Other studies have utilised fixation-related features to detect mental fatigue (Yamada and Kobayashi 2018), avoidance in phobias and anxiety disorders (Barnes 2016; Wieser *et al.* 2009), distress intolerance (Macatee *et al.* 2018) and attention and memory (Gehrer *et al.* 2019; Subramanian *et al.* 2014). As such, the potential of VR in such research areas is immense; future research could explore whether such interventions could be replicated in VR, and by that, researchers can combine the advantages of immersive technologies such as VR with eye-tracking potentials.

The benefits of VR in therapies, assessments, rehabilitation protocols and many other forms of support within PC&B domains have been demonstrated through decades of research (see section 2.3). However, eye-tracking in VR in the context of mental healthcare and wellbeing is still an untapped research area with great potential. Many research works have demonstrated how eye-tracking in non-immersive mediums could provide researchers with a critical lens to understand users further, assess and design better therapies for users.

The research work done in this study has demonstrated the potential of assessing emotional responses in VR using eye-tracking, hoping that it would be a motivation for researchers to explore the use of eye-tracking VR in mental healthcare and wellbeing contexts.

3.7 Summary

This chapter describes a quantitative study that explored the feasibility of eye-tracking in VR as a low-cost, non-invasive method to assess emotional elicitation when engaging in 360-VEs. This study demonstrated that 360-VEs could elicit emotions in all quadrants of the CMA. Furthermore, participants did not report adverse effects of VR, such as dizziness throughout the sessions. The analysis of eye-gaze behaviours is promising, suggesting that eye-tracking in VR has strong potential in predicting emotional responses over the arousal and valence dimensions. The efficacy of 360-VEs in PC&B domains is still to be examined; however, 360-VEs may have the potential to be a solution for interventions that do not need complex interactivity methods, or for when time and resources are limited. The data collected in this study is to be published, which may serve as a launching pad for researchers interested in examining their hypotheses and algorithms to expand knowledge in emotional elicitation in VR and its relationship with gaze-behaviour.

Building on the findings in this study, the study in the next chapter investigated emotional elicitation in VR within a healthcare setting. The study aimed to explore the feasibility, design, and deployment of emotional spaces in VR in a healthcare setting, hoping to gain a hands-on and practical understanding of real-world healthcare circumstances and how VR can correspond to such needs requirements. Specifically, the next chapter explores the use of low arousal positive 360-VEs in VR for individuals with moderate to severe dementia residing in a locked psychiatric hospital.

Chapter 4: Exploring the Feasibility, Design & Deployment of Virtual Reality for People with Dementia in Locked Psychiatric Hospitals

4.1 Introduction

The previous chapter (Chapter 3) reported findings from a quantitative study that provided an insight into the efficacy of eye-tracking using Virtual Reality (VR) in predicting emotional elicitation when engaging in 360° Video-Based Virtual Environments (360-VEs) in healthy participants. Specifically, the study explored emotional elicitation in four categories: high arousal positive, low arousal positive, high arousal negative, and low arousal negative. The study also discussed the potential of eye-tracking in VR as a low-cost non-invasive emotional assessment and valuation modality and its potential applications in the mental healthcare and wellbeing domain in general and Psychological, Cognitive and Behavioural (PC&B) domains in specific. In addition, as part of a larger collaborative work, the study composed a dataset that is to be made publicly available, where the self-reported data and eye-tracking data of the study are included, in the hopes that other researchers can experiment and test their algorithms and hypotheses using the dataset to understand emotional elicitation in 360-VEs further.

However, research shows that user groups within mental healthcare respond differently to stimuli in VR (Baños *et al.* 2004). Therefore, it is unclear how emotional elicitation in VR could be designed and deployed to fit the needs and requirements of a real-world healthcare setting; little is known about the applications where emotional elicitation and modulation using 360-VEs in VR could be used to benefit clinical populations. In collaboration with St. Andrews Healthcare, Northampton – United Kingdom, this chapter presents a study that explored the use of VR with individuals living with moderate to severe dementia residing in a locked psychiatric hospital. Specifically, VR was explored as an emotional space to “bring the outside in” by providing 360-VEs as a virtual alternative to experiences that may be difficult to reach for People With Dementia (PWD) residing in a locked psychiatric hospital.

The study was originally planned to follow the same methodology as the study in Chapter 3, including the use of eye-tracking VR as a tool to measure emotional elicitation; however, during consultations with the clinical research team at the hospital, concerns were raised in regards to the implications of incorporating a VR headset with an eye-tracking functionality (see section 4.2.6 for full details). Considering the severity of the dementia diagnosis of the selected user-group, eye-gaze calibration required for eye-tracking may be hard or impossible to complete in some cases. Secondly, it is not clear whether PWD would tolerate a VR headset; therefore, the removal of any unnecessary steps to increase the acceptability of VR was crucial. Thirdly, current VR headsets that come with eye-tracking functionality are System-Dependant and wired, which was found not to be friendly to a locked psychiatric hospital environment. The locked psychiatric hospital's security procedures required the researchers to conduct the study in different rooms within the wards or PWD's own living spaces. As such, a Portable HMD was deemed more appropriate. Finally, System-Dependant VR HMDs are wire-connected, to which, the clinical team expressed safety concerns considering that PWD at the hospital can present with behaviour that challenges. As such, parts of the methodology from the study conducted in Chapter 3 were adapted to fit this deployment context.

As such, many questions arise around the feasibility and deployment of emotional spaces in VR for such a unique user-group. Specifically, this study aimed to address the following research questions:

- Is VR feasible and deployable for use in a restricted healthcare setting such as a locked psychiatric hospital? Can VR be tolerated and accepted by PWD who are in their later stages of dementia?

- How could emotional spaces within VR have an impact on behaviour and wellbeing for people with moderate to severe dementia? What kind of benefits could VR provide to this user-group?
- How could VR be deployed to provide a meaningfully emotional experience for PWD? How could VR be designed to enhance and maximise the benefits of VR?

The author of this thesis (referred to as the "technical researcher") and a clinical researcher collected the data together, where the technical researcher managed the equipment set up before, during and after every PWD visit (i.e. managing and administering the VR headset, camera set up for video recordings of the sessions, microphone set up for audio recordings of interviews – see section 4.2.6). The clinical researcher managed and filled the observed measures because these psychological measures are of a clinical nature (see section 4.2.7). The clinical researcher collected pre and post measures (collected in care, as usual, which may be a communal room with other patients, for example) due to security and safety reasons. Both researchers engaged in interviews with PWD and caregivers equally. Pre-analysis processes such as transcription of interviews were completed collaboratively by the technical and clinical researcher. The analysis presented in this thesis has been fully analysed by the author of the thesis.

This collaboration produced two scholarly papers; the first article was published in a peer-reviewed international conference, the 2019 CHI Conference on Human Factors in Computing Systems (CHI'19) (Tabbaa *et al.* 2019). This paper examined the Human-Computer Interaction (HCI) aspect of the study; specifically, the paper discussed how VR could benefit PWD, how VR could be designed to enhance those benefits, and what are the design considerations for VR deployment in a locked psychiatric hospital setting. In this paper, the author of this thesis led the analysis and write up of the publication. The second article was published in the peer-reviewed international SAGE Journal, Dementia (Rose *et al.* 2019). This paper explored the psychological effect of VR experiences on behaviour and wellbeing of PWD.

In this paper, the author of this thesis collaboratively led on the qualitative analysis with the clinical researcher, and supported the write up of the publication.

Considering the specific context this study examined, it is essential to understand the nature of the dementia disorder, long-term services for dementia care, and the research that has been done in the HCI community to support PWD. Therefore, in the next two sections, an introduction to dementia in general and dementia in long-term services in specific is presented, as well as a brief literature review about VR for dementia is explored. Then, the research methodology is presented, describing the participant selection process, final participant sample, study design, and materials. Afterwards, quantitative findings are reported, followed by qualitative findings combined with discussion.

4.1.1 **Dementia in Long-Term Care**

There are approximately 850,000 PWD in the United Kingdom (Prince *et al.* 2014) and 46 million people worldwide (Prince *et al.* 2015). Dementia is an umbrella term that describes disorders of the brain, which are progressive in nature and affect cognitive functions. With a complex array of symptoms of dementia, PWD can progressively lose their sense of autonomy, including engagement in activities of daily living and capacity to make decisions in various or all aspects of their life (Garcia-Palacios *et al.* 2002). Furthermore, behaviour that challenges are very common with individuals with moderate to severe dementia (Beck *et al.* 1998). Behaviour that challenges can include physical aggression toward self or others and verbal aggression (Cohen-Mansfield 2001). Currently, there is no cure for dementia. Since dementia remains incurable and progressive, institutional care is essential for some (Verbeek *et al.* 2010).

Similar to the growing number of PWD, older offenders with mental and cognitive disorders, including dementia, are the fastest-growing group in the prison population (Girardi *et al.* 2018). In some cases, for offenders with mental and cognitive disorders and comorbidities, including dementia, referral to psychiatric hospitals is required to meet their specialised psychiatric and psychological needs.

The levels of security within psychiatric hospitals (such as locked, low secure, medium secure or high secure) depend on the risk(s) the individual pose to themselves and/or others. PWD who reside in a locked psychiatric hospital often present with symptoms of dementia that requires a level of psychiatric care and safety measures, such as behaviour that challenges and/or forensic-related risk, may have offence-related histories, and maybe detained within the hospital for their own safety and/or for the safety of others under the Mental Health Act (*Mental Health Act* 2007).

Promoting wellbeing in PWD or Quality of Life (QOL) is considered a quintessential measure of effective dementia care (Kane 2001; Van Nieuwenhuizen and Nijman 2009). Within forensic healthcare, researchers found that higher QOL results in lower levels of anxiety, depression and hostility within wards (Long *et al.* 2008). Measures for QOL can include preserving autonomy for as long as possible and enabling PWD to maintain their lifestyle and identity, including partaking in meaningful activities and supporting social networks (Chenoweth *et al.* 2009).

However, such QOL measures could be difficult to achieve in long-term care. Many PWD residing in long-term care may face barriers in accessing experiences, lifestyle outlets or activities beyond their physical premises; this may be due to location, ill health, mobility constraints, restrictions by a mental health section or offence-related histories. In addition, many existing interventions that aim to support PWD can become difficult to achieve in more rigid settings, including in-patient services that are locked, low secure, medium secure or high secure, where environmental and procedural restrictions are implemented depending on the risk that individuals may pose to themselves or others.

The effect of such challenges to meet QOL measures in long-term services is observed in the literature. Research suggests that almost half of long-term residents in care services with cognitive disorders are diagnosed with depression (Schreiner, Yamamoto and Shiotani 2005). Subsequent reaction to symptoms of depression can contribute to cognitive decline, social withdrawal, lack of motivation and loss of interest in oneself and others (Kitching 2015). Furthermore, studies found that security measures within hospitals contribute to a lower QOL due to decreased autonomy, privacy, personal control and restricted access to leisure opportunities (Long *et al.* 2008).

For all the aforementioned reasons, research in dementia for individuals living with moderate to severe dementia residing in in-patient services is directed towards delivering innovative interventions that reduce behaviour that challenges and supports their QOL.

4.1.2 **Virtual Reality in Dementia Care**

Research in dementia has attracted substantial attention within the HCI community, especially because of the specific needs such population requires due to the decline in cognitive functions that affects the usability and acceptance of technologies. Such research examined various uses of technology to aid and assist PWD residing within the community, including those in care homes. For example, some research evaluated the use of serious gaming to train PWD on skills such as cognitive control (Anguera *et al.* 2013), spatial navigation (Cushman, Stein and Duffy 2008) and cooking activities (Manera *et al.* 2015). Others utilised technologies for detection, such as detection of cognitive status using computer games (Jimison *et al.* 2004) and agitation in dementia using body sensors (Bankole *et al.* 2012). In addition, several studies explored technology-based therapies such as reminiscence (Gowans *et al.* 2004; Kikhia *et al.* 2010; Kuwahara *et al.* 2006) or assistive technologies for PWD (see a summary in Bharucha et al. (2009)).

As for VR research in the context of dementia, there exist some studies that have focused on assessment (Mendez, Joshi and Jimenez 2015), training on specific skills such as spatial navigation (White and Moussavi 2016; Zakzanis *et al.* 2009) or therapeutic activities such as reminiscence (Hodge *et al.* 2018) for individuals with early or mild dementia. However, little is known about the feasibility of VR for individuals who are at the later stages of dementia residing within in-patient services such as a locked psychiatric hospital. Therefore, it is unclear how VR can be designed to benefit this user-group and what barriers a locked hospital may present to the deployment of VR.

As for VR design, prior studies have explored design requirements when developing Virtual Environments (VEs) for PWD in both semi-immersive and fully immersive modalities (Hodge *et al.* 2018; Siriaraya and Ang 2014). These studies demonstrated the importance of developing Three-Dimensional Computer-Generated Virtual Environments (3D-VEs) that are custom to preferences, stories or activities PWD would enjoy, as this could contribute to a more meaningful and sustained engagement. However, the potential pitfalls of developing tailored 3D-VEs were highlighted in both studies. First, the time it takes to understand individual preferences and the time needed to visualise, generate and test 3D-VEs is substantial and therefore places a time constraint for deployment. Second, the cost constraints when it comes to operating such methodologies to broader use within in-patient services is considerable. Both significant constraints could become a barrier to deployment.

A different approach was adopted in this study by utilising 360-VEs. 360-VEs are recorded using omnidirectional cameras, a technology that allows several cameras to record in every direction all at the same time. As such, users are able to look around by rotating their head and upper body (see section 2.1). Considering the widespread use of VR and 360° cameras in the consumer market, 360-VEs have become readily available at large quantities across online platforms. Thus, using 360-VEs could reduce the cost and development time, and by that, make VR more realistically deployable within a hospital medium and still be able to provide a tailored experience.

There is a lot to be learnt in regards to the potential of deploying VR technology within more complicated healthcare settings such as locked and secure hospitals. In such environments, the symptoms of later stages of dementia could be more challenging for meaningful and effective user interaction. To summarise the research questions in this study, at the most fundamental level, it is essential to understand whether a Head-Mounted Display (HMD) would be tolerated by PWD who can exhibit behaviour that challenges. If so, what kind of benefits VR could provide to such a user-group, how VR can be deployed to enhance and maximise these benefits and finally, what are the practical considerations to the deployment of VR in a restricted healthcare environment?

4.2 Methodology

4.2.1 **Ethics**

As summarised in Figure 4.1, participants were recruited from a locked psychiatric hospital in the United Kingdom that specialises in progressive neurological conditions, including dementia. The hospital provides specialist care to individuals who may present with behaviour that challenges and/or forensic-related risk. Ethical approval was sought from the hospital (ID: 21) as well as the United Kingdom National Health Services (NHS) research committee (ID: 17/LO/1477).

Informed consent was sought from participating caregivers as well as PWDs and/or their representatives. Due to the nature of dementia as a neurological condition, it is likely that individuals with moderate to severe dementia may not have the capacity to consent to participate in the study. Therefore, capacity assessments were completed by the hospital's multi-disciplinary teams to explore the capacity of PWD to consent to their participation using the "Mental Capacity Act (MCA) 2005 Assessment Checklist" (*Mental Capacity Act* 2005).

Where individuals were deemed to have the capacity to consent, a "consent to be approached" was first sought (see Appendix–I), then if consented, PWDs were introduced to the study aims and the VR technology using an information sheet (see Appendix–J). Once all questions and concerns were addressed, consent to participate was sought (see Appendix–L). Where individuals were deemed to lack capacity, a relevant consultee or next of kin was identified and invited to consider providing consent on their behalf. A letter of introduction and information (see Appendix–K) was sent to the representative alongside a "consent to be approached" form (see Appendix–I). If the "consent to be approached" form was signed, consent (see Appendix–M) to allow PWD to participate in the study was then explored as part of the best interest decision in accordance with the Mental Capacity Act (2005). All participants and/or consultees were debriefed after the data collection (see Appendix–N).

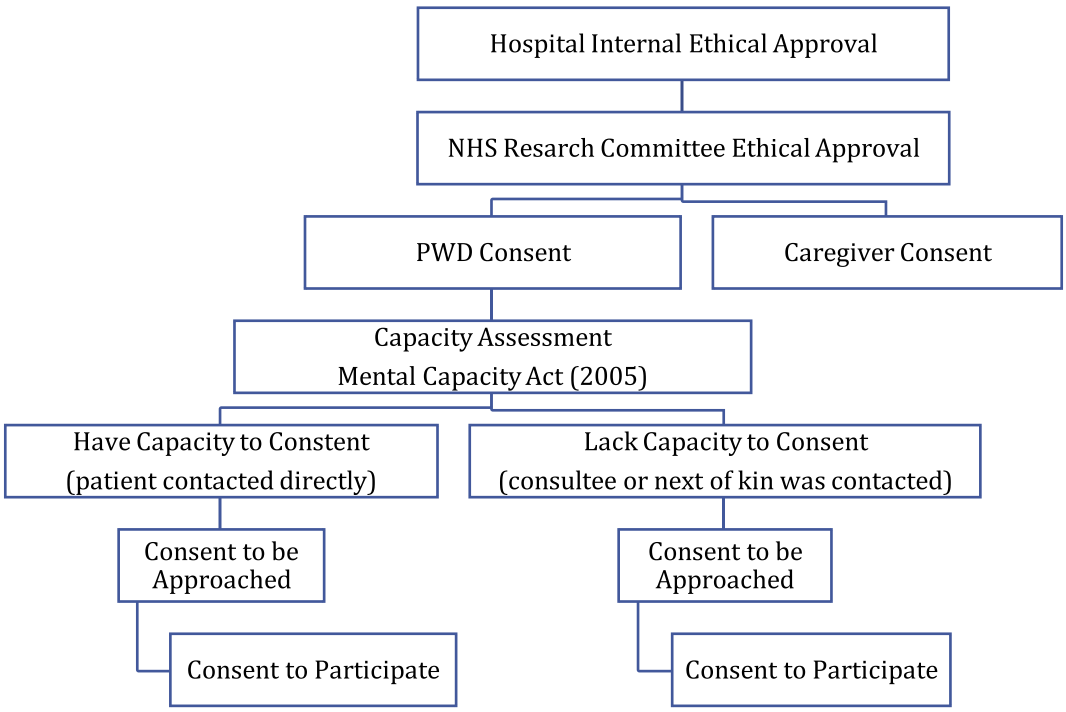


Figure 4.1: Ethical approval and consent process

4.2.2 **Participant Screening Process**

A total of 153 individuals within the hospital were screened for inclusion in this study. Fifty-one individuals were identified as having a dementia diagnosis. After applying the exclusion criteria, the total eligible sample included 38 individuals living with dementia. Exclusions included: epilepsy (n=5); multidisciplinary team's clinical judgement (n=5); visual impairment (n=1); imminent discharge (n=1); and death (during selection process, n=1).

Of PWD who were deemed to have the capacity to consent to their participation (n=8), six PWD consented to participate, and two declined. As for the remaining PWD (n=30), an assessment to explore their capacity to consent to their participation was required. Capacity assessments were completed for 18 PWD whom all were found to lack the capacity to consent. For these PWD, a potential consultee was contacted to consider consent to participate on the PWD's behalf (next of kin or an advocate). A total of thirteen consultees did not respond, three consultees did not give consent to be approached, and two consented to participate on the PWD's behalf.

Despite the broad patient group at the hospital, difficulties were faced in accessing more participants with severe cognitive impairment and, therefore, do not have the capacity to consent. This was largely due to the lengthy process of assessing capacity, which relied on busy multi-disciplinary teams at the hospital and seeking consent from potential consultees, many of whom were also at a distance from the hospital and were approached using postal correspondence only.

4.2.3 **Participants**

Of the pool of eligible PWD (n=38) within the hospital, six PWD were deemed to have the capacity to consent and provided consent to participate, and two consultees consented on behalf of PWD that were deemed to lack capacity to consent. Therefore, the final sample included eight PWD (two females and six males). The mean age was 69.63 years (range=41-88 years). Primary diagnoses included: dementia in Alzheimer's disease (n=2); unspecified dementia (n=2); dementia in Huntington's disease (n=2); mixed cortical and subcortical vascular dementia (n=1); and frontotemporal dementia (n=1). Secondary diagnoses included: recurrent depressive disorder (n=3); depressive episode (n=1); organic mood disorder (n=1) and paranoid schizophrenia (n=1).

The Global Deterioration Scale (GDS) (Reisberg *et al.* 1982), which consists of seven stages of cognitive functions in dementia ranging from 1: "no cognitive decline" to 7: "very severe cognitive decline", was completed by the treating multidisciplinary teams at the hospital and used to assess participant's cognitive functions in dementia. The GDS mean score of participants was 5 (indicating moderately severe cognitive decline) with a minimum of 2 (indicating very mild cognitive decline) and a maximum of 6 (indicating severe cognitive decline).

Sixteen caregivers were recruited to support PWD during their exposure to VR, whose professions included nursing (n=11); occupational therapy (n=3); psychology (n=1) and physiotherapy (n=1).

4.2.4 **Study Design and Procedure**

The study design emerged from rigorous discussions with experts in the fields of dementia care and HCI in healthcare and a completion of a systematic review that examined the feasibility of VR for individuals with moderate to severe dementia (Rose *et al.* 2018). A mixed-methods design was used to collect data over a two-week period which included interviews and qualitative and quantitative observations.

First, a clinical researcher observed PWDs in care as usual for 15 minutes prior to the VR session and recorded "pre-exposure" quantitative measures (see section 4.2.7). Then, escorted by a caregiver, PWDs were invited to use VR in a room within the ward they reside on or in their personal space, depending on the hospital's restriction per PWD. PWDs were offered an A3 paper "menu" of 360-VEs to choose from. They were offered to spend time in VR for a maximum of 15 minutes and were reassured they had the choice to stop using VR at any time or not use it at all. The maximum duration was suggested to reduce the risk of PWDs having adverse effects of using VR, such as dizziness and disorientation. Afterwards, PWDs participated in a semi-structured interview then returned to care as usual, and the clinical researcher observed the PWDs for 15 minutes to record the "post-exposure" quantitative measures (see section 4.2.7). Lastly, the caregiver supporting the PWDs during the session participated in a semi-structured interview. During the VR session, a technical researcher (author of the thesis) managed the equipment and recorded qualitative observations, then corroborated the notes using the video recordings of the sessions. As for "during-exposure" quantitative measures (see section 4.2.7), the clinical researcher was occupied with supporting PWDs during the session and therefore, the measures were taken after the session by reviewing the video recordings. Overall, each session lasted approximately an hour to one and a half hours on average. Using the same procedure, PWDs were invited to a second session two weeks later; therefore, each PWD was visited twice (referred to in this chapter as visit-1 and visit-2). Figure 4.2 summarises the procedure that the study followed.

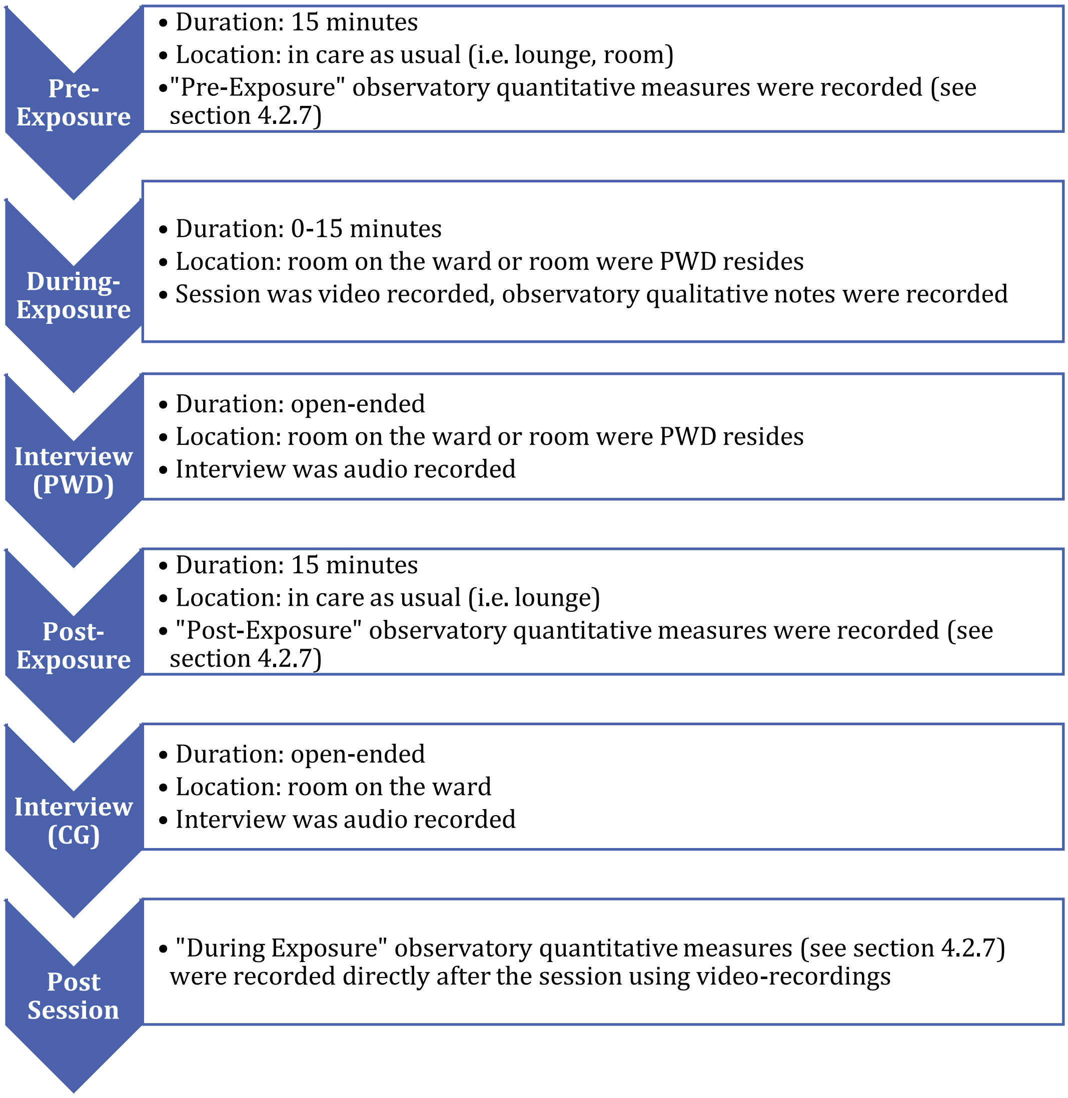


Figure 4.2: Study procedure per visit

4.2.5 **Stimuli Selection Process**

A 90-minute workshop was conducted at a Specialist Neuro-Care Conference organised at the participating hospital. Attendees of the workshop were a group of approximately fifteen specialists such as clinical psychologists, psychiatrists, nurses and managers within dementia healthcare.

During the workshop, the researchers presented an introduction to VR technology and the results of the systematic literature review (Rose *et al.* 2018)[30]. Attendees then were offered to engage in a variety of VR experiences, evaluate the size and weight of different HMDs and reflect on their experiences. Afterwards, attendees split into three groups and brainstormed the type of 360-VE content suitable for PWD based on their experience and knowledge. The attendees' suggestions were written, collected and collated into groups of categories. Table 4.1 describes the categories and keywords workshop attendees wrote and suggested as potentially suitable experiences for PWD.

Table 4.1: Categories and keywords of potentially suitable 360-VEs for PWD suggested by workshop attendees

Category	Keywords Attendees Used
Travel	google maps, cities around the world, cruises
Nature	beaches, woodlands, parks
Art Experiences	music, cinema, museums
Hobbies and Sports	football, fishing, golf, bowling
Social Experiences	pubs
Home	kitchens, workshops, gardens
Pets	puppies, kittens
PWD-Custom Content	Christmas or a thanksgiving content with the family, locations from earlier life

Through the workshop and based on the technical experience of the researchers in the HCI field, the following exclusion criteria were critically discussed and agreed upon to be used to identify potential 360-VEs:

- Resolution less than 2K (2048×1080); that is to avoid compromising resolution quality of content.

[30] Whilst this literature review was an output of the study, the author of this thesis was not directly involved in the research conducted for the literature review or the write up of the consequent publication.

- Sudden transitions between scenes; that is to avoid PWD being startled or confused.
- Moving, shaking, unstable camera recording; that is to avoid inducing motion sickness.
- Animals or people that are close to the camera may be perceived as startling or scary.
- Negative high arousal content that may be perceived as startling or scary.
- Audial content that is not consistent with the visual content, aiming to provide coherent audial-visual feedback and avoid distraction.
- Audial content that is perceived loud, low or noisy.
- Explicit audial narration; as it is important for the PWD to be able to hear the caregiver's directions and prompts whilst using VR.
- Computer-generated content or special effects added onto 360-VE due to the lack of evidence on the effects such type of content could have on PWD.

Based on the criteria above, 360-VEs were identified (n=78) using YouTube online platform, where the researcher attempted to harvest potential 360-VEs using the filter "360" (which refers to 360-VEs) available on the platform then manually checked the 360-VEs against the exclusion criteria. Table 4.2 describes the number of 360-VEs that were identified within each category.

Table 4.2: Number of 360-VEs identified within each VE category

Category	360-VEs Identified
Travel	n=21
Nature	n=14
Art Experiences	n=25
Hobbies and Sports	n=11
Social Experiences	n=0
Home	n=2
Pets	n=5
PWD-Custom Content	The research team decided to discard this category due to the feasibility and scope of the current study.

Six researchers (of which, three have clinical experience with PWD, three have HCI experience, including the author of this thesis) discussed and rated the 360-VEs independently. Researchers rated each 360-VE as 1: include, -1: exclude or 0: not sure. The highest-rated VEs were the cathedral, woodland, sandy beach, rocky beach, and countryside VEs, and were therefore included in the study. Snapshots of these 360-VEs are displayed in Figure 4.3.

Countryside 360-VE

Rocky Beach 360-VE

Sandy Beach 360-VE

Woodland 360-VE

Cathedral 360-VE

Figure 4.3: Snapshots of 360-VEs used in the study

4.2.6 **Equipment**

At the beginning of this collaboration, the researcher (author of the thesis) considered employing a VR HMD that incorporates eye-tracking functionality; to expand on the understanding of eye-gaze behaviour that was explored in Chapter 3. However, the clinical researchers outlined the following barriers to the deployment of an HMD with an eye-tracking feature. To start with, in the first research question, this study aimed to examine was whether PWD would tolerate and accept VR. With such a fundamental research question, the clinical research team stressed the importance of removing any unnecessary steps that might affect PWD's acceptability of VR. As such, considering eye-tracking VR would require eye-gaze calibration, it was decided that it was best not to incorporate this functionality at this stage of the research. In addition, considering the severity of the dementia diagnosis of the selected user-group, eye-tracking calibration would have been hard or maybe impossible to complete in some cases. Second, current eye-tracking HMDs are System-Dependant, which posed a barrier to the practicality of conducting the VR sessions. Unlike a traditional experimental setup where researchers set up the equipment in one space and participants are expected to visit that space, the security requirements within the locked psychiatric hospital required the researchers to conduct the study at rooms within the wards that PWD reside in, or if security measures require, at PWD's own living space. As such, a Portable HMD was deemed more appropriate. Finally, System-Dependant VR HMDs are wire-connected, to which, the clinical team expressed safety concerns considering that PWD at the hospital can present with behaviour that challenges.

Therefore, the Samsung Gear VR[31] HMD paired with a Samsung Galaxy S6 mobile phone was used to stream the audial and visual content. The Samsung Gear VR is a wireless HMD that can be used hands-free using its 3-point harness head strap and features an optical lens with a 96° Field of View. The

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

combined weight of the HMD (318 grams) and phone (138 grams) is 456 grams. The VR content was wirelessly streamed to an external laptop screen, mirroring the user's real-time VE's viewing angle, allowing caregivers to provide relevant prompts and support during the exposure. A video camera with a tripod was used to film participants during the VR session, and a dictaphone was used when interviewing all participants. A laminated A3 paper VE menu was presented to the participant at the beginning of the session, which included pictures and titles of the five different VE options they could choose from.

4.2.7 **Data Collection & Analysis**

A clinical researcher, who is experienced in using the observatory instruments, recorded the following measures for pre, during and post exposure to VR:

- Behaviour that Challenges:
    - Overt Aggression Scale-Modified for Neurorehabilitation (OAS-MNR) (Alderman, Knight and Morgan 1997): this scale offers continuous and direct observation and assessment of antecedents, contexts and interventions. It records the type and severity of aggression from four defined categories: verbal aggression, physical aggression against objects, physical aggression against self and physical aggression against others.
    - St Andrews Sexual Behaviour Assessment (SASBA) (Knight *et al.* 2008): The scale measures in the same way as the OAS-MNR but captures inappropriate or overfamiliar behaviour across four defined categories: verbal comments, non-contact, exposure and touching others.
- Observed Emotional Expression:
    - Observed Emotion Rating Scale (OERS) (Van Haitsma and Klapper 1999): the scale offers continuous, direct observation of the time spent expressing five affect types and measures the time spent in each of the following emotions: pleasure, anger, anxiety/fear, sadness and general alertness. Ratings are

measured on a Likert scale (1= never; 2= <16 seconds; 3= 16-59 seconds; 4= 1-5 minutes; 5= >5 minutes; and 7= not in view).

Two researchers (including the author of this thesis) conducted semi-structured interviews. However, for interviews with PWD, in some instances, an experienced caregiver who was familiar with the participant's clinical background was sought to support facilitating the interview when barriers in communication (i.e. severe cognitive impairment, other medical issues) arose. Interviews with PWD aimed to reflect on their experience using VR over technology acceptance, presence, and emotional affect. Some of the questions were constructed based on the Usability Evaluation in Industry Questionnaire (Brooke 1996) and Presence Questionnaire (Nichols, Haldane and Wilson 2000). For PWD who are able to express their answers elaborately, questions were asked in an open-ended nature to allow discussions. A simplified version was adopted for PWD, who best respond to questions that are simple and closed-ended. Finally, to ensure the reliability of the answers, the same questions were asked more than once and sometimes in a different format. See Appendix–R for both versions of the interview questionnaires.

Interviews with caregivers aimed to reflect on their observations of the PWD using VR and sought their professional opinion on the usability of VR in the locked hospital environment. See Appendix–S for the caregiver's interview questionnaires.

All interviews were transcribed verbatim by two researchers (see Appendix–O and Appendix–P for PWD and caregivers' transcript templates).

Qualitative observations were also taken by a technical researcher who was dedicated during the sessions to record observations (see Appendix–Q for observations template).

These observations aimed to record any physical interaction participants had with the HMD, their behavioural responses, reactions and facial expressions in response to the VR experience. Furthermore, the notes captured the interaction between PWD, caregivers, and the HMD, as well as explore how the technology could be designed and enhanced to best fit such interaction in a locked care environment.

The observation notes were verified and corroborated later using the video recording, then by two researchers independently to gain an overall understanding and to ensure the reliability of the observations.

4.3 Quantitative Findings

Whilst this section will present the results of the analyses, a more detailed discussion about these findings and how they relate to research questions will follow in section 4.4.

All statistical analyses carried out in this study were performed using the Statistical Package for the Social Sciences (SPSS) version 25[32].

4.3.1 **Observed Ratings of Emotions (OERS)**

Pleasure: Friedman test indicated that ratings of pleasure significantly differed between pre, during and post exposure to VR, $\chi^2(2)=8.0$, $p=.018$. Post-Hoc analysis using Wilcoxon signed-rank tests revealed a significant increase in pleasure from pre-exposure (Mdn=1.25) to during-exposure (Mdn=2.0) to VR ($Z=-2.06$, $p=.039$) and from pre-exposure to post-exposure (Mdn=1.75) to VR ($Z=-2.060$, $p=.039$). There was no significant difference between during-exposure and post-exposure to VR ($p=.28$).

Anger, Anxiety/Fear & Sadness: There was no significant difference in ratings of anger ($p=1.0$), anxiety/fear ($p=.21$) or sadness ($p=.23$) pre, during and post exposure to VR.

General Alertness: Ratings of general alertness significantly differed between pre, during and post exposure to VR, $\chi^2(2)=6.30$, $p=.043$. Post-Hoc analysis using Wilcoxon signed-rank tests revealed a significant increase in general alertness from pre-exposure (Mdn=4.50) to post-exposure (Mdn=5.0) to VR

[32] https://www.ibm.com/products/spss-statistics

(Z=-2.06, *p*=.039). There was no significant difference between pre-exposure and during-exposure (Mdn=5.0) to VR (*p*=.24) or during-exposure and post-exposure to VR (*p*=.41). These results are presented in Figure 4.4 (see also Table 4.3, where significant *p* values are in bold).

In summary, PWDs appeared to experience increased levels of pleasure from pre to post VR, and from pre-to-during VR. Furthermore, PWDs appeared to be more alert from pre to during VR. Finally, PWDs did not appear to experience significant levels of anger, anxiety/fear and sadness.

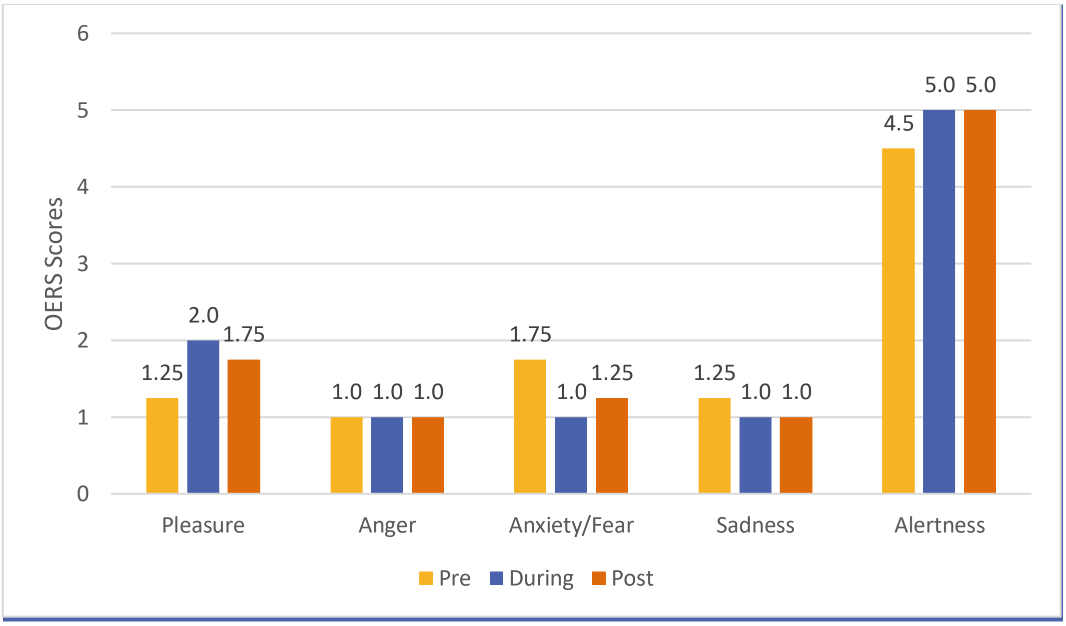


Figure 4.4: Median of observed ratings of emotions pre, during and post VR

Table 4.3: Analysis of observed ratings of emotions pre, during and post VR

Affect	*p*	Phase	M	Mdn	From-To	*p*
Pleasure	**.018**	**Pre**	1.31	1.25	Pre-During	**.039**
		During	1.81	2.0	Pre-Post	**.039**
		Post	2.12	1.75	During-Post	0.28
Anger	1.0	**Pre**	1.06	1.0	Pre-During	1.0
		During	1.06	1.0	Pre-Post	1.0
		Post	1.06	1.0	During-Post	1.0
Anxiety/Fear	.21	**Pre**	1.94	1.75	Pre-During	.10
		During	1.25	1.0	Pre-Post	.24
		Post	1.62	1.25	During-Post	.10
Sadness	.23	**Pre**	2.31	1.25	Pre-During	.10
		During	1.44	1.0	Pre-Post	.22
		Post	1.62	1.0	During-Post	.41
Alertness	**.043**	**Pre**	4.00	4.50	Pre-During	.23
		During	4.50	5.0	Pre-Post	**.039**
		Post	4.69	5.0	During-Post	.41

4.3.2 **Observed Behaviour That Challenges (OAS-MNR & SASBA)**

A total of nine behaviours were observed and recorded (OAS-MNR=8; SASBA=1), where seven behaviours were observed in pre-exposure (OAS-MNR=7; SASBA=0), one during exposure (OAS-MNR=0; SASBA=1), and one post-exposure (OAS-MNR=1; SASBA=0). Figure 4.5 shows the frequency of OAS-MNR and SASBA for pre, during and post exposure to VR.

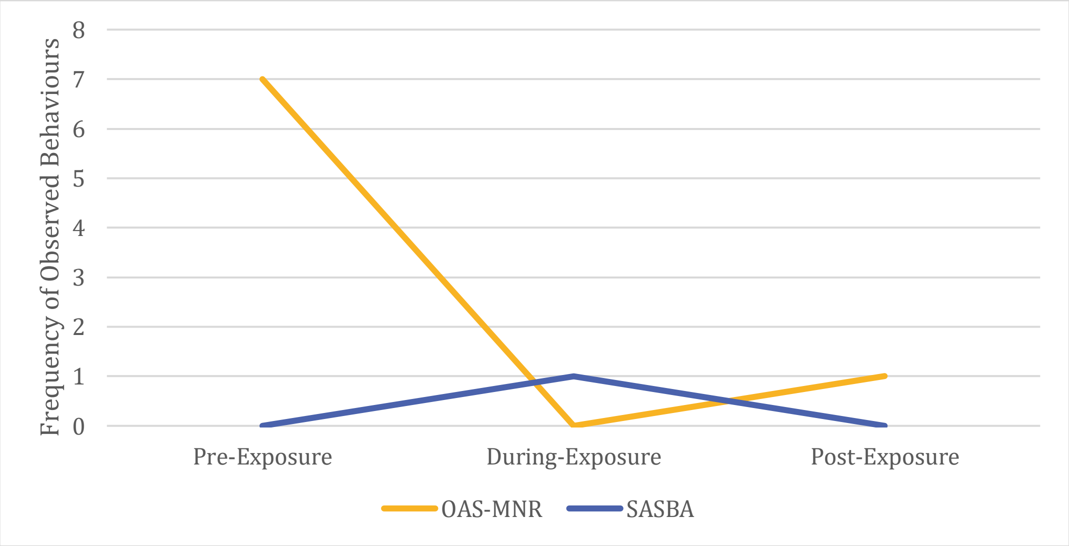


Figure 4.5: Number of observed behaviours

4.3.3 Time Spent in VR

Collectively, PWDs spent 01:13:18 hours using VR in visit-1 (range=00:00:07–00:15:00, Mdn=00:13:30), and 01:31:48 hours in visit-2 (range=00:01:10–00:15:00, Mdn=00:15:00). Figure 4.6 demonstrates the total time spent in VR per visit. A Wilcoxon signed-rank test demonstrated that there were no significant differences between PWD's time spent exposed to VR from visit-1 (Mdn=00:13:30) and visit-2 (Mdn=15:00), Z=-1.483, *p*=.14.

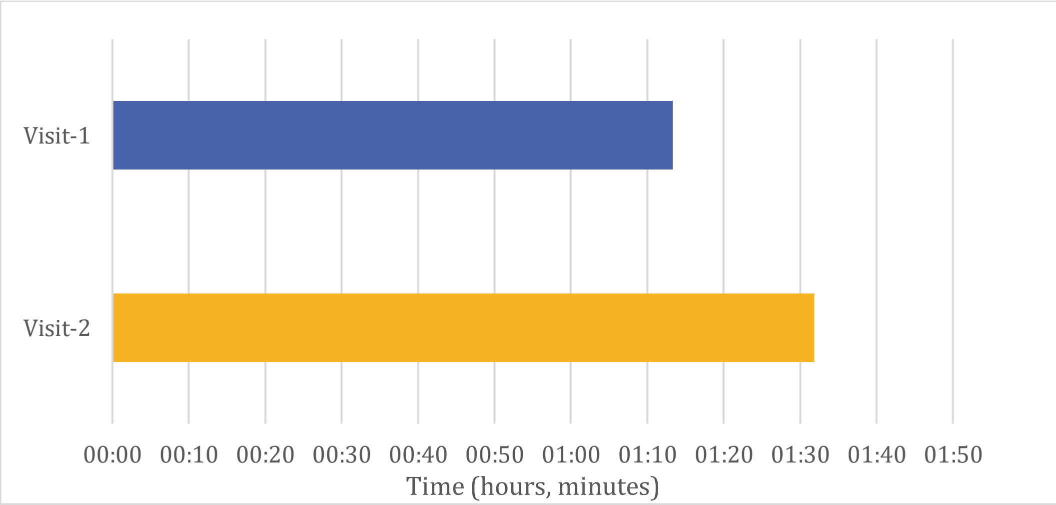


Figure 4.6: Total time spent in VR

Below, Figure 4.7 shows the amount of time each PWD spent in VR per visit.

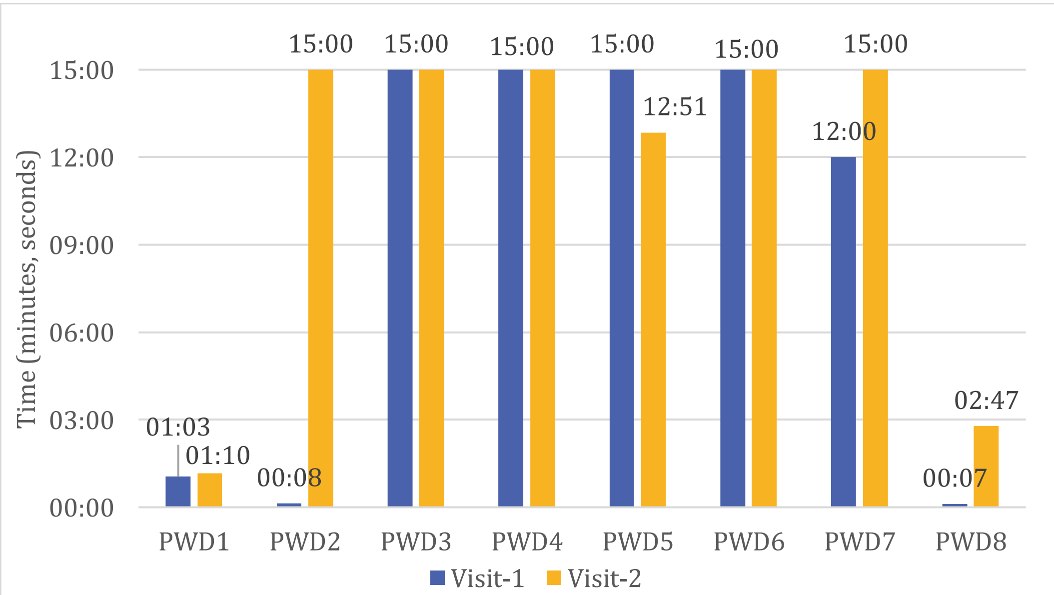


Figure 4.7: Time spent in VR per PWD per visit

Figure 4.8 shows the number of PWD (both visits combined) who spent a specific amount of time in VR per session. Amongst the sixteen sessions (eight PWD, visited twice), PWD spent either twelve minutes or more in VR (n=11) or spent three minutes or less in VR (n=5) in a session.

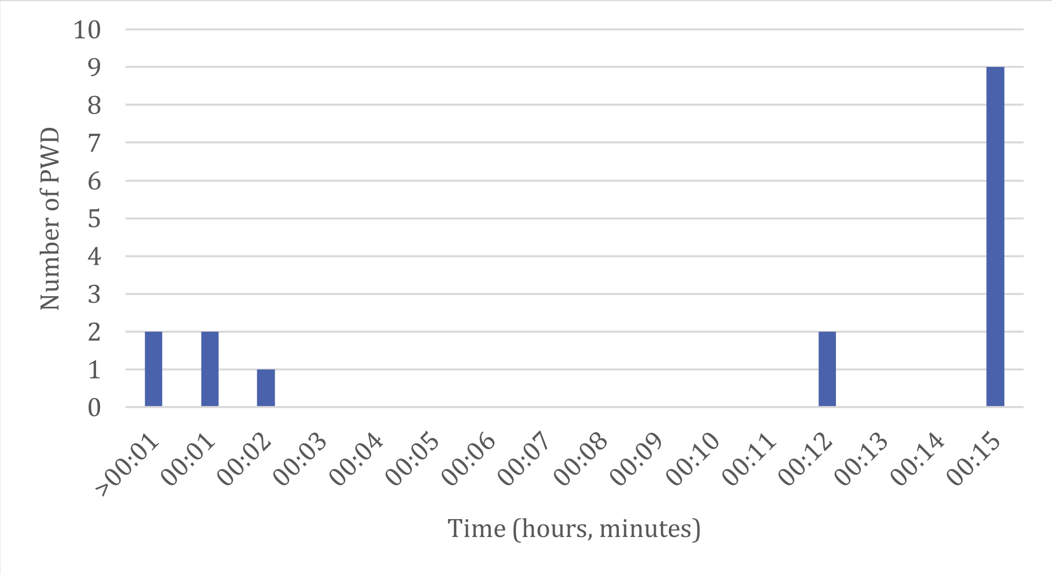


Figure 4.8: The frequency of PWD who spent a specific amount of time in VR

4.3.4 360-VEs Selection

Figure 4.9 displays the total number of times PWD selected a 360-VE in each visit, while Figure 4.10 displays the total time spent in VR per VE per visit and in total.

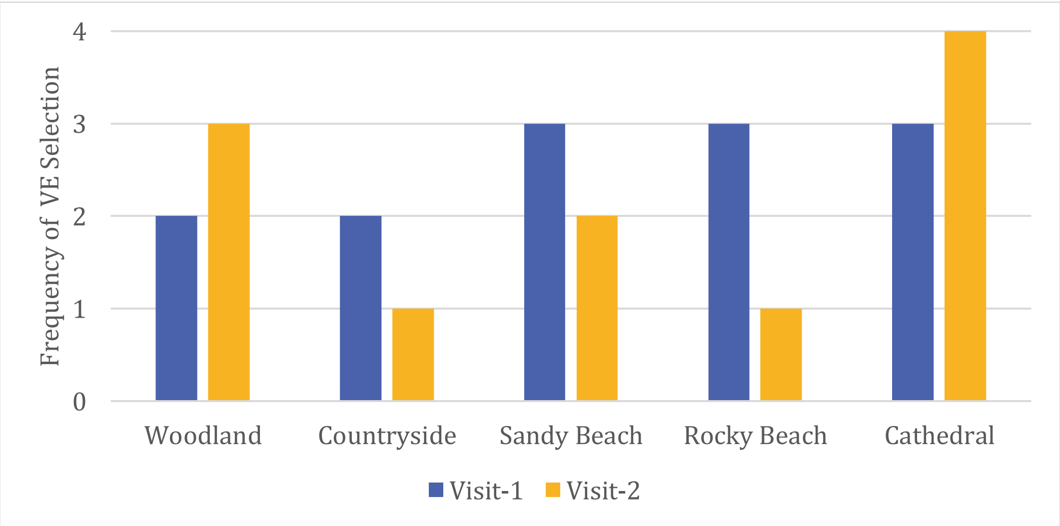


Figure 4.9: Frequency of VE selection per visit

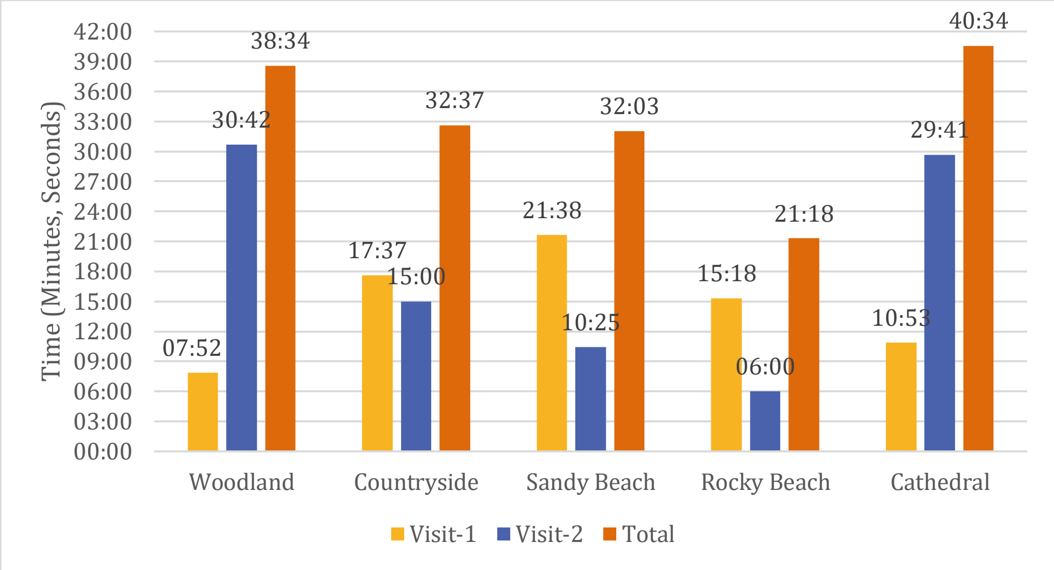


Figure 4.10: Time PWD spent in VR per VE

4.4 Qualitative Findings & Discussion

The qualitative findings were drawn using thematic analysis, a method used for identifying, interpreting, and reporting patterns within datasets (Braun and Clarke 2006). Overall, the findings were organised, presented and discussed to answer the following questions: "What potential benefits could VR experiences have within a locked hospital environment?", "How could these experiences be designed to benefit this patient group?" and "What are the deployment challenges that need to addressed for successful implementation?".

To answer the research questions, patterns in the data were coded then refined into themes. Finally, to further refine and verify the themes, three expert clinical psychologists in the field of dementia healthcare and two experts in HCI for healthcare critically discussed and reviewed each theme and underlying codes together. The discussion of the statistical results was embedded within the themes where suitable.

Three main themes were identified as a result of the thematic analysis: i) the appeal of slipping into a virtual reality, ii) multi-dimensional benefits and iii) holistic user-centred intervention design. The thematic scheme is summarised in Table 4.4.

Table 4.4: Thematic scheme summary

The Appeal of Slipping Into A Virtual Reality	Multi-Dimensional Benefits	A Holistic User-Centred Intervention Design
Virtual Outreach for a Personal Space	Therapeutic Effects of VR	Designing Meaningful Experiences
Engross Attention & Empower Autonomous Experiences	Cognitively Stimulating Interaction	Tailoring the VR Technology
A Portable Experience	A Unique Space for Building Therapeutic Rapport	The Role of the Caregiver

4.4.1 The Appeal of Slipping into a Virtual Reality

When assessing the potential of VR within restricted hospitals or in long-term care facilities, it is essential to understand what unique aspects of a virtual experience makes VR technology viable and valuable. Three sub-themes were identified; i) virtual outreach for a personal space, ii) engross attention and empower autonomous experiences and iii) a portable experience.

4.4.1.1 Virtual Outreach for a Personal Space

There exist extensive research in preventing violence and aggression in psychiatric services due to the significant concerns toward the health and safety of the patients and caregivers (Johnson and Hauser 2001). Clinical practice has moved from restrictive approaches to manage risk such as seclusion (placement of a patient in an area where the patient is not allowed to leave) or restraint (administering mechanical, pharmacological or medical interventions) towards less restrictive approaches when possible. These approaches include preventive interventions by identifying and addressing the triggers to behaviours or developing interventions that aim to reduce these behaviours once they had developed (Gaynes *et al.* 2017). The body of research identified the hospital physical environment as one factor that affects the behaviour of patients, including behaviour that challenges and aggression. Such environment design factors could include space density and excessive stimuli, such as the activity level within the hospital (Chou, Lu and Mao 2002).

In such cases, studies suggest that one of the most effective non-pharmacological interventions in de-escalating patients include caregivers re-directing patients to a low stimulus environment and taking action in changing antecedent condition that might have elicited the aggressive behaviour (Canatsey and Roper 1997).

Observation notes show that VR could be utilised to create a private and isolated space. Through this space, PWD can momentarily "escape" the reality of the hospital while receiving the necessary support from the caregivers. The observations suggest that this could be especially helpful in reducing behaviour that challenges. Using OAS-MNR, a total of eight aggressive behaviours were observed and recorded throughout the study. Of those behaviours, seven behaviours were observed pre-exposure to VR, zero during, and one post-exposure to VR (see section 4.3.2). Although not many aggressive behaviours were observed overall, which may in part have been due to the small sample size, aggression was not observed whilst using VR, and the total number of aggressive behaviours was considerably less from pre to post-exposure. Two out of these observations included PWD who were unsettled and verbally aggressive due to the changes in the environment (i.e. presence of the researchers), ceased to be aggressive once exposed to VR, and became calm for the entire time they spent in the VR.

> *"PWD at the beginning was verbally aggressive by swearing at the researchers [...] asking them to leave the room; however, when CG [caregiver] demonstrated using VR, even though he was still verbally aggressive and unsettled, he was interested in using VR. When PWD was using VR, he appeared to enjoy being in his own world. We were informed this PWD could become agitated easily, and yet surprisingly, he tolerated VR and used it for the maximum period." [PWD7, Observations, 1[33]]*

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[33] PWD = person with dementia, CG = caregiver, source: observation notes or interview transcript, visit: 1 or 2.

It is as if VR "teleported" the PWD to a low stimulus world and isolated them from the physical world, which contained elements that could have triggered their aggressive behaviour. Unlike other non-immersive or semi-immersive devices that are normally available on wards, such as a television set where PWD could still be distracted by the high stimulus surrounding, VR is capable of physically isolating PWD from the physical world instantly without having to physically remove them from the high stimulus physical environment. Moreover, VR can simulate realistic and immersive experiences by providing PWD with an experience with a high degree of presence and yet retain the safety of PWD. Most participants reported a high level of presence during the interviews, reporting that it felt "real" or "like they were in there".

> *"I was quite happy to be on my own." [PWD4, Interview, 2]*

> *"It moves when you move; you feel like you're within it, I guess. You can't see the [physical] room that you're actually in, so you are in that picture [VE]." [CG04, Interview, 1]*

The sense of isolation in VR coupled with a suitable VE could provide a "soothing effect" for those who are agitated. Caregivers also noticed this, and some expressed their desire to try using VR for de-escalation in the future.

> *"It was relaxing for him so [to] me as a nurse I think that I'm [going to] use it if someone is distressed […] I can see the trigger coming, I can take him in the quiet environment [VE], and we can go through this as a session. I think that may get somebody more relaxed […] so he's inside [the VE] when you distressed in your mental state, you have something there to focus on it that will distract your mind, make you more relaxed."[CG05, Interview, 1]*

In fact, this potential benefit of VR is not too foreign to the existing body of literature; VR has been used as a distraction technique in different areas, including pain management (see section 2.3.2) for burns (Hoffman *et al.* 2001), painful procedures for cancer patients (Wolitzky *et al.* 2005) and acute pain in exercising (Matsangidou *et al.* 2017, 2019). The distraction technique in previous literature examined the context of providing the brain with alternative imagery to alleviate the users' physical pain. However, to the knowledge of the author, none examined the context of "escapism" in VR as an anchor to regulate one's emotions through immersive personal spaces for individuals who are in long-term care. The observations seem to point to the possibility of utilising VR for this purpose; however, further in-depth research is needed to examine whether PWD will tolerate using VR at the moment when they are aggressive.

4.4.1.2 Engross Attention and Empower Autonomous Experiences

A key challenge when designing activities in general and recreational interventions specifically for PWD is to engage and sustain their attention and interest for a meaningful period of time. The fluctuation of cognitive impairment is a marked deficit of a dementia diagnosis, which contributes to difficulties in maintaining attention and struggles to deactivate irrelevant stimuli (Cohen-Mansfield 2001). Throughout the observations, it is prevalent that VR was able to sustain the attention of PWD, whether that was through "thorough exploration" of a single VE or "surfing through" various VEs within one session (see section 4.3.4). The ease of changing the VE allowed PWD to be quickly "transported" to different experiences, which was particularly useful for PWD who had a short attention span and could lose interest in one virtual space quickly.

> *"She reread the menu after each experience and became excited when a VE on the menu caught her interest. She viewed the VE and engaged in VR, and then when she no longer was interested in that VE, she went back to the menu and so on. It appears that having multiple VEs, with the menu in front of her the entire time, as well as being able to set up the VEs, swiftly continued the momentum of engagement even when the PWD had a short attention span or lost interest within a specific VE." [PWD8, Observations, 2]*

In five (out of sixteen) sessions, PWD spent 3 minutes or less in VR and in eleven sessions, PWD spent 12 minutes or more (see section 4.3.3). Nonetheless, it is important to note that the measure of success of a session with PWD is very individualised and that the quality of the time spent in VR is often more important than the length of time spent. For example, for an individual who may find engagement in activities of daily living difficult, if VR is able to trigger alertness and interest, the engagement could be perceived as meaningful regardless of how short it is.

> *"Looking at PWD's engagement, it may look like he did not engage much or the time spent in VR was short; however, today he explored the VE on his own on multiple occasions, which is in comparison to last session, an achievement on its own, particularly for a PWD who presents with apathy." [PWD1, Observations, 2]*

One aspect that could have contributed to an active prolonged interaction is the element of surprise in VR. It is crucial to clarify that the VEs used did not include any quick motions or the sudden appearance of visual elements. Therefore, the element of surprise, in this case, refers to elements that are not accessible within the hospital or something the PWD did not expect to see in the VE.

> *"He giggled whilst saying, 'I think it's a cow, yes it is, it's moving [the cow], I think it's a cow!' CG responded, 'yeah?' he replied, 'yes, it is! It's moving, with its front legs and back legs, it's a cow!'" [PWD4, Observations, 2]*

Having the autonomy to choose the VE also seems to have contributed to the PWD's interest in the VR experience as it was "their" choice, and it piqued their interest at the time. In the study, PWD were invited to simply explore an open VE space (i.e. without having to perform specific tasks), in which they engaged in open-ended discussions with caregivers.

> *"PWD: It [VE] reminds you of some of the places I have been to [giggles]. CG: So what places does it remind you of? PWD: [country name]. CR: [country name]? PWD: Yeah, I stayed there for a month, yeah, four-star hotel and everything, it was nice, it wasn't too expensive neither! [Giggles] And they have got a flea market." [PWD5, Interview, 1]*

The open space within VEs provided PWD with the autonomy to steer the engagement and conversation in the direction that the individual felt like at the time. Such shared thoughts ranged from personal and emotional life events to their inner feelings and reflections. This is especially beneficial to such user-group where PWD may no longer exercise exhaustive autonomous lifestyles in their daily living within a locked psychiatric hospital medium; autonomous experiences could become more valuable.

4.4.1.3 A Portable Experience

In contrast to deploying VR in other settings, understanding the locked hospitals' structure and restrictions was needed as it may add an additional challenge to design and implementation. There are a number of wards within the locked hospital, each focusing on different levels of care and diagnosis. The type of restrictions put in place are based on the risk(s) each individual pose to themselves and/or others. Hence, choosing a technology that is portable and easy to admit to these wards is essential. In addition, in the case where equipment was set up in the PWD's own room while the PWD was present, the need for a speedy and easy set up to avoid participants experiencing discomfort or loss of interest was vital.

> *"With this PWD, we had to conduct the session at their living space as per the hospital protocol. Which meant we carried the equipment and set it up on the spot. Furthermore, this PWD has a tendency to be short-tempered and can easily become unsettled by changes in the environment; this meant that we needed to set up the equipment in a rapid manner." [PWD7, Observations, 1]*

VR has the advantage of creating experiences that may be difficult for PWD to access. Such restrictions could be due to lack of mobility, ill health, or offence-related background. Inaccessibility could also refer to having environments that are unavailable due to uncontrolled factors like weather, location availability, or places of interest in the past, which no longer exist.

> *"Well, especially in an environment like this, you can't get them to a forest walk every day, you can't get them to a beach every day, you can't get them to a cathedral every day, and it's as close to those environments that they can then get to regularly. So, it is definitely beneficial for them because I mean [PWD] wouldn't have seen the lovely countryside today if it hadn't of been virtual reality […] walking is more difficult so he can't access those environments as easily as an abled bodied person." [CG04, Interview, 1]*

PWDs in the study were excited about the fact that they had a variety of VEs to discover. Such variety motivated some individuals to choose to explore two or more VEs within the same session, whilst others decided to go through the VE experiences one by one in different sessions. One PWD chose the same VE in both sessions, which highlights another important feature in VR: generating consistent experiences. Caregivers expressed the potential of VR bringing experiences that might not be reproducible in real life, such as experiences from the past, or activities PWD loved but cannot do within the locked hospital environment. Both of which could be enjoyable and stimulating.

> *"Using it itself [VR] for transporting them back to, days gone by […] I think it would be quite good, quite beneficial." [CG08, Interview, 1]*

> *"Especially stuff like the beach, for instance, they might have had a, previous love of going to the beach which is not something we can do here […] it might bring back memories of something they've not done for a while if they do that one."[CG11, Interview, 2]*

Only in recent years, VR technology has advanced from System-Dependant to Portable VR using mobile devices. Having a wireless and portable HMD that can be easily carried, admitted to the wards, and set up contributed to the successful inclusion of this patient-group. In particular, VR has the ability to provide virtual mobility to PWD who may no longer experience the outside, simulating various types of experiences that can be "new" every time and can be easily reproduced and customised to individual preferences all in line with the hospital's security requirements and therefore reduce the "inertia and friction" of deployment to a minimal.

4.4.2 **Multi-Dimensional Mutual Benefits**

During the study, the various benefits related directly or indirectly to the significance of exploring such VEs were explored. Three sub-themes were identified under this theme: i) therapeutic effects of VR, ii) cognitively stimulating interaction, and iii) a unique space for building therapeutic rapport.

4.4.2.1 Therapeutic Effects of Virtual Reality

A common objective in many non-pharmacological interventions within long-term care is to provide experiences that enhance the overall wellbeing of the residents through promoting positive effects amongst PWD (Beck *et al.* 1998;

Canatsey and Roper 1997; Chou, Lu and Mao 2002; Garcia, Kartolo and Methot-Curtis 2012). The majority of PWD enjoyed the VR experience, and through the observations, it is prominent that VR promoted a positive, uplifting mood and general wellbeing. In addition, the effect of VR was not only temporary whilst using VR, but also remained for a short term after the session.

> *"Post VR Observations – shared his experience with others, talked about the VR, laughed and smiled when talking about it, shook CG's hand and thanked them. Commented, "It was the best day ever". Talked to others, including peers and CGs commenting, "Best day I've ever had." [PWD3, Observations, 1]*

The results of the quantitative measure (OERS) confirmed these observations (see section 4.3.1). Results indicated a significant increase in pleasure from before VR exposure (Mdn=1.25) to during (Mdn=2.0) VR exposure (p<.05) and from before to after (Mdn=1.75) VR exposure (p<.05). Ratings of general alertness also significantly increased from before (Mdn=4.50) to after (Mdn=5.0) VR exposure (p<.05).

The emotional state and mood of the PWD at the time of the VR session was one important factor that played a role in determining how participants used VR and what type of benefit they gained from the 360-VE experience. For example, participants who were unsettled appeared to be physically relaxed and frequently took deep breaths when they engaged with VR. In this case, the caregivers gave them the space to be in the VE without interruptions.

> *"CG said: He looks mesmerised… it'd be a shame to take him out of the state he's in now just to check if he wanted something else [view another VE]." [PWD7, Observations, 2]*

Sometimes the same PWD seemed to have experienced a different form of therapeutic effect in each session. The type of stimuli within the VE may have played an additional role in how PWD perceived and interacted with VR.

"Today PWD was energised and actively describing VE, whilst in the last session he sat calmly and appeared to be relaxed. The VE selected today (countryside) contains animals and elements in the rear and far, whilst in comparison to last time's VE (beach) didn't have as many elements to stimulate his mind. PWD was not directed to engage in a certain way in order to sense those feelings; instead, he seems to go with the VE naturally." [PWD4, Observations, 2]

Exploring VEs that could be inaccessible for this user-group was perceived positively. Some found the VEs calming and relaxing, while others found them exciting and energising. In conclusion, exploring VEs broke the routine, was out of the norm and had a positive effect on PWD.

4.4.2.2 Cognitively Stimulating Interaction

Multi-sensory cognitive stimulation for dementia has received a growing interest when exploring the applications in VR for this patient-group. An increasing body of research explored the use of VR as a tool to enhance, train or assess specific skills that are degenerated or disrupted due to the diagnosis of dementia, i.e. relearning everyday activities (Yamaguchi *et al.* 2012), memory training (Optale *et al.* 2010), exercise and balance (McEwen *et al.* 2014) and cognitive assessment (Mendez, Joshi and Jimenez 2015). These studies adopted a task-oriented design approach, in which the PWD would typically need to complete a series of pre-designed tasks in a specifically designed VE for the purpose of the assessment or training. Whilst such approaches have proved its efficacy, especially with individuals with mild dementia, throughout the observations, it was found that the open-ended nature of the design used in this study instead provided individuals with free-form interactions where could PWD construct their own stories. Most PWDs were self-motivated to engage with the VE at their own pace, paying attention to aspects that interest them at that moment. Caregivers' involvement in this sense included responding to PWD thoughts with relevant prompts. This was also beneficial to caregivers as it allowed them to informally learn more about individuals' cognitive abilities through the VR interaction. During the caregivers' interviews, many reflected on their knowledge about PWD's cognitive abilities and compared it to what they observed during the VR session, discovering a new medium of learning more about the PWD they care for.

> *"I didn't realise […] how good he could describe things. And that's taught me something that if he's telling me something now, I know that he's quite good at telling me […] because he just described that [VE] scene you see, and he did really describe it in detail, which surprised me." [CG13, Interview, 2]*

Some domains within the cognitive functions could be easy to spot informally whilst PWD was using the VR. One example is recognition memory and language domains, which includes the ability to recognise the elements and describe the surroundings.

> *"He pointed with his finger, he looked like he was about to say something, but he didn't. It appeared like he was trying to find the words to describe the element he was pointing at, but he couldn't find the words to describe it."[PWD3, Observations, 1]*

Another interesting outcome is reminiscence during or post exposure to VR. It is important to clarify that the VEs were not personalised to match specific participants' interests during the VE selection process. Despite this, several PWD found connections with the VEs and reminisced about countries they are from and holidays they had been to, etc. In consistence with previous literature, PWD reminisced through the similarity and resemblance the VE is to a memory from the past or being reminded of memory through an element within the VE (Siriaraya and Ang 2014).

> *"I think it's a bridge! It's got the road, the road going like in [country] we call them [the word bridge in their mother tongue]." [PWD4, Observations, 2]*

In conclusion, it seems that exploring a VE is not only providing a free-form engagement space for PWD but also a lens for caregivers to understand further the patient they care for in a non-intrusive, informal approach.

4.4.2.3 A Unique Space for Building Therapeutic Rapport

Due to the changes in cognitive capacity, social abilities and communication skills, PWD may be reluctant to participate in daily activities, in a bid to protect their dignity should they carry a task incorrectly, which is often accompanied by concerns towards how other people view PWD (Nolan *et al.* 2006). Hence, it is a challenge not only to persuade individuals to join an activity but also to let their guard down and be truly engaged. During the sessions with PWD, there was a general sense of openness when stepping into the VE, whether it was by physically getting into a more comfortable position and exploring different angles within the VE more freely, or verbally by opening up about a variety of topics; memories and previous experiences, preferences and dislikes or something as simple as sharing a joke. Many instances were recorded across the data, where PWD and caregivers shared a moment together.

> *"He said 'oh yeah, I can see the steps and the ladder'... then jokingly said 'oh I would not use that ladder', everyone joined the laughter." [PWD5, Observations, 1]*

One key measure of presence in VR is the forgetfulness about the physical world surroundings (Nichols, Haldane and Wilson 2000). It is arguable that perhaps "forgetting" the real world could present a mutual benefit for both PWD and caregivers. From one side, PWD felt free to be open, engaged and sharing whilst in VR. On another side, caregivers were able to see the PWD more translucently not only as a patient but also as a person with life experiences and further learn about their personal attributes, which could potentially be used in the future when caring for their patients in existing activities.

It has been established that relationships, including therapeutic relationships with caregivers, is a key factor for a good outcome in long-term care (Kane

2001). It was clearly visible that VR allowed PWD to open up about their feelings and tell more about themselves. Thus, VR became a mutual platform where both PWD and caregivers could enjoy new experiences and promote a positive therapeutic connection between them.

4.4.3 **A Holistic User-Centred Intervention Design**

This theme emerged from the research teams' reflections that it is worthwhile to consider the experience, examine the shortcomings of the current approach and provide illustrations to the strengths and core aspects that contribute to a successful design and deployment of VR for PWD. Each sub-theme outlines the constraints, trade-offs and opportunities involved in the following aspects: i) designing meaningful experiences, ii) tailoring the VR technology, and iii) the role of the caregiver.

4.4.3.1 Designing Meaningful Experiences

One symptom of dementia is the loss of interest in activities, social life, and self (Kitching 2015). Therefore, a vital aspect of HCI research for PWD is to design experiences that are engaging and meaningful for such user-group (Hodge *et al.* 2018; Morrissey, McCarthy and Pantidi 2017; Siriaraya and Ang 2014). Perhaps unsurprisingly, the choice of the VE plays an important role in how PWD perceive the VR experience. Almost all caregivers stressed the importance of creating experiences that are relevant to the individual's interests and how that could contribute to a more engaging experience.

> *"I know quite a lot of our patients like music, [it] is really important to them so maybe like, being at some sort of music venue or being at a gig or a concert, or perhaps for patients who love cooking, maybe a kitchen for them…" [CG07, Interview, 1]*

In addition to considering individual preferences, it is also important to consider the behaviour of PWD and their symptoms of dementia. All selected VEs in the study fell under the low arousal positive quadrant in the Circumplex Model of Affect (CMA, see section 3.2.1) (Bradley and Lang 1994), which are perceived as calming and relaxing. In one instance, a PWD with a history of apathy did not find VR engaging. In such a case, more research is needed to investigate the type of VEs that could be perceived as positively arousing and engaging for such PWD.

> *"This PWD presents with apathy; he was not engaged with the low arousal VEs that we provided. Whether it was the sounds of the choir in the cathedral or watching subtle waves on the shore of the beach, having a PWD that struggled to be alert, soothing audial/visual feedback was not helpful." [PWD1, Observations, 1]*

Generally, a simple interaction modality that included rotating the head and upper body to explore the VE is perceived to be accessible for PWD, but that was not always the case, such as with one PWD with disorders of involuntary movements.

> *"CG encouraged her to move her head to the right; she attempted to and immediately smiled. However, she could only hold her head for a brief second. The fact that the only way to view different parts of the VE is to move the head resulted in PWD not being in control considering her involuntary movement." [PWD6, Observations, 1]*

A common challenge within HCI research is finding the balance between designing engaging experiences and yet retaining the simplicity of interaction. Maintaining the sense of suspension from the physical world is crucial for PWD to sustain the engagement and feel present in the VE. The concept of embodiment within the VE (i.e. the sense of body ownership) is something that was not fully explored in this study, although some PWD commented on it. From the observations, some PWD enjoyed the simple interaction and did not appear to notice the lack of "owning" a virtual body within the VE. On the other hand, many participants found that laughable.

"She said: 'Look at the mountain over there [while pointing with her finger]' She stopped describing the VE suddenly once she realised she couldn't see her finger, she moved around her finger whilst still pointing, in an attempt to 'find' it, then said: 'where is my finger!'[…] She took off the HMD and burst into laughter."[PWD8, Observations, 2]

Some studies explored the use of embodied interactions by providing individuals with mild dementia with interactive virtual avatars that respond to PWD's bodily movements (Morrissey, McCarthy and Pantidi 2017; Siriaraya and Ang 2014) within 3D-VEs, and expressed the gained benefits of enhancing interaction by empowering PWD to achieve a greater sense of engagement in a natural manner. Such interaction modality could be further explored in the future within 360-VEs to examine whether these benefits could be replicated.

In addition to considering the content design and interaction modality, some considerations need to be made in the physical world environment to support PWD's virtual experience. These aspects include having a physical "interaction space" around the participant to allow them to lean forward, rotate around, etc., as well as choosing the suitable seating arrangement to support the VR experience whilst considering the physical abilities of PWD.

"He tried to push the chair back in attempts to look further to the far-right side, CG asked him to try to stay where he is for safety […] The chair didn't seem suitable, especially for this PWD who was interested in the full 360 view and didn't have the physical capability to fully turn around easily. A swivel chair could've been much helpful." [PWD3, Observations, 1]

4.4.3.2 Tailoring the Virtual Reality Technology

Unlike many digital technologies, HMDs needs to be worn on the head/face of the users. Having little literature examining the feasibility of using VR with individuals within the later stages of dementia, the first question that comes to mind is whether or not this user-group will tolerate wearing an HMD in the first place. Of the sixteen sessions, one instance was observed where PWD did not wish to keep the HMD. PWD elaborated that it felt unnatural to breathe whilst using VR, although her reaction changed positively in the second visit.

> *"PWD explained that she didn't like the HMD because she couldn't breathe. CG asked if she felt claustrophobic, she answered 'yes'." [PWD8, Observations, 1]*

One aspect future design could consider is the physical health of PWD. For example, with an individual who wears corrective glasses, it would have been impossible to use a rigid HMD that cannot contain the medical glasses' frames. Another example is in regards to PWD with involuntary movement disorders and the choice of handheld versus 3-strap harnessed HMDs.

> *"The session with this PWD who have a type of an involuntary movement disorder could have resulted in failure if the headset we used was handheld. The 3-strap harness has to be solid onto PWD's head to ensure her safety." [PWD6, Observations, 1]*

Research has concluded that handheld headsets were more acceptable to individuals with mild dementia in comparison to harnessed HMD (Hodge *et al.* 2018). However, herein, only one PWD preferred to hold the headset using their hands, which resulted in her experiencing a temporary feeling of dizziness as she was struggling with coordinating her head-hands movements. This was the only PWD who also reported feeling dizzy.

> *"PWD didn't rotate her head; instead, she shook it. The pads of the HMD were not rested on the PWD's forehead and cheeks. The HMD was following through the head position rather than being in sync with head movement." [PWD8, Observations, 2]*

4.4.3.3 The Role of the Caregiver

In line with the important notion of person-centred care in the therapeutic milieu (Brechin *et al.* 2020), herein, it was found that the open-ended approach allowed caregivers to adjust the interaction dynamically to best suit PWD. The role of the caregiver and the amount of "assisted interaction" differed from one PWD to another. It highly depended on the PWD's mood, how they wished to explore the VE, coupled with the individual's skills and abilities. Assisted interaction is a well-known notion in HCI and has been briefly discussed in the context of dementia (Boumpa *et al.* 2017; Hoey *et al.* 2013). One interesting angle which could be considered further based on the observations in this study is how assistive interactions within the VE could be developed to enhance the interaction from the "inside" world, to complement the caregivers' support from the "outside" world. For instance, from the observations, it is crucial that the caregiver is aware and able to interpret PWD verbal and non-verbal reactions, especially to those who are unable to verbalise their thoughts.

> *"PWD didn't verbalise a word; however, he immediately started to look visibly distressed. It appeared that he did not know how to take the HMD off even though he was physically able to. CG immediately responded by removing the HMD, and assured him verbally that it's okay and patted his shoulder to comfort him." [PWD2, Observations, 1]*

Hence, it might be useful to draw from the wealth of knowledge generated in the affective computing community, a field that aims to enable intelligent systems to recognise, infer and interpret human reactions, to support future deployment of VR, especially at large-scale. Such research examined the recognition of emotional elicitation using different modalities such as gestures, eye gaze and biofeedback (see a summary in Poria et al. (2017)). Thus, examining the potential in aiding caregivers by providing them with additional insights to prompt changes and modify the interaction accordingly could be beneficial. This is especially crucial as PWD's face was covered by the HMD hence preventing the caregivers to interpret their emotional responses effectively.

The important role of caregivers in helping "transition" PWD from the physical world to VR and back was also observed. One individual was tearing up and feeling emotional, saying, *"it's all gone now"*. The caregiver provided PWD with support then expanded on how they felt and what this experience meant to them. The PWD reported feeling happy about the experience.

> *"CG: so these, this is a happy emotion? PWD: Yes. CG: Or was it a sad emotion? CG: No, happy… I feel happy […] it was [a] very good feeling […] I felt quite emotional." [PWD4, Interview, 1]*

Many examples were given throughout the findings that demonstrate the importance of being aware of the patient's abilities and how to best interact with them. Furthermore, the role of the caregiver varied from one patient to another. This was driven by the support that PWD needed, and dependant on their mood and presentation at that time.

4.5 Summary

This chapter describes a study that examined the deployment of emotional spaces in VR for individuals with moderate to severe dementia residing in a locked psychiatric hospital. The results demonstrated the potential of VR in a variety of ways, in which, VR could promote positive mood, cognitive stimulation and general wellbeing. Furthermore, VR presented with a new venture for caregivers to connect with PWD, build therapeutic connections and informally learn more about their patients.

In the next chapter, a wider understanding of the design and deployment of emotional spaces in VR within PC&B contexts was investigated. Specifically, the design and deployment processes of a total of four user-centred VR-based PC&B interventions were examined (including the study examined in this chapter). The study aimed to identify design elements required for effective, meaningful and enriched VR interventions within PC&B contexts as well as the design needs, opportunities and challenges within these elements.

Chapter 5: Exploring the Design Needs, Opportunities & Challenges for Meaningful Experiences in Virtual Reality for Mental Healthcare & Wellbeing

5.1 Introduction

The previous chapter (Chapter 4) reported findings from a study that explored the feasibility, design and deployment of Virtual Reality (VR) for individuals living with dementia residing in a locked psychiatric hospital. The outcomes of the study demonstrated the feasibility of VR as a therapeutic tool for people living with moderate to severe dementia, even with those presenting with behaviour that challenges. Throughout the study, it was prevalent that VR had a positive therapeutic effect on People with Dementia (PWD), whether that was through reducing aggression, cognitive stimulation or reminiscence, to name a few. The study also presented with design opportunities, challenges and deployment considerations of VR in a mental healthcare setting.

The feasibility, efficacy and acceptance of VR in the previous study are consistent with the wealth of research that supported the efficacy of VR in mental healthcare and wellbeing in general and Psychological, Cognitive and Behavioural (PC&B) interventions in specific (see section 2.3). However, despite the substantial research interest in using VR in mental healthcare and wellbeing, the design process of translating therapies into VR to meet the needs of critical stakeholders such as users and clinicians is rarely addressed (see section 2.4). The knowledge on how VR can be designed as an emotional space, a therapeutic medium where users "step into" and emotionally engage in the therapy through VR is lacking. Little has been done to understand the design process of translating conventional therapies into VR, meeting the design needs of stakeholders, or constructing a design framework that allows researchers to replicate best-case practices in designing future PC&B-VR interventions. This is partially due to a few studies that have described the design process for their PC&B-VR interventions (Hodge *et al.* 2018; Lindner *et al.* 2017). Finally, considering that much research in VR and mental healthcare has been done in a controlled experimental setting, it is unclear how the real-world healthcare context may present with challenges to VR deployment.

Therefore, the study in this chapter aimed to highlight design needs, opportunities and challenges for designing efficient, effective and deployable PC&B-VR interventions. Specifically, this study aimed to address the following research questions:

- What are the design challenges when translating conventional therapies into VR in a way that meets therapy requirements?
- What are the design elements for meaningful experiences within healthcare and wellbeing contexts, and how can they adapt to meet stakeholders' sensitive requirements?
- How the understanding of healthcare contexts contributes to the deployment of VR?

To answer the research questions, harvesting design data related to PC&B-VR intervention design was required. Therefore, in addition to the study examined in Chapter 4, three additional VR interventions were included in the analysis of this study to provide a more broadened understanding of design requirements for PC&B-VR interventions in different mental healthcare contexts. All interventions were co-designed by multidisciplinary teams of researchers within the Intelligent Interactions research group at the School of Engineering & Digital Arts – University of Kent and in collaboration with domain-specific healthcare practitioners. The four user-centred PC&B-VR interventions addressed:

- Behaviour that challenges in dementia: as described in Chapter 4, the research work produced one authored and some co-authored scholarly papers (Rose *et al.* 2019; Tabbaa *et al.* 2019).
- Anxiety disorder (Otkhmezuri *et al.* 2019) – in this collaboration, the author of this thesis was involved as a design researcher, where the visual aspect of the intervention was designed and developed by the author.

- Eating disorders (Matsangidou *et al.* 2020) – in this collaboration, the author of this thesis was involved in some of the design operations.
- Pain management in exercise: this collaborative research work produced an article that was co-authored and published at the peer-reviewed international IFIP International Conference on Human-Computer Interaction (INTERACT) (Matsangidou *et al.* 2017) – in this collaboration, the author of this thesis led on the design aspect of the VR intervention design.

Furthermore, in this study, the author of this thesis collated the data from collaboration teams and led on the analysis of the findings. Finally, the study presented in this chapter was published in the peer-reviewed Journal, the International Journal of Human-Computer Interaction (Tabbaa *et al.* 2020).

In the next sections, a detailed description of the four PC&B-VR interventions is provided. Then, materials used for analysis in this qualitative study are described. Finally, findings are presented and combined with theme-specific discussion.

5.2 The PC&B-VR Interventions

This study combines a corpus of data collected from four user-centred PC&B-VR interventions. In this section, the intervention goal, design, materials and how users interacted with the proposed VR intervention are described for each intervention.

5.2.1 **Behaviour that Challenges in Dementia (VR-Dementia)**

Almost half of the cognitively impaired residents in long-term care are diagnosed with depression (Schreiner, Yamamoto and Shiotani 2005). Furthermore, people with moderate to severe dementia often present behaviour that challenges such as physical and verbal aggression (Verbeek *et al.* 2010), which in many cases, requires a level of psychiatric care and safety measures. The intervention in this project offered VR as a non-pharmacological intervention for people living with moderate to severe dementia residing in a locked psychiatric hospital to promote overall wellbeing and reduce behaviour that challenges (Rose *et al.* 2019; Tabbaa *et al.* 2019).

The intervention was co-designed with specialists within dementia healthcare across five sessions (see Table 5.1) to identify suitable VEs that could be therapeutic for this patient-group. PWD (see Table 5.1) were offered five 360° Video-Based Virtual Environments (360-VEs) to choose from and were offered to spend time in VR for a maximum of 15 minutes. PWD explored the VEs (snapshots are presented in Chapter 4; Figure 4.3) using their head and upper body rotation, whilst being supported by caregivers next to them.

The content was wirelessly streamed to a laptop, allowing caregivers to provide relevant prompts during exposure. The Samsung Gear VR, paired with a Samsung S6 phone, was used to stream the audial and visual content. Adobe Premiere Pro[34] and Unity[35] were used to deploy the content.

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[34] https://adobe.com/uk/products/premiere
[35] https://unity.com

Table 5.1: VR-Dementia design duration in months, design brainstorm sessions and workshops (number of sessions and expertise profile) and final prototype evaluation participants (end-users)

VR Intervention	VR-Dementia
Designing Process Duration	Three months
Design Brainstorm Sessions & Workshops	Five design sessions including: • Experts in HCI (n=2) • Research designers & developers (n=2, one of which is the author of this thesis) • Clinical psychologist (n=1) • Consultant clinical psychologist (n=1) • Consultant clinical neuropsychologist (n=1) One design workshop including attendees (n=15) within dementia care such as psychologists, psychiatrists, managers and nurses
Representative End-Users Evaluation	• PWD with moderate to severe dementia (n=8; 2 females and 6 males) • Caregivers (n=16) including nurses (n=11), occupational therapists (n=3), psychologist (n=1), and physiotherapist (n=1)

5.2.2 **VR-Anxiety**

There exist serious concerns as university students are at high risk of developing mental health problems, including anxiety (Rith-Najarian, Boustani and Chorpita 2019). Researchers found that anxiety can be reduced through reducing negative bias interpretations over situations university students face or experience that typically elevates their anxiety (Mathews and Mackintosh 2000). Therefore, the VR intervention was designed to reduce the anxiety of students with “Moderate to High” or “High Anxiety” (Otkhmezuri *et al.* 2019) based on the Cognitive Bias Modification of Interpretations (CBM-I) approach (Mathews and Mackintosh 2000).

In collaboration with psychologists (see Table 5.2), a total of five design sessions were conducted to understand how the intervention could be translated from a flat-screen text-based system to VR space effectively. Participants (see Table 5.2) engaged in 40 CBM-I scenarios using VR for ~ 45 minutes. Specifically, university students were exposed to Three-Dimensional Computer-Generated Virtual Environments (3D-VEs) during a period where they would typically have high levels of anxiety, i.e. exam hall (see Figure 5.1), then presented with scenarios to which they were required to respond to using voice. Participants used VR independently whilst being supported by the investigator if needed.

The Samsung Gear VR, paired with a Samsung S6 phone, was used to stream the visual content and the audial feedback. Autodesk Maya[36], Unity and Android SpeakNow[37] plugin for voice recognition were used for development.

Figure 5.1: Examples of VEs used in the VR-Anxiety intervention

Table 5.2: VR-Anxiety design duration in months, design brainstorm sessions and workshops (number of sessions and expertise profile) and final prototype evaluation participants (end-users)

VR Intervention	VR-Anxiety
Designing Process Duration	Four months
Design Brainstorm Sessions & Workshops	Five design sessions including: • Experts in HCI (n=2) • Research designers & developers (n=2, one of which is the author of this thesis) • Social, behavioural and developmental psychologists (n=2) • Cognitive psychologist (n=1) • Volunteer test users (n=2)
Representative End-Users Evaluation	University students (n=42; 23 females and 19 males) with “moderate to high” and “high” anxiety

36 https://autodesk.com/products/maya
37 https://assetstore.unity.com/packages/tools/integration/android-speaknow-16781

5.2.3 **Eating Disorders (VR-ED)**

There exist well-established treatments for ED, including VR interventions (Riva *et al.* 1999, 2002). However, many patients with ED are reluctant to engage in treatment due to reasons including; self-stigma, anxiety that comes with disclosing body image satisfaction and feeling anxious around the therapist (Hackler, Vogel and Wade 2010; Halmi 2013). The intervention in this project involved a remote VR therapy for people with Eating Disorders (ED). The intervention design emerged as a result of eight co-design sessions (see Table 5.3).

The co-design sessions aimed to understand how conventional ED therapy sessions could be translated into VR and how the therapist and users with ED could engage in the therapy virtually. The remote VR therapy was constructed by drawing knowledge from Acceptance & Commitment Therapy (ACT) (Hayes, Strosahl and Wilson 2011), Play Therapy (PT) (Schaefer 2003) and Mirror Exposure Therapy (MET) (Waller, Walsh and Wright 2016). Therapists and users with ED (see Table 5.3) logged-in from remote locations without having met each other face-to-face and were presented in the 3D-VE as 3D avatars. Participants engaged in a 25-minute training game to familiarise themselves with VR. Then, therapists and participants with ED engaged in a range of activities within VR to motivate conversation about troubling body-image thoughts. Afterwards, people with ED engaged in MET by discussing their feelings and concerns about each body part via a customisable avatar that resembled how participants thought their body looked like (see Figure 5.2). The therapy session lasted approximately one hour.

Therapists and participants each were provided with a set of Oculus Rift Head Mounted Display (HMD), controllers and sensors. 3D art was created using Adobe Fuse[38], Autodesk Maya, Unity assets and Mixamo[39]. Steam VR[40] and Unity were used for development, coupled with an array of plugins to enable

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[38] https://adobe.com/products/fuse
[39] https://mixamo.com
[40] https://store.steampowered.com/steamvr

various functionalities including: Photon Unity Networking[41] to enable multi-user capability, Photon Voice[42] to process the user's verbal communication in real-time, and Salsa Lip-Sync/Random Eyes[43] to synchronise the avatars mouths movements with phonemes, and blink and random eye movement animation.

Table 5.3: VR-ED design duration in months, design brainstorm sessions and workshops (number of sessions and expertise profile) and final prototype evaluation participants (end-users)

VR Intervention	VR-ED
Designing Process Duration	Six months
Design Brainstorm Sessions & Workshops	Eight design sessions including: • Expert in HCI (n=1) • Research designers & developers (n=2, one of which is the author of this thesis) • Cognitive psychologist (n=1) • Clinical psychologists (n=2) • Volunteer test users (n=4)
Representative End-Users Evaluation	• Individuals deemed at high risk of developing ED (n=14; all females) • Clinical psychologists (n=7) whom each carried the therapy for two sessions

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41 https://assetstore.unity.com/packages/tools/audio/photon-voice-45848
42 https://assetstore.unity.com/packages/tools/animation/salsa-with-randomeyes-16944
43https://assetstore.unity.com/packages/tools/network/photon-unity-networking-free-1786

Figure 5.2: Example of an avatar used in the VR-ED MET

5.2.4 **Pain Management in Exercise (VR-Pain)**

Acute pain in exercise may influence decision making when considering the exercise intensity or the thought of continuing the exercise at all (Mauger *et al.* 2014). This intervention utilised the Altered Visual Feedback Strategy (Harvie *et al.* 2015) as a method to prolong exercise by manipulating the visual cues to reduce the perceived pain: i.e. by manipulating the size of a virtual dumbbell the user was physically holding during exercise (see Figure 5.3) (Matsangidou *et al.* 2017).

Over the span of four design sessions, the intervention was co-designed with experts in exercise and pain (see Table 5.4), aiming to understand how the parameters of altered visual feedback in VR could prolong exercise. Participants (see Table 5.4) attended three sessions over three different days, where participants were simply asked to hold a dumbbell for as long as they could, whilst using VR. The visual appeal of the dumbbell in VR varied each session, where the weight appeared to be 50% smaller, 50% larger, and exactly the same; however, without the knowledge of the participant, they held the same physical dumbbell in all sessions. Participants used VR independently whilst being supported by the investigator if needed.

The Samsung Gear VR, paired with a Samsung S6 phone, was used to stream the visual content, and a Microsoft Band was used to synchronise the participant-avatar arm using the band's gyroscope. Autodesk Maya and Unity were used for development.

Table 5.4: VR-Pain design duration in months, design brainstorm sessions and workshops (number of sessions and expertise profile) and final prototype evaluation participants (end-users)

VR Intervention	VR-Pain
Designing Process Duration	Four months
Design Brainstorm Sessions & Workshops	Four design sessions including: • Expert in HCI (n=1) • Research designers & developers (n=4, one of which is the author of this thesis) • Cognitive psychologist (n=1) • Sports, exercise and pain in exercise consultant (n=1) • Volunteer test users (n=2)
Representative End-Users Evaluation	Healthy participants (n=110; 73 females and 37 males)

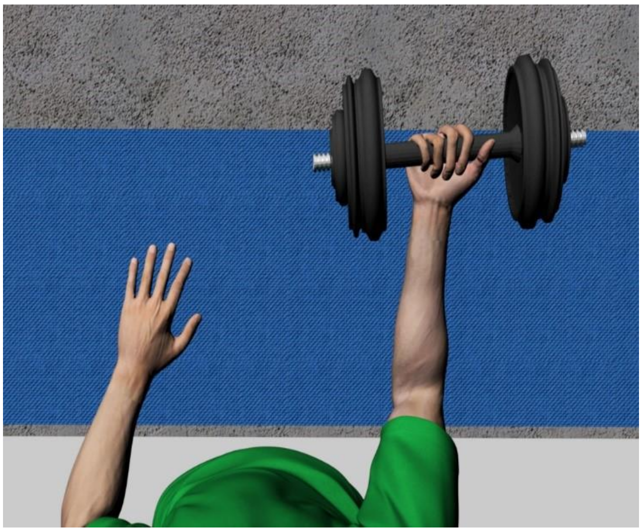

Figure 5.3: Participant's point of view of their virtual body in the VR-Pain intervention

5.3 Materials & Analysis

Across the four interventions, a total of 31 researchers participated in brainstorm sessions, design workshops and evaluation of the prototype iterations to design and develop the interventions. Seven of such researchers are developers, designers (one of which is the author of this thesis) and HCI experts, and twenty-four had intervention-specific clinical expertise (details are described in Table 5.1, Table 5.2, Table 5.3 and Table 5.4). Additionally, eight test users volunteered to test and feedback prototype iterations during development. Final prototype evaluation included representative users (n=174) and therapists and/or caregivers (n=23).

Overall, this study combines the following forms of data (summarised per intervention in Table 5.5):

Brainstorm Workshops and Co-Design Sessions Notes: Detailed notes were collected during co-design sessions and brainstorm workshops. These notes aimed to understand the co-design process as well as design opportunities and challenges. In each session, a dedicated researcher wrote down notes describing the discussions and decisions made during these sessions. Then, these notes were shared with the attendees/research members who were present to verify the accuracy of the notes. Where other materials were produced (i.e. brainstorm session notes, drawings, etc.), such material was collected, scanned and included in the session notes as supplementary material. Overall, at least two researchers with HCI expertise independently read through all notes to verify and ensure the precision of details within the notes.

Users' Feedback during Iterative Design: Feedback notes, including verbal feedback from the intervention-specific research team and volunteer test users, were compiled. A dedicated researcher during test sessions took handwritten notes of observations and verbal feedback from test users. In addition, researchers logged hardware issues (i.e. related to the HMD) and software issues (i.e. related to usability, blurriness, etc.) that occurred. Overall, the notes aimed to understand the effectiveness of translating conventional therapies into VR, as well as assessing the usability and acceptability of each artefact iteration.

Transcribed Interviews or Open-Ended Questionnaires with Representative End-Users and Caregivers/Therapists: Semi-structured interviews were conducted, and open-ended questionnaires were collected from representative end-users and caregivers or therapists after engaging in the VR intervention. Semi-structured interviews (n=32) were conducted in the VR-Dementia intervention with PWD (n=16, eight PWD visited twice) and caregivers who supported PWD during exposure to VR (n=16). All interviews were audio-recorded and then transcribed verbatim by two researchers; where first, one transcript was coded simultaneously and compared to measure consistency in coding. Open-ended questionnaires (n=21) were answered by people with ED (n=14) and therapists who carried the VR-ED therapy (n=7). For representative end-users, the aim was to reflect on their experience in VR concerning acceptance, presence and emotional affect. For caregivers/therapists, the aim was to reflect on their observations and views related to acceptance, usability, and deployment of VR in their respective domains.

Observation Notes During Evaluation Sessions: For the VR-Dementia (n=16) and VR-ED (n=14) interventions, a researcher with HCI expertise was dedicated during the sessions to record observations. These observations aimed to record any physical interactions participants had with the HMD, controllers or the environment around them, their behavioural responses and reactions during exposure to VR, and their interaction with their therapist/caregiver. The notes were corroborated later using video recordings, then by two researchers independently to ensure the reliability of the observations.

Table 5.5: Type of data used for analysis in this study per VR intervention

Intervention	Analysed Data
VR-Dementia	• Workshops & sessions notes (n=6) • Test users' artefact feedback (n=2) • Caregiver interviews (n=16) • PWD interviews (n=16, eight PWD visited twice) • Observation notes during evaluation sessions (n=16)
VR-Anxiety	• Workshops & sessions notes (n=5) • Test user's artefact feedback (n=3)
VR-ED	• Workshops & sessions notes (n=8) • Test user's artefact feedback (n=5) • Therapist open-ended questionnaire (n=7) • Patient open-ended questionnaire (n=14) • Observation notes during evaluation sessions (n=14)
VR-Pain	• Workshops & sessions notes (n=4) • Test user's artefact feedback (n=2)

The data were retrospectively analysed using thematic analysis, a method used for identifying, interpreting, and reporting patterns within datasets (Braun and Clarke 2006). To summarise research questions identified in this study, this chapter aimed to understand: (i) the challenges in adapting conventional interventions into VR, (ii) the usability and acceptance of VR by clinicians and users, (iii) the design problems and requirements for PC&B-VR interventions, and (iv) how best to incorporate the understanding of the broader healthcare contexts in the deployment of VR. An inductive approach to the analysis was used, where codes and themes were developed from the data. Two researchers with HCI expertise reviewed and analysed the data from initial coding to the final scheme delivery.

5.4 Findings & Discussion

From the analysis, four key themes relating to the "PC&B-VR design" were identified: (i) building a virtual therapeutic milieu, (ii) interactions that fit, (iii) design for therapeutic connections with self and others and (iv) an enabling deployment context. The thematic scheme is visually represented in Figure 5.4. In the following, these themes are discussed at depth.

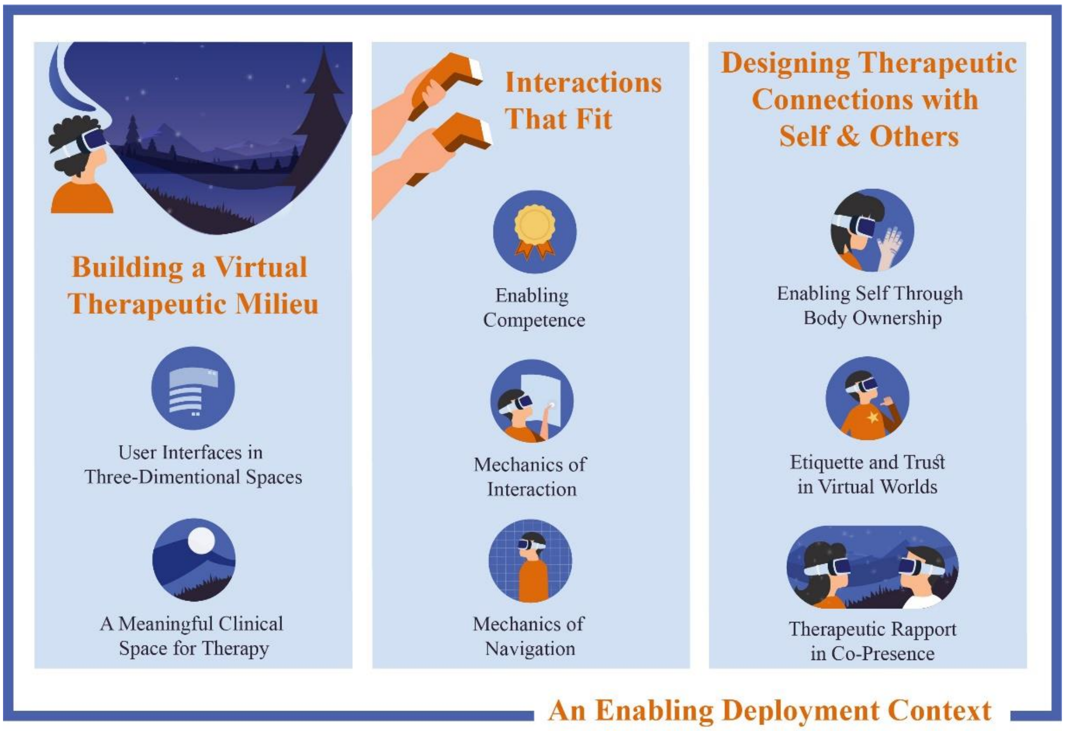

Figure 5.4: Thematic scheme visual representation

5.4.1 Building a Virtual Therapeutic Milieu

Unlike non-immersive 2D platforms, where users are "distant" and interact with the content as "outsiders", one of the key attributes of VR for mental healthcare is immersion, where users can be fully and deeply engaged within a VR space. As such, the VR experience design needs to assist users to "step" into the intervention environment, allowing them to immerse themselves in the therapy; hence, building the appropriate therapeutic milieu. The UI design of 2D platforms is typically based on the "page" metaphor, where users flip or scroll between page-based UIs. In this sense, designing VEs fundamentally differs by principle; herein, the idea of shifting our design thinking from "page" metaphor to "world" metaphor is proposed, focusing on building a virtual reality that fosters the appropriate therapeutic milieu; where users "step into" the therapy space. As such, key aspects in the design of the following elements are highlighted: (i) user interfaces in three-dimensional spaces, and (ii) a meaningful clinical space for therapy.

5.4.1.1 User Interfaces in Three-Dimensional Spaces

Emerging research is looking into how information and UI elements should be organised within 3D-VEs. Very fundamental issues occur when translating interventions from traditional digital mediums into VR; a simple task as transferring vital therapy textual information from the 2D screen such as PC or mobile into VR could be challenging. For instance, the PC-based version of the anxiety intervention (VR-Anxiety) presented scenarios as paragraphs (~8 lines) using serif typography, a style that is prominently used in flat-screen platforms to enhance the readability of paragraphs. However, in VR, users are surrounded by a rich VE; therefore, when the textual scenarios were directly translated into VR in an early VR-Anxiety prototype iteration, users experienced considerable eye strain and mental fatigue. This was due to the lack of contrast between the text and the VE. In addition, there were too many lines for users to read at once. Finally, due to the limited capabilities of mobile VR to render the letter edges of serif typography, they were rendered as artefacts which were hazy and blurry looking.

> *At the 15th scenario (out of 40), the test user asked to stop; reading was exhausting in VR. In the second iteration, a semi-transparent backdrop was added to distance the UI from the VE, sans-serif typography was used, and users read ~2 lines at a time then pressed "next" to proceed. – VR-Anxiety, Artefact Feedback & Evaluation*

This design problem is not specific to this intervention; many PC&B interventions are generated using popular psychology software packages such as E-Prime (Stahl 2006), where typically, they heavily rely on delivering information or instructions textually. Such design approaches drastically differ from designing VEs, wherein gaming, for example, information tends to be conveyed visually, i.e. through storytelling or animations (Dillman *et al.* 2018; Siriaraya *et al.* 2018).

Unlike most 2D software applications where UI now follows well-established design conventions, UI design for 3D-VE spaces is at its infancy, and currently, it relies on individual designer's interpretation to visualise the UI layout from 2D space to 3D space. This is a reminiscence of early UI design for mobile-web; when the UI layout was directly adopted from PC-web, it resulted in highly unsatisfactory user experience and required a new design paradigm to optimise the content layout UI that is user-friendly to mobile-web (Chen *et al.* 2002). In the PC&B-VR interventions examined in this study, different layouts were explored to present critical therapy information. For example, VR-Pain intervention's UI was used to convey instructions about the therapy was embedded in the VE itself as part of the 3D room design, a poster on the wall, clearly visible to the user. Although this was effective in this particular intervention, such an approach is still limited; it may be challenging to embed with open, outdoor or natural VEs, when there might be no flat spaces to embed the UI within. Another common UI layout modality in VR is floating UI windows. In such layout, two design approaches were tested (see Figure 5.5); a floating UI bounded to the user's head coordinates; always in front of the user, and a floating UI that is static in place. As for the floating UI connected to the participant's head movement, it was found that this layout posed a barrier to the user's ability to explore the VE surroundings comfortably as the UI was always obscuring the VE. Such a design not only caused annoyance but also hindered the user's emotional engagement and immersion in VR, which are vital reasons why VR was used in the PC&B-VR intervention in the first place.

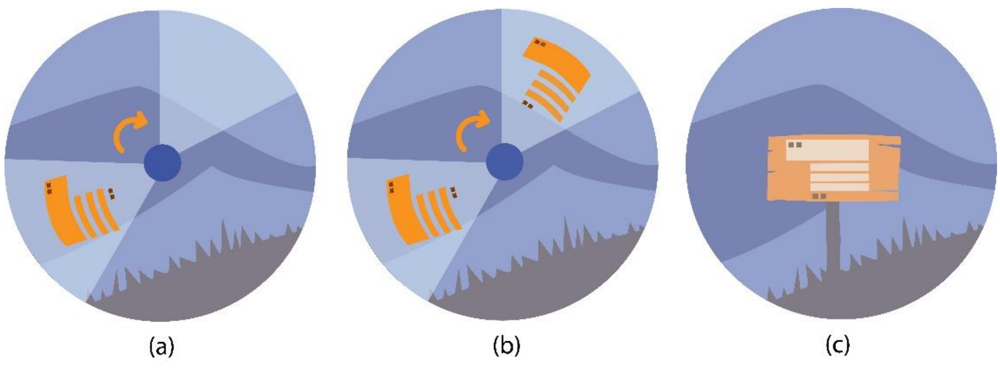

Figure 5.5: UI embedded part of the VE, b: UI bound to the user's head coordinates and c: bound-free UI

5.4.1.2 A Meaningful Clinical Space for Therapy

In the context of a traditional therapy space (i.e. therapist office), research has suggested that the design of such space has an influence on the patient's behaviour, emotion and mental process; thus, such space should be carefully designed in a way that supports effective therapies (Augustin and Morelli 2017). However, designing such a therapeutic space in VR could be challenging, as technically, VE designers can take users "anywhere". In research and practice, we know that content presented through a well-designed VE could transport the user visually to an emotionally altered state, whether that is through eliciting, reducing or regulating emotions (see section 2.2.2). However, in a mental healthcare context, where delivering emotional experiences that attend to the user's needs and therapy aims is vital, it is unclear what a "well-designed" VE may look like. Drawing from the wealth of research in games literature, the research suggests that all visual and audial effects must, in pragmatic terms, be made meaningful; in a way that serves and delivers the game's storyline (Kirschner and Williams 2014). As such, the existence of a specific object or element, and the design of it, must pragmatically contribute to the therapy aims toward building a virtual space that fosters emotional engagement and satisfies the therapy aims.

For example, the VR-Pain intervention aimed to assess the impact of the visually altered lifted dumbbell on the user's perceived levels of pain. Thus, when creating the VE space in an earlier prototype, the designers aimed to produce a close-to-the-real-world experience by designing a gym VE to be as similar as possible to a real-world gym by including various decorative elements (i.e. gym equipment, posters, etc.) with the intention of creating a more believable, immersive VE. However, in user testing, it was found that even though users enjoyed and perceived the VE as an immersive, close-to-reality experience, the rich VE was found to be distracting from the therapy aims, as it shifted users' focus from the visually altered dumbbell.

This prompts further discussion on the importance of directing attention within 3D spaces in VR, as the lack of, could result in feeling lost.

> *"I am lost; I am in the middle of nowhere." She is looking around in the desert VE, seemingly worried. – VR-ED, Observations, P10*

Directing attention has been briefly examined within VR contexts, mainly for 360-VEs (Lin *et al.* 2017). Thus, there exists a need to explore further how to design VEs that do not explicitly restrict or dictate the user's ability to explore the VE, nor distracts them from the main therapeutic activities. This is especially crucial for VR healthcare, as distracted or divided attention from the main therapeutic aims could dampen the intensity of the user's altered emotional state, thus, reduce the effectiveness of the PC&B-VR intervention.

The analysis shows that users' perceived control can result in increased engagement and motivation (Peters, Calvo and Ryan 2018). The effect of providing autonomous experiences was viewed in the VR-Dementia intervention, where PWDs were drawn to the idea of choosing the experiences and determining the narrative they wanted to construct within VR. Another aspect of empowering perceived control was observed by enabling users to control the speed of the therapy. VR can break down the exposure to the patient's own pace, which is a unique feature in VR identified by literature (Emmelkamp *et al.* 2001; Gonçalves *et al.* 2012). Users in VR-ED controlled the process of taking off layers of clothing as they proceeded in therapy. Such ability to control therapy pace was appreciated by users and motivated them to proceed further with the therapy.

> *If I was asked to continue doing it [VR], undress [the avatar], and wear less clothes, I'm willing to cross that line. I really liked it. – VR-ED, Questionnaire, P12.*

Therefore, allowing intervention designers to replicate such positive results by offering experiences that empower patients' autonomy is crucial. Nonetheless, such autonomous experiences may not be applicable for some PC&B interventions, specifically, for therapies that require a controlled flow for its effectiveness, such as the implicit association test and the go/no go association task (Nosek and Banaji 2001). Thus, it is important to recognise that this could pose a challenge in design for some therapies; hence, research needs to understand further how VR design can work around such intervention modalities.

5.4.2 **Interactions That Fit**

Interactions in VR are mediated by handheld controllers that serve as an intermediary between the user's body and virtual objects the user interacts with. Thus, interaction peripherals play a vital role in delivering effective interactions. Currently, VR controllers that are available in the market are closer to gaming controllers in contrast to more widely used input devices (i.e. a touchscreen or a mouse). Since we cannot assume users within healthcare to be avid gamers; hence, they may be unfamiliar with such interaction modalities. Three aspects related to interaction within the VR space were identified from the data analysis: (i) enabling competence, (ii) mechanics of interaction, and (iii) mechanics of navigation.

5.4.2.1 Enabling Competence

Feeling capable and effective, or competence, is a well-known factor in positive computing that reflects in the user's successful engagement, as well as their willingness to use the technology (Peters, Calvo and Ryan 2018). In the mental healthcare and wellbeing context, the lack of competence and effective interactions in VR could lead to the failure of the intervention. First, users may feel that their failure to perform tasks in the VE represents their failure to progress in therapy. Secondly, such incompetence could increase frustration and reduce the user's interest in the therapy or the use of VR.

> *After spending time painting the details of the 3D model's head, she mistakenly paints the entire head with the colour she intended to paint the eye with. As a result, she was frustrated and eventually lost interest in the activity altogether. – VR-ED, Observations, P06*

Research in gaming shows that games that are too hard to play results in the loss of competence and, ultimately, engagement (Lomas *et al.* 2017). In mental healthcare contexts, users with different cognitive, sensory and physical abilities will inherently be affected by such abilities when interacting with VR. Thus, such abilities of target users should be examined when designing interactions that fit; interactions that are balanced with users' abilities which enables them to feel competent and allows them to use VR naturally. For example, the cognitive deficits within dementia cause PWD to struggle when deactivating irrelevant stimuli, and therefore, struggle to maintain attention (Cohen-Mansfield 2001). Thus, when designing VR experiences for PWD, such experiences must not necessitate prolonged periods of attention. Therefore, when designing the VR-Dementia intervention, users, should they wished to, were able to view multiple VEs within the span of the 15 minutes allowed in one session, in an attempt to increase the engagement momentum. As a result, some PWD chose to immerse themselves into multiple VEs dynamically and engaged actively with caregivers by reflecting on their varied experiences. Thus, such design aided PWD to overcome the deficits of attention and provide caregivers with a platform to engage PWD for more extended periods.

Understanding how to design VEs which meets the user's physical and cognitive abilities naturally extends to the field of accessibility, a relatively unexplored research area in VR in the context of healthcare. Only one study was found concerning VR accessibility that evaluated accessibility features for users with visual impairment (Teófilo *et al.* 2018). Thus, much research is needed to produce accessibility guidelines to enhance usability and user competency in VR for those with cognitive, physical and mental constraints as likely; they are key targets of many PC&B-VR interventions.

5.4.2.2 Mechanics of Interactions

In PC&B-VR interventions, users may need to interact with 3D objects and elements within the VE as part of the therapeutic tasks. To which, designing intuitive and natural interaction mechanisms are fundamentally crucial, as the lack of such mechanisms could significantly interfere with the therapy flow.

It is difficult for me to follow a strict… [drops the ball] program, well if you exercise with a friend, wait a minute [unable to pick up the ball], yes so, I was saying… [Struggling in executing game tasks, which resulted in a much-interrupted conversation with the therapist]. – VR-ED, Observations, P06

As such, one of the design challenges which was encountered when translating a therapy into VR is the translation of the interaction, in a way that still delivers the therapy in a meaningful manner. This could be especially challenging when interaction modalities could not be identically mirrored into VR. For instance, the PC-based version of the anxiety intervention (VR-Anxiety) gave users 10 seconds to type the answer for each question using a keyboard; that is to exploit the user's unconscious bias, which is vital for the intervention's success in modifying the cognitive interpretation bias. Thus, it is vital to comply with such a requirement when translating the intervention into VR. Currently, QWERTY virtual keyboards are available in VR, which is a text entry modality directly adapted from non-VR mediums. Using the virtual keyboard, it was impossible to type within the time limit in VR. Thus, the designers opted for using voice recognition, as it allows the fulfilment of the interventions' requirement to give quick answers.

Some users found it difficult to perform tasks within VR, primarily when the mechanism of interaction drastically differed from the way such tasks are performed in real life.

I didn't like the basketball task; it was difficult to perform in comparison to real life. – VR-ED, Questionnaire, P08

Throughout the design sessions, it was found that some methods of interaction could get inspiration from conventional interaction approaches, which users are more familiar with. During VR-ED iteration testing, the most intuitive grab-and-drop method users preferred was the one similar to a drag-and-drop interaction using a mouse. However, whilst click-and-drag from one corner to another in a PC could be done effortlessly, drag-and-drop could become problematic when considering the full range of a 360° VE.

The lack of intuitive and closer-to-real-life interaction modalities could affect technology acceptance and willingness to use the VR healthcare intervention in the future. Only until recently, research has developed and validated novel methods in interactivity mechanisms that would enable interactions to be more natural and intuitive in VR. Such research explored novel keyboard solutions that enable smooth and faster data entry (Speicher *et al.* 2018; Yu *et al.* 2018) or interaction peripherals that enable more real-life-like grabbing and touching objects in VR (Choi *et al.* 2018).

5.4.2.3 Mechanics of Navigation

Navigation is one of the core tasks within VEs, from simply moving eyes gaze and head, to fully "walking around" within the VE. Designing navigation for PC&B contexts could be particularly challenging. Many user groups in mental health, such as autism, aphasia, dyslexia and dementia, to mention a few, lack spatial navigation, space perception, self-orientation and path detection skills (Slatin and Rush 2003). Even with a rather simple navigation modality, several PWD lost their sense of self-orientation while in the VE.

> *The caregiver asked: what can you see on your left-hand side, [P04]? He is hesitant and unsure which way "left" would be. The caregiver notices his confusion and asks him to follow her voice, to which he was able to respond. In this case, the caregiver guided the user into overcoming such lack of orientation skills.*
> *– VR-Dementia, Observations, P04*

During iteration testing for navigation mechanisms for VR-ED, several modalities were explored to deliver comfortable and natural navigation to move within the VE. One modality explored was the use of the user's natural walk cycle by capturing the user's arm swing motion whilst walking and translate such motion into the user's viewing camera (see Figure 5.6). However, such method caused motion sickness during testing, a common side effect of VR that can be caused by many factors, including navigation. In such a navigation mechanism, the test user felt sick as they were able to see and feel the mismatch in the perception of movement in each step they took. On the other hand, "point and click" teleportation, i.e. user aims at the destination and clicks to teleport was much more accepted, as when the user clicks to teleport, the camera moves swiftly at a steady pace in a way that does not cause any adverse effects.

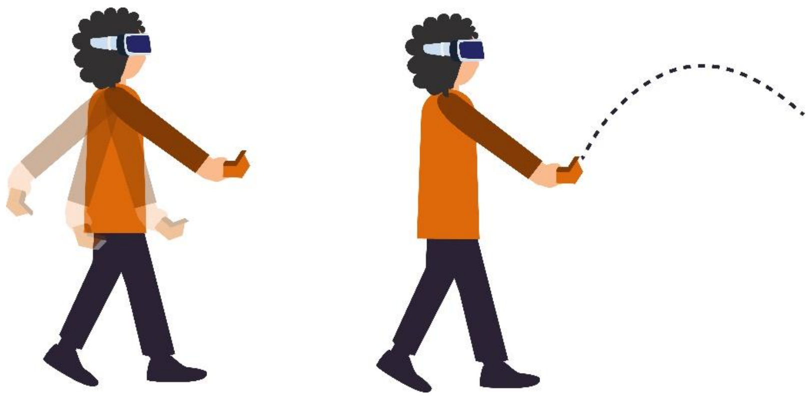

Figure 5.6: Left: navigation within the VE through capturing motion in the user's arm swing, Right: navigation within the VE through point-and-click teleportation

Teleportation between VEs is another aspect of designing navigation mechanisms that were explored. Users with ED (in the VR-ED intervention) teleported between VEs using portals similar to gaming, i.e. glowing circles. However, the user's unfamiliarity to the concept of portals caused some users to feel anxious.

> *I don't want to put my hand in this circle. I am afraid. Oh! This is so scary! – VR-ED, Observations, P08*

The importance of a therapy-friendly and inviting VR design which includes the appeal of navigation mechanisms for mental healthcare, cannot be understated; for example, research has established clear and detailed design guidelines for web applications, including colours and navigational path modalities that are friendly to healthcare (Baig, GholamHosseini and Connolly 2015; Holzinger and Errath 2007). Moving forward, there exists a clear need to extend knowledge in the good practices when moving within the VE and teleporting between VEs. Such practices for mental healthcare and wellbeing need to be user friendly and enable users to navigate in a way that suits their abilities. Furthermore, navigation for VR mental healthcare must not cause unwanted physical side effects such as motion sickness. Such an adverse effect not only is a safety issue for users or an inconvenience but also is an identified concern by therapists that discourages them from choosing to use VR (Bush 2008).

5.4.3 **Designing Therapeutic Connections with Self & Others**

Designing experiences that empowers an understanding of oneself and facilitates trustful, safe and therapeutic connections with others are essential for a positive outcome in mental healthcare (Fletcher-Tomenius and Vossler 2009; Leach 2005). Thus, reflecting such understanding within PC&B-VR intervention design cannot be understated. Herein, three design elements were identified: (i) enabling self through body ownership, (ii) etiquette and trust in virtual worlds, and (iii) therapeutic rapport in co-presence.

5.4.3.1 Enabling Self through Body Ownership

Body ownership in VR refers to the perceptual illusion that the virtual body is one's own (Petkova, Khoshnevis and Ehrsson 2011). One key aspect which was found to be essential for the users to feel connected to their virtual body is the visual resemblance of the avatar. In the VR-ED intervention, people with ED were first asked to create their own body, where they were asked to create the body that resembled how they thought they looked like, not how they wished they looked like. The UI in VR offered pick-and-choose customisations for the hair colour, hairstyle, and skin tone. To modify the body size, users were provided with scroll bars for each body part (i.e. thighs, buttocks, chest, etc.), where at one extreme of the slider the body part is extremely slim, and the other extreme of the slider the body part is extremely thick (see Figure 5.7). Considering that the body appeal and shape is the heart of the ED intervention, it was crucial that the user feels the virtual body as their own. Interestingly, not only did users identify with their avatars, but their insecurities and self-criticism also manifested through their virtual bodies.

I would like to modify the [avatar] face because my face is fatter than the avatars'. I would like to make the face fatter because my [real] face is troubling me. – VR-ED, Observations, P06

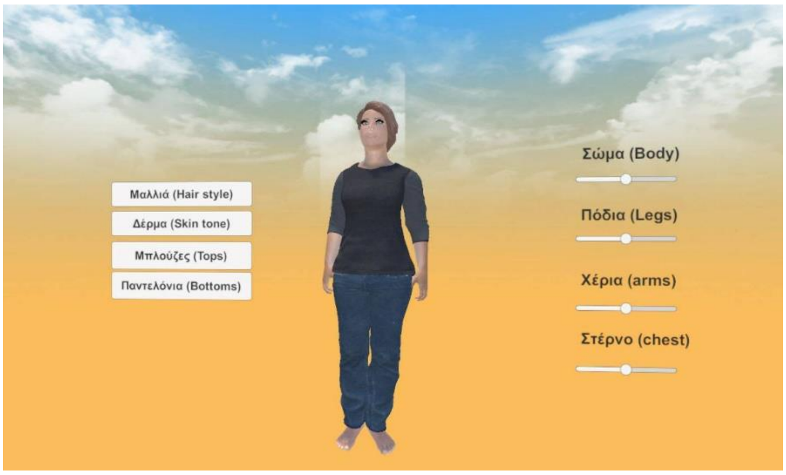

Figure 5.7: 3D avatar with customisation UI used in the ED-VR intervention for the mirror exposure therapy

Research in game design concluded that greater embodiment cultivates greater intrinsic motivation (Birk *et al.* 2016). In the VR-ED intervention, mirror exposure therapy was utilised to elicit the user's true feelings about their body image; thus, the resemblance of avatars played an important role. However, this is not always the case for other interventions; game research showed that the avatar does not necessarily need to resemble the real user's physical appearance for the user to sense body-ownership. In fact, people in games create amplified versions of themselves, versions that do not exist in real life (Bessière, Seay and Kiesler 2007) or versions that resembled old memories of their younger selves (Carrasco *et al.* 2018).

The need for further sensory modalities, i.e. proprioceptive feedback to enhance the sense of embodiment is another common point of importance within VR research and practice. Depending on the type of activity the user will perform, the user's ability to view the body parts that are required to perform the activity, and the need and extent of proprioceptive feedback can vary. In the VR-Pain intervention, the need for proprioceptive feedback was not initially anticipated as the user (and the avatar) is seated. Also, as part of the therapy task, the user is expected to hold the dumbbell still. Nonetheless, the lack of the avatar's mimicry to the real body's behaviour was immediately spotted in an early prototype.

> *"Why my [virtual] arm isn't moving, that's so weird!" while shaking his real arm, waiting for the virtual arm to respond. Considering that the user's attention in the intervention is directed at the arm lifting the dumbbell, he easily noticed the lack of proprioception. – VR-Pain, Artefact Feedback & Evaluation*

Numerous studies employed the use of proprioceptive feedback for a specific part of the body, i.e. arm or full-body proprioception in semi-immersive modalities as rehabilitation system for patients with neurological diseases (Cho *et al.* 2014; Kim *et al.* 2013; Lewek *et al.* 2012); however, little literature examined the use of proprioceptive feedback within a fully immersive modality such as VR (Bortone *et al.* 2018). Furthermore, several barriers to deployment are faced when using such interactive modalities due to the complexity of the programming and developing required to incorporate them into the intervention design.

5.4.3.2 Etiquette and Trust in Virtual Worlds

Research illustrates that people treat and interact with technology as they would do with other humans and often become unclear on how to operate when using new machinery or unfamiliar environments, which may affect their feelings of trust in the technology and themselves in a negative manner (Reeves and Nass 1996). Such a lack of understanding of etiquette within VR was observed across interventions. Some participants were overly self-aware of trying not to do something "wrong" or foolish, which resulted in many users expressing anxiety when interacting with VR.

He is hesitant to turn around; he turns a little bit from the centre to the left. His arms are slightly raised as if he's preparing himself for something to go "wrong". The caregiver is encouraging him and reinforcing his actions in VR. – VR-Dementia, Observations, P03

In some cases, some PWDs were amazed and laughed when their caregiver "disappeared".

PWD grabs the HMD with her hands and places it in front of her eyes. When she turns to the side where the caregiver is sitting, she says: "oooh this is a big sea! But where are you!" She took the HMD off immediately and looks at the caregiver, once PWD realised that she's still "there" she bursts into laughter. – VR-Dementia, Observations, P08.

In the case where therapists did not co-locate with users, some became anxious when the therapist was first presented within the VE as an avatar.

Dear God, something is talking to me! Oh God! Do I have to reply to this? – VR-ED, Observations, P10

All of such observations indicate that people from diverse backgrounds with different cognitive abilities need design protocols that support them when "entering" the VR experience, which informs them with the know-how to enable their self-trust and trust in the VR experience as a whole. This element in VR design is still relatively unexplored, and there is a need in research to understand the design needs and strategies further to support users in this sense.

5.4.3.3 Therapeutic Rapport in Co-Presence

When we log into a virtual space such as social media and Massive Multiplayer Online Role-Playing Games (MMORPG), for the majority of people, our most essential psychological need is to find authentic connections with others (Ang and Zaphiris 2010; Stenros, Paavilainen and Mäyrä 2009). In the mental healthcare and wellbeing domain, such connections need to be designed to foster a positive, constructive and trustful relationship between the user and caregiver, or what is known as therapeutic rapport (Leach 2005); a key factor to a good therapeutic outcome in mental healthcare (Leach 2005; Norfolk, Birdi and Walsh 2007). For instance, research shows that the main clinical concern in web-based online therapies was how patients and therapists could build a strong therapeutic relationship in the absence of physical presence (Cook and Doyle 2002). Similarly, such concerns were raised during the design of the VR-ED intervention.

One design aspect that was adopted to address such concerns was by utilising playful activities within VR before the primary intervention. Therapists and users with ED were given two game-based activities before proceeding to the exposure therapy: a 3D painting activity and basketball game. It was found that playful activities created therapeutic rapport effectively.

> *The games helped me to feel closer to the therapist. She was not a therapist; she was a friend of whom I had some fun with and shared my inner thoughts and emotions. – VR-ED, Questionnaire, P10*

Another design aspect that is crucial to incorporate when assisting therapists and users build therapeutic relationships is the design of the therapist's avatar. The avatar's design in all its aspects (i.e. appeal, liveliness, attitude, posture, etc.) need to be appropriate for the user to perceive the virtual therapist as friendly, inviting and trustful and thus, enable therapeutic rapport. For the ED therapist's avatar, considering the user demographics, a cartoon-like cube design was used enhanced with lip-syncing and eye-movement animations to convey the liveliness of the avatar. Generally, users with ED found the avatar friendly and inviting, which allowed them to relieve their anxiety from feeling judged and were able to elaborate on their inner thoughts and feelings.

> *The fact that she [therapist] was a cube made me feel safe to talk about myself. – VR-ED, Questionnaire, P13*

On the other hand, a handful of users with ED felt that the avatar could not provide them with the psychological needs to build a therapeutic relationship such as empathy and emotional connections with the therapist.

> *I wanted to share my feelings and emotions, and I was looking at a cube. I would like to see her [therapist] emotional connection to my problem. I would like to see at least some sympathy. The virtual therapist was "Mr No-One". – VR-ED, Questionnaire, P05*

The lack of non-verbal cues is a long-standing design challenge in any computer-mediated communication, including VR. Very few and recent studies examined some workarounds towards more non-verbally expressive avatars in VR, including some pre-designed facial expressions and life-size emojis in VR chat rooms (McVeigh-Schultz, Kolesnichenko and Isbister 2019). In mental healthcare and wellbeing contexts, there is a lot to be learnt from literature in clinical psychology that directs clinicians with strategies and behaviours that would help them build therapeutic relationships with their patients. For example, enthusiasm, eye contact and open posture are defined attributes of a trustful therapist that helps the patient trust and build rapport (Leach 2005). Future research could examine how to embed such characteristics into therapist avatars.

5.4.4 An Enabling Deployment Context

Throughout the co-design process, it became clear that the design of effective VR for mental healthcare and wellbeing, like any other technology, goes beyond the technology itself (i.e. hardware and software) and involves designing for the context in which the system would be deployed.

The physical-world setting (i.e. a hospital, therapist office, care home, etc.) are often overcrowded and generally lack a dedicated space for a VR system. Even when such arrangements are made, a hospital or clinic's environment is not always ideal for VR. For example, in the VR-ED intervention, where users were required to walk around physically, there were occasions where users bumped into a floating shelf; a shelf hanging on the wall, even though efforts were made to avoid this issue by clearing the participation rooms from furniture to allow free movement. Although no injuries resulted, these users were very wary of their movement, which hindered their sense of presence in VR. Some research work has been done to explore solutions for walking in virtual spaces that are larger than the real physical space (Interrante, Ries and Anderson 2007; Peck, Fuchs and Whitton 2010), such as having the VE continuously and imperceptibly rotating around the user, in a way that keeps the user's immediate path within the tracked space. Such a design problem is not generic to all VR interventions; some interventions may not require the user to be walking around in the physical space.

Furthermore, the design of how and where the user will receive support and guidance while using VR needs to consider the design context and the needs of the users in detail. Throughout the interventions, different support modalities were explored according to the circumstances that surrounded each intervention (see Figure 5.8). For example, textual guidance was embedded within the VR-Anxiety intervention to enable users to use VR in a standalone setting and be guided independently. In the case of dementia, PWD residing in a hospital require assistance in most if not all activities of daily living (Garcia, Kartolo and Methot-Curtis 2012); thus, the system was designed so that caregivers are by PWD's side to provide support and guidance. Finally, many users with ED are hesitant to seek therapy due to the anxiety related to body image dissatisfaction in the presence of therapists (Halmi 2013). Thus, through presenting the therapist as a virtual avatar, users felt less anxious and were more open to discuss their thoughts and feelings.

Figure 5.8: user supported within the VE using UI, Middle: user supported from the "outside" in the real world, Right: user supported by a virtually present support provider (i.e. clinician, therapist, etc.)

5.5 Summary

The potential of VR in healthcare in general and PC&B interventions in specific have been demonstrated through decades of research. Yet, the lack of standardised and coherent design paradigms for healthcare VR poses a barrier to real-world deployment within healthcare. In this chapter, four user-centred VR-based PC&B interventions were examined, including the co-design and iterative development processes and evaluation by representative users and clinicians/caregivers. Critical design elements of these interventions were identified and examined on how they were translated and adapted into VR, including the incorporation of the needs of users, clinicians, and the context of the real-world healthcare setting. Afterwards, the results of thematic analysis discussing the design needs, opportunities and challenges for designing meaningful and effective PC&B-VR interventions were presented.

In the next chapter, a discussion of the overall findings from Chapters 3, 4 and 5 and their significance in relation to the existing research is discussed. At the end of the chapter, directions for future work are also presented.

Chapter 6: Discussion & Conclusion

Due to the increasing demands within mental healthcare and wellbeing, as well as the challenges that are faced in the deployment of assessments, treatments, training and other forms of support (see section 2.3), researchers within the Human-Computer Interaction (HCI) community have shown tremendous interests in developing novel technologies to support this. In particular, Virtual Reality (VR) is a technological platform that has received substantial attention in the mental healthcare and wellbeing field in general and the Psychological, Cognitive & Behavioural (PC&B) domains in particular (see section 2.3). Despite the emerging research that supports the efficacy of PC&B-VR interventions, knowledge and best-practices that relates to the design of these VR interventions are still scarce (see section 2.4). As such, there is a need to explore how conventional therapies can be translated into VR in a way that fosters the appropriate therapeutic milieu for PC&B-VR interventions while attending to the critical needs of key stakeholders and, importantly, how examining the healthcare settings can play a role in VR intervention design to maximise its deployability in the real-world healthcare environment.

Herein, this thesis aimed to investigate the design and deployment opportunities, issues and challenges of VR in mental healthcare and wellbeing in general and PC&B domains in particular. Taking into consideration the scope of a single PhD thesis, the research work done in this thesis aimed to address specific literature gaps that are under the umbrella of the overarching research problem. In particular, this thesis presented a collection of three studies that investigated the effects of engaging in emotional experiences in VR using 360° Video-Based Virtual Environments (360-VEs) (Chapter 3), the feasibility, design and deployability of VR in a healthcare setting (Chapter 4) and the design elements required for meaningful, efficient and effective VR experiences in the context of mental healthcare and wellbeing (Chapter 5). Herein, this chapter summarises and discusses the findings from the three studies, followed by an overall discussion of the implications of these findings. Afterwards, the contributions and limitations of the work done in this thesis are presented. Finally, potential research opportunities that stem from the work done in this thesis, which could be investigated in the future, are discussed. Table 6.1 shows a summary of the details of the three studies carried out in this thesis.

Table 6.1: Details of the studies carried out in this thesis

Research Questions	Can VR be used as an emotional space, a tool for emotional elicitation? What are its potentials within PC&B contexts?	What is the potential of VR as an emotional space within a real-world healthcare setting?	What are the design elements that are required for meaningful, deployable and effective PC&B-VR experiences? What are the current needs, opportunities and challenges within these design elements?
Order	Chapter 3	Chapter 4	Chapter 5
Objectives	1) Investigate the emotional effects of engaging in 360-VEs and its potential in PC&B applications 2) Explore whether eye-gaze behaviour in VR can predict emotional elicitation 3) Explore the potentials of eye-tracking VR as a tool to measure emotional responses in PC&B domains	1) Explore whether VR is feasible and deployable for use in restricted healthcare settings and whether VR can be tolerated and accepted by PWD 2) Investigate how VR impacts behaviour and wellbeing in people with moderate to severe dementia and the kind of benefits VR could offer 3) Identify how VR could be deployed to provide a meaningfully emotional experience for PWD	1) Identify the design challenges when translating therapies into VR in a way that meets therapy requirements 2) Identify the design elements for meaningful experiences within healthcare and wellbeing contexts and how VR can be adapted to meet stakeholders' requirements 3) Explore how the understanding of healthcare contexts can contribute to the deployment of VR
Method	Quantitative study	Mixed-methods design study	Qualitative study

Approach	Analysis of subjective ratings and eye-gaze behaviour data	Analysis of semi-structured interviews, observation notes and quantitative measures	Analysis of workshops and session notes, test user's artefact feedback, open-ended questionnaires and interviews, and observation notes during evaluation sessions
Sample Size	34 participants who engaged in twelve 360-VEs, yielding a total of 408 trials.	8 participants with moderate to severe dementia visited twice, and 16 caregivers who supported PWD during exposure to VR.	Data from 4 PC&B-VR interventions, including 24 brainstorm workshops and co-design sessions notes, 12 feedback notes during iterative design, 30 observation notes during evaluation sessions and 53 transcribed interviews or open-ended questionnaires with representative end-users and caregivers/therapists.

Analysis	1) Two-way repeated-measures ANOVAs for subjective-ratings to understand emotional elicitation in the four quadrants of emotions, followed by Tukey's HSD tests to evaluate emotional elicitation over valence and arousal dimensions 2) Two-way repeated-measures ANOVA for ratings of presence to understand the level of presence in the four quadrants of emotions, followed by Tukey's HSD tests to evaluate the level of presence over valence and arousal dimensions 3) Paired-samples t-test to evaluate ratings of dizziness 4) Binomial logistic regression to explore whether eye-gaze behaviour could predict emotional elicitation in VR	1) Thematic analysis, which included semi-structured interviews with PWD and caregivers as well as observation notes during the sessions 2) Friedman test to evaluate the overall difference between pre-during-post exposure to VR over observed emotional responses, followed by Wilcoxon signed-rank tests to explore the difference from pre-to-during, during-to-post and pre-to-post exposure to VR 3) Frequency of behaviour that challenges 4) Wilcoxon signed-rank test to evaluate the difference between time spent in VR in visit-1 and visit-2	Thematic analysis included a corpus of data collected from four user-centred PC&B-VR interventions. Across the four PC&B-VR interventions, 31 researchers participated in brainstorm sessions, design workshops, and evaluation of the prototype iterations to design and develop the interventions, 8 test users participated in prototype testing and feedback during iterative development, and finally, a total of 147 representative users and 23 therapists and caregivers evaluated the final intervention prototype

6.1 Research Questions Addressed

Each chapter addressed a research question, through which, the design and deployment of VR in mental health and wellbeing in general and PC&B domains are explored. The following subsections summarise the thesis research questions and key findings as well as implications to those findings.

6.1.1 Can VR be used as an emotional space, a tool for emotional elicitation? What are its potentials within PC&B contexts?

The study described in Chapter 3 explored emotional elicitation in VR when engaging in 360-VEs and the use of eye-tracking VR in assessing emotional responses and its potential applications within mental healthcare and well-being.

This study's results proved the efficacy of 360-VEs in eliciting emotional responses; using VR, 360-VEs in all categories of emotions elicited the desired emotional responses; high arousal positive, low arousal positive, high arousal negative and low arousal negative. Participants perceived the relevant emotions in the desired quadrants; participants' subjective ratings indicated that high arousal positive 360-VEs induced happiness and joy, low arousal 360-VEs induced calmness and relaxation, high arousal negative 360-VEs induced fear and anxiety and low arousal negative 360-VEs induced sadness. Ratings of anger and disgust were found mainly in the low arousal negative 360-VEs, which may be due to the narratives presented in the selected 360-VEs (see section 3.5.2). Although high arousal 360-VEs were not rated as high arousing, they were still more arousing than low arousal 360-VEs. The results also indicated that participants felt present in all 360-VEs, but higher levels of presence were reported when engaging in negative 360-VEs.

Although the use of VR in emotional elicitation and modulation have received significant interests in HCI research (see section 2.2.2), where research mainly utilised 3D-VEs to elicit and modulate emotional responses relevant to therapies, assessments and other forms of support within the mental healthcare and wellbeing domain (see section 2.3), the use of 360-VEs is relatively new. The results in this study found that 360-VEs were able to elicit a range of emotions, to which the use of 360-VEs may be useful for applications in mental healthcare and wellbeing.

In addition, the efficacy of eye-tracking VR in predicting emotional elicitation was demonstrated through the results of the study. Specifically, eye-gaze behaviour in VR successfully predicted emotional elicitation over the arousal and valence dimensions using an array of eye-gaze behaviour features, including fixations, micro-saccades, saccades and blinks. These features have been proved to be relevant to mental healthcare and wellbeing contexts by previous literature using non-VR mediums (see section 3.6.3).

The study concluded that eye-tracking VR has great potential in mental healthcare and wellbeing (see section 3.6.3). For instance, unlike many physiological and behavioural measures, eye-tracking is embedded within the VR system; therefore, it does not require the user to wear any additional peripherals or be attached to additional devices. Such an advantage may not only be for user comfort purposes, but it can also allow users to engage in VR experiences without being overly wary of their physical surrounding. Such an advantage has been recognised in VR research for forensic psychiatry, where eye-tracking in VR was far less intrusive than the gold standard (penile plethysmography) in assessing sexual arousal in offenders (Trottier *et al.* 2014). The research work highlighted that VR provided an alternative reality where sexual offenders can immerse and be forgetful about the real world (i.e. the assessment environment or people in the room); hence, the researchers were able to gain closer-to-reality responses and therefore, VR provided a robust assessment tool for sexual deviancy.

The potential of eye-tracking VR was also demonstrated in the findings section of Chapter 4; i.e. VR can be used to understand PWD's emotional responses better, especially when PWD cannot verbalise their emotions (see section 4.4.3.3). As such, eye-tracking could be explored when evaluating emotional elicitation (i.e. cognitive stimulation, reminiscence) and modulation (i.e. reduce behaviour that challenges). Eye-tracking VR could also be utilised to modify the therapy or VE content depending on PWD's fixated interest(s). In addition, previous studies have explored the use of eye-tracking in non-immersive mediums to evaluate many attributes that are of interest in dementia diagnosis and assessment protocols, such as detecting mental fatigue and cognitive load (Krejtz *et al.* 2018; Yamada and Kobayashi 2018) and memory (Subramanian *et al.* 2014). As such, eye-tracking VR could hold strong potential in providing researchers and practitioners with a critical lens into the cognitive processes behind PWD's actions and behaviours, and therefore, potentially provide a better understanding of dementia.

Finally, despite the plethora of literature that has explored the use of VR and supported its efficacy in mental healthcare and wellbeing (see section 2.3), only a little research has employed the use of eye-tracking using VR in this context (Trottier *et al.* 2014). One reason could be that the eye-tracking hardware and software have only been recently embedded in mainstream VR Head Mounted Displays (HMDs) available in the consumer market. As such, there are promising opportunities in exploring the deployment of eye-tracking in PC&B-VR applications and how it can assist clinicians and practitioners in assessment, diagnosis and ultimately, delivering enhanced modalities of therapies and treatments.

6.1.2 **What is the potential of VR as an emotional space within a real-world healthcare setting?**

The study described in Chapter 4 examined a relatively unexplored medium in terms of the user population and healthcare space. In particular, the study examined the feasibility and design of VR for people living with moderate to severe dementia residing in a locked psychiatric hospital.

The study found that both PWD and caregivers largely well-accepted VR. Out of 16 sessions, PWD accepted to engage with VR in 15 sessions. The maximum exposure to VR duration in each session was fifteen minutes, of which, PWD engaged in VR for twelve minutes or more in 11 sessions. All PWD either reported or were observed to find exposure to VR a positive experience; however, one PWD reported feeling temporarily dizzy, although still reported they liked and would repeat the VR experience.

Some research work examined the use of non-immersive or fully-immersive technology-based interventions for PWD, in which, the user-group predominantly included people with early-onset or mild dementia (Hodge *et al.* 2018; Moyle *et al.* 2018; Siriaraya and Ang 2014; White and Moussavi 2016;

Zakzanis *et al.* 2009). This study demonstrates the feasibility and acceptability of VR with people with moderate to severe dementia who may present with behaviour that challenges. Further research could look into technology acceptance with PWD who are at their later stages of dementia in more depth using well-established technology acceptance related measures such as the System Usability Scale (SUS) (Brooke 1996) and Technology Acceptance Model (TAM) for Virtual Reality (Sagnier *et al.* 2020).

As for the feasibility of VR in a restricted healthcare setting, such as a locked psychiatric hospital, the study concluded that examining the hospital's structure (i.e. where will patients engage with VR, ease of setting up/moving equipment, physical structure and layout, etc.) is a vital factor that contributes to its deployability within this setting. In this study, using a light, portable and easily administered VR HMD allowed a flexible deployment of VR in terms of setting up the equipment quickly in different wards within the hospital, to accommodate hospital restrictions per PWD. It was also less intrusive for PWD when setting up and packing away in their own living space. In addition, having such an easy-to-administer VR enabled caregivers to take the lead in introducing and using the equipment easily, which is more close to a deployable solution in the real-world healthcare context. As such, the deployability of VR within healthcare settings could be made possible by examining the environment in which VR is expected to fit . Such environmental factors may include the physical layout of the healthcare setting, security restrictions and spatial restrictions.

In addition, the results showed that VR promoted alertness, positive moods and general wellbeing, not only observed during exposure to VR but also in the short-term after the session. Throughout the study, it was prevalent that VR has the potential to offer benefits to PWD in varied ways, from reminiscence, cognitive stimulation, promoting social interaction to therapeutic rapport.

As for the experiences that VR offered, by "bringing the outside in", PWD had access to environments, experiences or locations that may be difficult to reach in their daily life at the locked hospital. By capitalising on the immersion and sense of presence in VR, PWD can "transfer" to various locations and experiences when PWD may not be able to explore such locations in reality, whether that was due to lack of mobility, ill-health, safety or legal restrictions, or extraneous variables such as weather and location availability. VR also offered the potential to provide experiences that are wholly consistent; if a PWD enjoys a particular 360-VE, they can revisit the same VE.

The therapeutic benefits of "bringing the outside in" through 360-VEs in VR have great potentials, not only within dementia healthcare but also within mental healthcare and wellbeing contexts. Recent work in the literature has also explored the use of 360-VEs in VR as a tool to promote wellbeing for oncology patients in palliative care, where visiting "home" or "somewhere memorable" was therapeutic, reduced depression, tiredness and pain and increased wellbeing (Niki *et al.* 2019). As such, VR may have the potential to be utilised as a therapeutic tool for a wider audience within clinical populations who may have restrictions (i.e. health, mobility, risk, legal, etc.) and face barriers in exploring real-world experiences.

Additionally, the idea of using VR as a "personal space" was introduced, especially for individuals in long-term care; VR could offer a novel approach to regulate emotions and reduce behaviour that challenges. The potential of VR as a low stimulating virtual space to reduce behaviour that challenges is not only restricted to dementia healthcare; many clinical population groups present with behaviour that challenges including autism, learning/intellectual disabilities, and sensory, hearing and mobility impairment (National Collaborating Centre for Mental Health (UK) 2015).

Finally, PWD gained a sense of autonomy through the VR experience using an open-ended non-task-oriented free-exploration approach. The ability to easily explore VEs and construct one's own narrative enabled PWD to gain a sense of autonomy that may not be available in real-life circumstances (i.e. freely explore the beach followed by a visit to a church) living in a locked hospital. Exercising an autonomous lifestyle and maintaining individuality is one critical measure to a good Quality-of-Life (QOL) within long term services

(Kane 2001). As such, VR could be used as a tool to support autonomous lifestyles within clinical populations residing in long term healthcare services such as care homes, locked hospitals, low secure hospitals, medium secure hospitals, high secure hospitals and forensic services.

6.1.3 What are the design elements that are required for meaningful, deployable and effective PC&B-VR experiences? What are the current needs, opportunities and challenges within these design elements?

The study in Chapter 5 aimed to understand the design needs in developing VR interventions for mental healthcare and wellbeing in general and PC&B domains in specific.

The study outlined a major challenge when translating conventional interventions into VR due to the lack of a design framework that can inform designers on how to design VEs and elements within the Virtual Environments (VEs) that can support the therapy to enable optimal engagement in VR. The study concluded that the design of VEs for PC&B-VR interventions need to emphasise the understanding of the "world" design metaphor, allowing users to receive critical information related to the intervention effectively. As such, the VR healthcare design paradigm is more akin to games than web/mobile design paradigms, where User-Interfaces (UIs) in web/mobile design uses a "page" design metaphor. In addition to the UI and VE design, the world metaphor also needs to incorporate the conveyance of information, guidelines or instructions that, in many conventional interventions, are in the form of text. Unlike game design, however, where the goal is to provide novel experiences in each game, there is a need to provide standardised and consistent experiences that considers the design needs and requirements for PC&B-VR interventions. Such standardisation could include best-practices in presenting therapy instructions, menus, questionnaires or any other textual and non-textual information that crucially relates to the therapy, in a way that does not obstruct or hinders the user's engagement in the therapy, or distracts the user's attention from the element(s) that is the centre of the therapy.

Another challenge that was identified in this study is in the translation of interaction mechanics in a way that still delivers the intervention in a user-friendly and meaningfully therapeutic manner (see section 5.4.2). Some PC&B interventions present with requirements that affect the interaction design when translating into VR; as such, VR design needs to adapt to meet these requirements (see section 5.4.2 for examples). Furthermore, currently, interaction and navigation mechanisms are more akin to gaming than to more widely used mechanisms (i.e. mouse and keyboard when using a PC, or touch-based interaction when using a smartphone or a pad); therefore, many users, including patients/users and clinicians/therapists may not be familiar with such mechanisms.

Additionally, this study outlined the importance of enabling the user's sense of autonomy and competency when engaging in VR. These attributes have been previously identified as important components to increase user's engagement and maintain interest within positive computing (Peters, Calvo and Ryan 2018) as well as games (Lomas *et al.* 2017) research. In healthcare and well-being contexts, the lack of such attributes could negatively affect the acceptability of VR and the PC&B intervention outcomes or willingness to progress in the therapy. As such, every aspect of the PC&B-VR intervention design (both software and hardware) needs to enable these competencies for meaningful and therapeutically engaging interventions.

Across all the PC&B-VR interventions that were examined in the study, it was clear that the usability and sociability go beyond the ease of use and interaction within VR; some users were anxious, apprehensive and self-aware in their interactions during exposure to VR. Many users (both clinicians and patients) may not have extensive experience with VR; therefore, the accepted etiquettes and social norms within VR are not clear. This aspect is important to consider, especially within healthcare and wellbeing contexts, as VR should not add to the anxiety of engaging in the therapy or intervention. Furthermore, this could be of interest, especially now that the research community is expressing interests in developing virtual multi-user PC&B-VR interventions, where sociability becomes more relevant in this context (Döllinger *et al.* 2019; Matsangidou *et al.* 2020).

It is crucial to recognise that some PC&B-VR interventions could be emotionally stressful by nature (i.e. exposure to frightening events) (Gonçalves *et al.* 2012; Mishkind *et al.* 2017), require a high level of attention (i.e. responding in a timely manner in an assessment) (Pettersson *et al.* 2018; Zakzanis *et al.* 2009), or cause mental or physical exhaustion (Bortone *et al.* 2018; Cho *et al.* 2014). All of these could increase cognitive load, which could affect performance and willingness to engage in VR. Thus, healthcare VR intervention design should facilitate intuitive, smooth and sensitive interactions in a way that does not unnecessarily add to the cognitive load or emotional distress. These recommendations contrast some findings in games research where certain forms of cognitive load are desirable to keep the gamers challenged and maintain the engagement momentum (Ang, Zaphiris and Mahmood 2007). Hence, PC&B-VR designers need to explore how the intervention could be delivered intuitively and naturally. For instance, researchers found that owning a virtual self (i.e. embodied avatar) in VR reduces the cognitive load when users are expected to perform a series of actions (Steed *et al.* 2016).

Furthermore, the study concluded that understanding the healthcare context and embedding this understanding into the VR intervention design could contribute to more deployable VR interventions in real-world contexts (see sections 5.4.2, 5.4.3 and 5.4.4). Understanding where (i.e. healthcare setting, home-based intervention, etc.) the VR intervention will be implemented can dictate many constraints to the type of VR technology that can be used and the level of interaction within the VR intervention. In addition, providing patients and clinicians/therapists with the appropriate tools, activities and environments may assist in fostering therapeutic connections within the VR space. Furthermore, the modalities of support during exposure to VR can depend on user needs and capabilities; the design of the VR intervention needs to adapt to such needs.

Finally, in consistence with the vital notion of person-centred care in healthcare practices (Brechin *et al.* 2020), the PC&B-VR intervention should be designed in a way that can adapt to and seamlessly embed with the patient's individual care regime. For successful deployment, a VR activity must be in line with individual patients' therapy regime, which enables the use of VR to fit seamlessly within the healthcare setting's practices. This could be done either by incorporating communication methods that best suit the patient, incorporating "before" and "after" procedures or rituals to best transition the patient in and out of the VR activity, or by adopting patient-specific protocols.

6.2 Overall Discussion

Despite the emerging research that supports the efficacy of VR for mental healthcare and wellbeing, knowledge and best-practices that relates to the design of VR interventions for this domain are still scarce (see section 2.4). First, the knowledge on how VR can be designed as an emotional space, a therapeutic medium where users "step into" and emotionally engage in the therapy through VR is lacking (see sections 2.2.2 and 2.3). Second, knowledge on how VR can be designed to cater to users' critical needs such as clinicians, therapists, patients or users is still limited. Third, the process of translating traditional clinical and therapeutic interventions to VR is unclear; it is unclear how to effectively translate the critical therapy elements from conventional mediums to the VR medium. Finally, considering that much research in VR and healthcare has been done in a controlled experimental setting, it is unclear how the real-world healthcare context may present with challenges to VR deployment. Addressing all these challenges are beyond the scope of a single PhD thesis. Therefore, this thesis's research work aimed to address specific literature gaps that are under the umbrella of the aforementioned research problem. Specifically, three studies were carried out to investigate the effects of engaging in emotional experiences in VR (Chapter 3), the feasibility, design and deployability of VR in a healthcare setting (Chapter 4), and the design elements required for meaningful, efficient and effective VR experiences in the context of mental healthcare and wellbeing (Chapter 5). The results presented in this thesis address literature gaps within under the overarching research problem through:

- *Extending the understanding of the effects of VR as a space for emotional elicitation within mental healthcare and wellbeing contexts (Chapters 3, 4 and 5):*

  The study in Chapter 3 extended the knowledge on how users perceive emotional 360-VE experiences in VR (see sections 3.5 and 3.6.1), how eye-gaze behaviours could predict emotional elicitation (see sections 3.6.2 and 3.5.5) and the potential of eye-tracking VR in mental healthcare and wellbeing (see section 3.6.3). Chapter 4 explored emotional elicitation in a healthcare setting; the study identified how emotional experiences in VR affect PWD over emotional wellbeing and behaviour (see section 4.3). Then, the chapter identified several streams on how emotional experiences in VR could be used to maximise the benefits of VR for PWD (see section 4.4). Finally, in Chapter 5, a more detailed investigation was done concerning building a virtual therapeutic milieu. The study identified some needs, challenges, and recommendations regarding the design of the VE content and the UI within VR to deliver meaningful clinical spaces for therapy (see section 5.4.1).
- *Extending the understanding of VR intervention design for effective and meaningful interventions that cater to the needs of key stakeholders (Chapter 5).*

  In Chapter 5, through the analysis of four user-centred PC&B-VR interventions, the study explored the process of translating conventional therapies into VR and the design needs and challenges in meeting conventional therapy requirements in VR as well as stakeholders' sensitive requirements. In addition, the study identified nine design elements for meaningful experiences within healthcare and wellbeing contexts, in which, the needs and challenges within these elements in regards to the VE content design (see section 5.4.1), interaction design (see section 5.4.2) and communication design (see section 5.4.3) were discussed.

- *Extending the understanding related to the deployment of VR in mental healthcare and wellbeing (Chapters 4 and 5):*
  The study in Chapter 4 explored the feasibility, design and deployment of VR within a healthcare setting, i.e. locked psychiatric hospital. The study contributed with real-world deployment challenges, opportunities and recommendations (see sections 4.4.1.3 and 4.4.3). In Chapter 5, the deployment contexts for successful implementation of VR were discussed and how the design of the VR intervention, including its hardware, software and interaction design, should consider the real-world healthcare setting to ensure VR is deployable in its intended medium (see section 5.4.4).

Overall, the work done in this thesis has addressed the research questions that contribute to addressing some of the identified challenges within the overarching research problem. As such, there are a number of contributions this thesis contributes to the body of literature, which are discussed in the next section.

6.3 Contributions

This thesis offers a number of contributions to the HCI research community. First, there are theoretical contributions to the existing literature that extends the understanding of emotional elicitation in VR and the use of such a virtual emotional space in the mental healthcare and wellbeing domain. Second, there are practical contributions that are concerned with the design and deployment of VR within healthcare settings. Third, design guidelines were formulated to assist future designers on how to develop effective and deployable PC&B-VR interventions that consider the stakeholders' needs and requirements. Finally, data contributions are also presented, in which, researchers can use the raw data to test their hypotheses and algorithms in the future.

6.3.1 Theoretical Contributions

For many interventions in mental healthcare and wellbeing in general and PC&B interventions in particular, emotional elicitation and modulation are paramount for many therapies and interventions within this domain. Due to the several advantages VR can offer when it comes to providing emotionally engaging experiences, including the immersion and high level of presence users experience when engaging in VR (see section 2.2.2), a strong body of literature has utilised VR as an emotional space; a therapeutic medium where users “step into” VR and emotionally engage in the therapy (see section 2.3). In addition, evaluating such emotional responses, including physiological and behavioural responses, is of substantial importance within the research community, as it can provide researchers with a critical lens to understand users further, assess and design better therapies for users within PC&B domains (see section 3.2.3).

This thesis's findings contribute to the existing literature by extending the understanding about the effects of engaging in emotionally eliciting VR experiences such as affective 360-VEs and its potential in mental healthcare and well-being domains. For instance:

- The findings in Chapter 3 show that 360-VEs can elicit a range of emotions over the valence and arousal dimensions. This chapter confirms the results from previous studies (Li *et al.* 2017) and builds on to further understand emotional elicitation in VR. The most popularly used resources of stimuli in research are images (Nuske *et al.* 2014; Pflugshaupt *et al.* 2005; Valenza, Lanata and Scilingo 2012) and sounds (Greco *et al.* 2017; Nardelli *et al.* 2015). Hopefully, the results in this study and the ease of administering 360-VEs can motivate future research within affective computing, psychology, and HCI desciplines to test their research questions and hypotheses related to emotional responses using 360-VEs as a new resource for emotional elicitation.
- In Chapter 4, 360-VEs were utilised in a healthcare setting. This chapter's findings showed positive results in relation to emotional elicitation and modulation when PWD engaged in 360-VEs using VR. In particular, significant observed improvements were found in relation to pleasure and alertness as well as a reduction in recorded behaviour

that challenges. In addition, the study found no adverse effects in the form of fear, anxiety, sadness and anger. To the knowledge of the author, there are no other studies that explored the use of VR for individuals with moderate to severe dementia, which was a literature gap that was defined in the body of research (Rose *et al.* 2018). Hence, the results in this research contribute original knowledge to the research community. As such, the results in this study can motivate researchers to explore the use of VR further, even with individuals who are at their later stages of dementia. Furthermore, the study revealed several opportunities on how VR could be utilised for this user-group, including providing a "personal space" and "bringing the outside in". Such opportunities are not restricted to dementia care; other clinical populations may make use of a virtual personal space as a non-pharmacological intervention to reduce distress and overstimulation from the real-world environment (see section 6.1.1). Furthermore, many clinical populations may not be able to experience real-world experiences for a variety of reasons; as such, VR could present with an alternative virtual offer (see section 6.1.1).

- Further understanding of emotional elicitation in VR, the study in Chapter 3 explored the efficacy of eye-tracking VR in predicting emotional elicitation and its potential in mental healthcare and wellbeing as a tool for emotional assessment. The results in this chapter show that eye-tracking VR can predict emotional elicitation over the valence and arousal dimensions using an array of eye-gaze behaviour features, including fixations, micro-saccades, saccades and blinks; all of which have demonstrated to be meaningful in mental healthcare and wellbeing contexts by previous literature using non-VR mediums (see section 3.6.3). Because VR HMDs that incorporate embedded eye-tracking sensors have only become available in the consumer market recently, research in eye-tracking VR in the context of mental healthcare and wellbeing is still an untapped research area with high potentials. Therefore, this study demonstrated the potential of eye-tracking in mental healthcare and well-being. Future research could utilise eye-tracking in VR as a robust, non-intrusive, low-cost modality to better understand the emotional and cognitive processes behind the user's reactions and interactions.

6.3.2 Practical Contributions

This thesis aimed to extend knowledge on the design and deployment of VR in the mental healthcare and wellbeing field through identifying the needs, challenges and opportunities of design and deployment in this domain; the study described in Chapter 5 aimed to achieve these research goals. The study presented many practical design recommendations in relation to design and deployment, in the aims that practitioners, designers and developers could use to develop emotionally engaging, meaningful, effective and deployable PC&B-VR interventions that attend to the needs of key stakeholders. For instance:

- The potential of 360-VEs in emotional elicitation was explored in Chapter 3 and demonstrated in Chapter 4. The use of 360-VEs could be a point of attraction to practitioners in the mental healthcare and wellbeing field. First of all, 360-VEs are readily-available on many free-to-use platforms such as YouTube and Facebook. Therefore, perhaps for some interventions, acquiring 360-VEs may only require searching for readily-available 360-VEs. Secondly, in contrast to the development of 3D-VEs, 360-VEs does not require an extensive technical background; therefore, relevant practitioners could easily capture relevant virtual experiences. Thirdly, because of how easy 360-VEs can be produced, this production pipeline could assist in making VR more deployable at large-scale. However, 360-VEs have limitations, especially when it comes to interactions (see section 3.6.1). Nonetheless, it is crucial to recognise that not all interventions require complex interactions, as many interventions predominantly rely on simple exploration. Such a simple interactivity method has been used in the diagnosis of eating disorders (Gorini *et al.* 2010), pain-management-related interventions (Hoffman *et al.* 2000) and phobia and anxiety-related interventions (Freeman *et al.* 2018; Garcia-Palacios *et al.* 2002; Miloff *et al.* 2016), just to mention a few.

- VE content design and UI design were discussed in section 5.4.1. The section describes the several challenges that were faced in translating critical therapy components into VR, translating components that cannot be directly copied into VR and design issues that affect the therapy outcomes, such as directing attention and maintaining emotional engagement in therapy. These challenges –along with design recommendations– can be useful for artists and UI designers when designing effective and enriched PC&B-VR interventions. Practical design considerations were also discussed in section 5.4.3, including avatar design recommendations for both patient/user avatars and therapist avatars.
- Section 5.4.2 shed light on the needs, challenges, and opportunities in designing interactions that fit; interactions that are balanced with users' physical, sensory, and cognitive abilities enable them to feel competent and allow them to use VR naturally. The section discusses how entertainment-oriented technology such as VR can be adapted to fit clinical use, and what limitations and barriers VR currently present to the deployment, acceptability and usability of VR within this domain. Several considerations discussed in this section where User Experience (UX) designers and developers could make use of when designing PC&B-VR interventions to ensure that the UX design does not interfere with the therapy flow, and enable users' competence, intuitive and natural interactions. Furthermore, many of the discussions related to interactivity and navigation mechanisms naturally extended to hardware design. Technology developers could evaluate the challenges faced in PC&B-VR intervention design and draw new directions to accommodate the need in this growing field. For example, the study outlined a lack of intuitive and closer-to-real-life interaction peripherals for some tasks (i.e. touch, grab and throw objects) available in the consumer market. Practical interaction considerations were also

discussed in section 5.4.3; these considerations could be especially helpful for future developers when taking into account that many healthcare services might lack the physical space to deploy VR or may not have the resources for sophisticated, fully-interactive systems. As such, some recommendations are laid out to accommodate these limitations that might be of use for future deployment within healthcare settings.

- Throughout Chapters 4 and 5, deployment challenges and opportunities were presented and discussed when it comes to implementing VR in real-world healthcare settings, in which, future practitioners could consider when designing PC&B-VR deployable interventions. Additionally, throughout Chapters 4 and 5, several modalities of support were investigated to ensure patients and users received the appropriate support during exposure to VR, of which, practitioners and developers could consider when designing their VR interventions. Finally, the potential of 360-VEs was discussed in Chapter 3 and demonstrated in Chapter 4; 360-VEs could offer a low-cost easy-to-administer deployable solution when resources and expertise to develop 3D-VEs are not available and/or when the intervention mainly rely on exploration and does not require complex interactions.

6.3.3 **Design Guidelines for Future Work**

Despite the abundance of research presented in section 2.3 that supports the efficacy of VR in mental healthcare and wellbeing, design frameworks, guidelines, or best practices for developing effective, efficient and deployable PC&B-VR interventions are scarce. Even though design frameworks, best-case practices or "cookbooks" have been identified for other technology platforms, such as games (Fanfarelli, McDaniel and Crossley 2018; Siriaraya *et al.* 2018; de Vette, Tabak and Vollenbroek-Hutten 2018), web (Britto and Pizzolato 2016) and mobile health (mHealth) (van Dooren *et al.* 2019; Miller, Cafazzo and Seto 2016) for mental healthcare and wellbeing applications, little is known about the best-case practices in VR design in this domain.

As such, as part of this thesis's contributions, the table below presents the set of design guidelines that emerged from this thesis.

Table 6.2: Design Guidelines for Future Work

Cat	#	Guideline	Description	Example
Environment & UI	G01	Define the emotion(s) the VE is meant to elicit	Colours, content, style and other aspects of VE design need to be considered to induce emotions that are meaningful to the PC&B-VR intervention.	Outdoor space with natural colours for relaxation.
	G02	Direct attention	The VE design needs to draw the user's attention to the PC&B-VR intervention point(s) of interest and deactivate irrelevant stimuli.	Unnecessary decoration that diverts the user's attention.
	G03	Understand the user's deficits and limitations	Understand the nature of the user's cognitive and mental deficits and limitations, then embed this understanding in the UI/VE design.	Presenting suitable VEs for PWD with low attention span.
	G04	Define input modalities	Define what input modalities in addition to the visual feedback are required to achieve the therapy aims.	3D audio, multi-sensorial feedback (Mulsemedia).
	G05	Adopt a world-metaphor UI	UI layout must not obscure or distract the user's ability to emotionally engage in VR.	UI embedded as part of the VE.
	G06	Avoid adverse effects caused by content design	Understanding the hardware's capabilities to render in real-time then embed this understanding through the choice and design of the VE content and UI.	Delay in rendering due to heavy CG leads to motion sickness.
Interaction & Navigation	G07	Enable accessibility & competence	Interaction and navigation modalities in VR need to be accessible and usable corresponding to the user's mental, cognitive and physical abilities.	Spatial navigation is a cognitive deficit in dementia.
	G08	Adopt intuitive & natural interactions	Natural and intuitive interactions could be adopted from familiar interactions with other technologies or interactions that are life-like.	Grab an object in VR using a haptic glove.
	G09	Interactions that satisfies therapy aims	Interactions must be translated from non-VR mediums to VR to deliver the therapy in a meaningful manner.	Interaction design for a therapy that is time-sensitive.
	G10	Consider the real-world space	Interaction and navigation modalities must be designed in a	Seated interactions may be more

			way that considers the constraints of the physical space.	suitable in a crowded office.
	G11	Avoid adverse effects caused by interactions	Interaction and navigational modalities must not induce adverse effects when using VR.	Movements without motion blur cause motion sickness.
Enabling Self	G12	Enable personalisation	Personalise experiences or elements within VR to maximise user's engagement.	PWD surfing through various VEs to keep up the engagement momentum.
	G13	Enable the sense of autonomy	Provide autonomous experiences to increase user engagement.	Users with ED were motivated; they controlled the therapy pace in VR.
	G14	Facilitate body-ownership	Avatar design needs to be effective in allowing the user's feel connected to their virtual self (i.e. appeal, proprioception, etc.).	Proprioceptive feedback in VR-Pain increased users' sense of body ownership.
Rapport & Support	G15	Design for Rapport	Intervention design must foster therapeutic relationships.	Therapist avatar design that is inviting and trustful.
	G16	Define the appropriate support modality	Identify how the user will receive instructions/support during VR exposure depending on the users' profile and deployment context.	Co-presence in VR for patients and therapists who cannot be in the same phyical location.
	G17	Support care providers	Support caregivers and therapists to understand the user's emotional responses and experience in VR.	The use of affective computing (i.e. eye tracking) in VR.
Deployment	G18	Examine the physical environment setting	The physical setting needs to be examined to identify the suitable hardware and interaction modality for practical and realistically deployable systems.	Portable VR for VR-Anxiety is meant to be used anywhere (i.e. home, study hall).
	G19	Evaluate safety & secruity considerations	Understand the safety and security requirements and how they relate to the design choices of the VR intervention.	PWD with involuntary movement disorder required harnessed HMD.
	G20	Reduce inertia & friction of deployment	This may be the use of appropriate hardware that would enable the deployment context, understanding patients' daily regime so that VR could fit seamlessly in, or perhaps utilising low-cost VR systems to enable large-scale deployment.	

6.3.4 **Data Contributions**

Although data-gathering is essential for many studies, data collection can often be a lengthy, difficult or expensive process that requires significant resources. One alternative to streamline this process is the use of publicly available datasets or open data. Researchers can use the data to test their research questions, hypotheses, and algorithms. In affective stimulation, there are a number of well-established datasets that are widely popular in the body of literature. Two of the most popular datasets are the International Affective Picutres System (IAPS) (Lang, Bradley and Cuthbert 2008) and the Affective Digital Sounds System (IADS) (Bradley and Lang 2007) in which, they provide hundreds of digital picture-based or sound-based emotional stimuli. In both datasets, the stimuli content and participant's ratings of each stimuli item are included in the dataset. In addition to subjective ratings, many affective datasets provide researchers with physiological and behavioural data. For example, the Database for Emotion Analysis using Physiological signals (DEAP) is a publicly available dataset that contains affective music videos, the subjective ratings of these videos and the recorded Electroencephalogram (EEG) data for participants when engaging in these videos (Koelstra *et al.* 2012).

In the context of affective stimulation in VR, the currently publicly available resources are significantly scarce. Only one affective dataset was found, in which a list of affective 360-VEs is shared with the research community (Li *et al.* 2017). To the knowledge of the author, there is no publicly available dataset of VR-based affective stimuli coupled with psychological, physiological and behavioural data. Hence, as part of the broader collaborative research that the study in Chapter 3 was part of, a publicly available dataset is currently ready to be published along with its scholarly paper. The dataset comprises the process of stimuli selection, including the pilot trial results, the metadata related to the selected 360-VEs, self-reported questionnaires, subjective ratings of the affective 360-VEs, eye-tracking data, Electrocardiogram (ECG) data and Galvanic Skin Response (GSR) data.

To the knowledge of the author, this dataset will have the highest number of participants who engaged in affective 360-VEs in VR, where physiological and behavioural data are captured and publicly shared. The dataset aims to provide a much-needed source to HCI researchers' growing community in emotional elicitation and recognition in VR.

6.4 Limitations

The work carried in this thesis had a few limitations that are important to consider. First of all, all three studies were limited due to the small sample size. In the VR eye-tracking study presented in Chapter 3, affective responses of 34 participants were captured and analysed over twelve 360-VEs. This dataset is considerably small compared to large scale dataset libraries in terms of the number of participants and the number of stimuli. However, in order to recruit and collect large-scale data of larger magnitude (i.e. 500+ participants), substantial effort, time and resources are required to complete such work. Furthermore, considering that the stimuli set only consisted of twelve 360-VEs, there is a breadth of emotions that were not examined. Nonetheless, the study demonstrated the efficacy of VR to elicit emotional responses in all four quadrants of the Circumplex Model of Affect (CMA). Furthermore, the produced dataset that is to be publicly available may allow other researchers to further extend knowledge on psychological and physiological emotional elicitation in VR when engaging in 360-VEs. As for the study presented in Chapter 4, only 8 PWD and 16 caregivers were recruited to participate in the study. Considering that due to the nature of dementia, PWD progressively lose their sense of autonomy and capacity to make decisions in various or all aspects of their life (Garcia-Palacios *et al.* 2002); therefore, when considering seeking participation from this user group, difficulties were inherently faced in accessing those with severe cognitive impairment. In line with the Mental Capacity Act (2005), the capacity to consent evaluation was required to all potential participants before being approached about the study. Such a process (although its importance is highly valued) is lengthy and relied on busy multi-disciplinary teams at the hospital. Furthermore, in the case where individuals were deemed to lack the capacity to consent, seeking consent from appropriate consultees was also a lengthy process, especially that many of whom did not respond and were also at a distance from the hospital and were contacted using postal correspondence only. Finally, as for the study in Chapter 5 that examined the co-design process, development and deployment of four PC&B-VR interventions, the limitation of the results lie in the small number of intervention cases that were examined. This is mainly because few studies have described the process of translating, designing, and developing therapies in VR. As such, there is a need to build on this knowledge through collaborative and iterative work within the HCI research community.

Secondly, none of the studies examined the effects of VR in the longer term. In the study described in Chapter 3, participants did not report adverse effects of VR. The selection criteria of 360-VEs, the time limitation (maximum of 3 minutes per 360-VEs) and the 2 minutes cool-down period between 360-VEs may have played a positive role in avoiding the adverse effects of VR. As for the study described in Chapter 4, only once a short-term adverse effect of VR was observed; however, a large-scale, longitudinal study is needed to systematically identify whether there are potential long-term adverse effects of VR and how they can be minimised. Finally, in the study described in Chapter 5, all four PC&B interventions examined in this study were evaluated in the short-term; thus, more large-scale, longitudinal studies are needed to assess the effectiveness of the design and potentially new design needs that might arise in correspondence to large-scale longitudinal use.

Furthermore, the study conducted in Chapter 3 did not include a control group. A within-subject design was adopted to examine the different emotional effects 360-VEs may induce by capturing psychological and physiological measures. Due to the nature of physiological measures, a within-subject design was required. Nonetheless, future research could investigate a between-subject design to manipulate emotional elicitation in VR versus non-VR mediums as control and explore the efficacy of eye-tracking in VR versus eye-tracking in non-VR.

Due to the nature of how the analysis conducted in Chapter 5, which was conducted retrospectively, the data varied in terms of measures collected, the format of data collected, and sample size per study. Future research could define a systematic method of collecting design data for VR studies in order to build on the design knowledge, iteratively, as an HCI community.

In addition, inter-coder reliability was not conducted for the qualitative analysis carried in Chapters 4 and 5. Nonetheless, in the thematic analysis carried in Chapter 4, two researchers with HCI expertise (including the author of this thesis) as well as three clinical psychologists in the field of dementia healthcare critically discussed and reviewed each theme and underlying codes together. Furthermore, in the thematic analysis carried in Chapter 5, at least two researchers with HCI expertise (including the author of this thesis) reviewed and analysed the data from initial coding to the final scheme delivery.

In addition, pupillary responses were not explored as part of the work done in Chapter 3. Due to the limited resources at the time of the data collection of the study, the VR headset used to collect eye-tracking data did not incorporate the hardware and software capabilities to acquire pupil dilation data. Pupil dilation in non-VR technologies has been explored in the context of emotional elicitation within mental healthcare and wellbeing (Nuske *et al.* 2014; Puviani, Rama and Vitetta 2016). Future researchers could examine the effect of emotional elicitation in VR and its effect on pupillary responses.

Finally, one limitation to recognise is exploring whether the positive results in assessing emotional elicitation using eye-tracking VR (Chapter 3) can be replicated in a healthcare setting (Chapter 4). Indeed, it would have been interesting to examine the feasibility of eye-tracking VR to assess emotional elicitation in a healthcare setting. However, the clinical researchers who are part of the collaborative team at the hospital outlined the following barriers to deploying an HMD with an eye-tracking feature. First of all, considering it is not clear whether PWD would tolerate VR in the first place, the research team stressed the importance of removing any unnecessary steps that might affect PWD's acceptability of VR eye-gaze calibration. In addition, considering the severity of the dementia diagnosis of the selected user-group, eye-tracking calibration would have been hard or maybe impossible to complete in some cases. Furthermore, due to the hospital's restrictions and physical layout, a Portable HMD was deemed more appropriate. Currently, there are no Portable HMDs that come with eye-tracking functionality. Nonetheless, it is crucial to recognise that the barriers to the deployment of eye-tracking VR that were faced in this particular research work do not negate the potential of eye-tracking VR in healthcare settings; it is merely that this case, in particular, had a set of requirements where eye-tracking VR did not fit.

6.5 Future Work

This thesis aimed to investigate the design and deployment opportunities, issues and challenges of VR in mental healthcare and wellbeing. Due to the complexity and depth of such a research problem and the substantial work that is beyond the scope of a single PhD thesis, the research work done in this thesis aimed to address specific literature gaps that are under the umbrella of this research problem. This thesis provided insights into the emotional and behavioural responses for when engaging in VR, the design and deployment of VR in a healthcare setting, the design and deployment challenges for when translating conventional interventions into VR and the design elements for meaningful VR experiences that meet stakeholders' sensitive requirements such as clinicians, therapists, patients and users within healthcare.

As such, there are several potential research directions derived from the findings in this thesis that future research could investigate. Below, are some of the proposed potential directions.

6.5.1 **Real-Time Emotional Evaluation System in Virtual Reality Using Eye-Tracking**

The effects of emotional elicitation when engaging in 360-VEs using VR was investigated in Chapter 3. The study utilised regression analyses to examine whether eye-tracking data could predict emotional responses. The results indicated several eye-gaze behaviour attributes that significantly predicted emotional elicitation. The Chapter also discussed the potential of eye-tracking VR for PC&B-VR applications. One research direction future research could explore how eye-tracking VR could be employed as a real-time emotion evaluation system and its applications within mental healthcare and wellbeing contexts.

Affective Computing is a well-established research field, providing machine learning algorithms for the automatic recognition of emotional elicitation and modulation (Nardelli *et al.* 2015). In such, eye-tracking in VR could inform useful insights to caregivers, clinicians and practitioners in real-time. As such, clinicians can prompt relevant changes according to the participant's responses. Furthermore, eye-tracking real-time feedback could be particularly useful to recent research approaches exploring multi-user VR therapy interventions, where clinicians and patients meet virtually and engaging in therapy using VR without meeting each other in reality (Matsangidou *et al.* 2019). As such, real-time emotional evaluation using eye-tracking in VR could open new potential for evaluating and understanding the patient's needs and emotional state when the clinician is not physically there to observe other bodily reactions.

6.5.2 **Semi-Automated 360° Video-Based Personalised Experiences**

The potential of 360-VEs in mental healthcare was explored in Chapters 3 and 4. The use of 360-VEs in this domain presented several advantages, such as the ease, speed and low cost of acquiring and recording 360- VEs (see sections 2.1 and 4.1.2). Although the interaction in 360-VEs is limited in comparison to 3D-VEs, it is important to note that not all PC&B-VR interventions require high complex interactions.

In Chapter 4, five free-to-view low arousal positive 360-VEs were utilised to "bring the outside in" for people with moderate to severe dementia residing in a locked psychiatric hospital. Although the study yielded positive results, one aspect that was not explored in this study was related to the personalisation of 360-VEs. The research team selected the 360-VEs that were used in the study, and PWD's individual interests and preferences were not factored in. During the interviews with caregivers, many have commented on how tailoring personalised 360-VEs that are relevant to activities, stories, sports, preferences or places PWD enjoy or used to enjoy would be particularly beneficial. Although such an approach could be beneficial as suggested by caregivers, it could be quite demanding when it comes to large-scale deployment, i.e. a hospital with 300+ residents.

One direction future research could explore is how to semi-automate the personalisation process of 360-VEs. Such a solution could have several routes. One route could include automatically characterising 360-VEs with relevant and reliable tags, i.e. short word(s) that describe the content of the 360-VEs, which would help a recommendation and retrieval system to assist caregivers in retrieving desirable 360-VEs fast and easy. Such an approach is well known in affective computing; implicit affective tagging refers to the automatic generation of subjective or emotional tagging (Koelstra *et al.* 2012). Such an approach, although it may not fully personalise the 360-VE content to great detail, however; it can offer a range of 360-VEs that are relevant to the user's interests. For example, if a PWD has an interest in "going to" a music concert, the caregiver could search for "music" and "concert" tags, and the system would list available 360-VE music concerts.

6.5.3 **Streamline Virtual Reality PC&B Development Toolbox**

Developing VR interventions in general and PC&B-VR interventions in specific require the specialised technical expertise of programmers and developers specialising in VR or 3D game-based applications, digital artists (2D and/or 3D) and UX designers. Such a pool of expertise may not be available for many research labs or healthcare practitioners who wish to develop their own VR applications. Therefore, the shortage of cost, time and access to such expertise may hinder the spread and deployment of VR.

To streamline the process of development, toolboxes (also referred to as Toolkits or Application Program Interfaces (APIs)) are popular to assist developers to speed up the process of content creation and development. Development toolboxes are a popular resource that could be deployed to assist developers in speeding up the process of content creation and development.

Currently, there exist a variety of commercial toolboxes such as Playmaker[44], Adventure Creator[45] and Probuilder[46] that can be added to popular game engines used for VR development such as Unity[47] and Unreal[48] engines. Such commercial toolboxes would contain pre-made elements or game components that developers use directly or with minimal adjustments, and hence, speed up the development time. However, these commercial packages come at a considerable cost and do not necessarily address the needs of clinical applications. Many user populations within mental healthcare and wellbeing require unique design requirements when designing user-friendly and effective experiences (see section 2.4). Given such unique design requirements, commercial VR toolboxes mostly targeted at entertainment VR and games, may not incorporate the tools of which, specific clinical populations would require for user-friendly and highly engaging yet clinically relevant experiences. As such, there exist a need for a highly usable VR development toolbox, a development package that is equipped with a user-friendly interface that provides non-technologists with the appropriate tools to translate and develop PC&B-VR interventions efficiently and effectively. Currently, there is no VR development toolbox designed specifically for mental healthcare and wellbeing.

Drawing from the recommendations on building effective toolboxes (Bloch 2006), it is crucial to deeply and fully understand the design needs of the specific application area so that the toolbox is effective and useful. In Chapter 5, the design challenges when translating conventional interventions to VR were described, the key design elements of PC&B-VR design were identified, and the needs, challenges and opportunities in designing PC&B-VR interventions were explored. As such, future research could utilise the findings in this Chapter to inform the development requirements of the toolbox

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[44] https://hutonggames.com
[45] https://www.adventurecreator.org
[46] https://unity3d.com/unity/features/worldbuilding/probuilder
[47] https://unity.com
[48] https://www.unrealengine.com

application. Furthermore, the toolbox could explore how to provide tools and solutions to overcome the challenges within these elements that were discussed in the chapter. In addition, such a toolbox could provide an interface that would help practitioners translate their interventions from conventional mediums to the VR medium. Such a toolbox could open the opportunities for research labs or healthcare practitioners to design and produce their own VR interventions efficiently and effectively and hence, empower VR to be deployed more widely.

The work done in this thesis provides a basis for future research related to the design and deployment of VR in mental healthcare and wellbeing in general and PC&B domains in specific. Hopefully, this thesis would encourage more research to share their design processes when developing PC&B-VR interventions, include best practices in the deployment of VR in real-world healthcare settings, and collectively as a research community, harvest knowledge towards a standardised design framework for developing PC&B-VR interventions.

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Appendix

Appendix–A: Final Stimuli – YouTube Links (Chapter 3)

The table below contains the YouTube links for the 360-VEs that were used in the study described in Chapter 3.

Tag	Duration (min:sec)	YouTube Link
Walk the Rope	02:31	https://www.youtube.com/watch?v=JtAzMFcUQ90&t=4s
Brazilian Dance	01:38	https://www.youtube.com/watch?v=dIYRrDzw2_4
Dancing with the Stars	01:15	https://www.youtube.com/watch?v=vEk2poiXSFU
Beautiful Resorts	02:41	https://www.youtube.com/watch?v=ondCdFcaJgA&index=11&list=PLidVUxLLu5K0Mn-mJQSDt4O7deMSwmyPQ
Calm Pond in the Forest	03:00	https://www.youtube.com/watch?v=Z-ihuDLNVR8
Cute Bunnies	03:00	https://www.youtube.com/watch?v=caooJknsZGs&t=2s
The Exorcist	02:01	Original (currently unavailable): https://www.youtube.com/watch?v=Zd-k_jrgDJk Alternative: https://www.youtube.com/watch?v=QS36ftzGBhw
Alone in Forest Tent	01:20	https://www.youtube.com/watch?v=-eG5O1WmQ6Y
Zombies Eating Flesh	01:15	https://www.youtube.com/watch?v=UXuUtnUEuCs
Post Terror Attacks	02:52	https://www.youtube.com/watch?v=o3yvjEMFbnM&list=PLidVUxLLu5K0E4oTfCG8i1J9pC_ihobFa&index=25
Refugee Story Collection	01:56	https://www.youtube.com/watch?v=J6gJk_s1gOM&t=53s
Refugee Rescue Boats	02:54	https://www.youtube.com/watch?v=ERAn51GPTes&index=13&list=PLidVUxLLu5K0E4oTfCG8i1J9pC_ihobFa

Appendix–B: Participant Information Sheet (Chapter 3)

We invite you to participate in a study of 360-degree video-based VR experiences. This project is carried out by Luma Tabbaa, supervised by Dr Chee Siang Ang, School of Engineering and Digital Arts at the University of Kent, in collaboration with Dr Mario Weick, School of Psychology at the University of Kent, and Maxine Glancy, BBC Research and Development. This study is funded by the University of Kent Faculty of Social Sciences.

Please find the information about the study below. It is important that you understand the reason why this research is being carried out and what your participation will involve. Please take your time, and if you have any questions, please do not hesitate to contact the research body using the contact information mentioned below.

Why have I been chosen to take part in this study?

You received an invitation email; however, if interested, only those who fulfil the eligibility criteria questionnaire will be able to participate. Eligibility criteria include that you are aged 18 or above, you do not have or ever reported a seizure, seizure disorder, epilepsy, heart condition, heart arrhythmias, hypertension, vestibular disorder, taking any medical condition affecting balance, have frequent headaches, light-headedness, or dizziness, visual or hearing impairment, head injury, neurological disease, learning disability, psychological disorders, or diagnosed with clinical depression. Lastly, you do not wear eyeglasses or get a rash on the skin from wearing non-precious metal or rubbing alcohol.

What is the purpose of the study?

We aim to understand the role of technology in relation to various 360-degrees video-based experiences. The experiment session will take place in a laboratory at Keynes College, Canterbury Campus, University of Kent. We will ask you to fill out some questionnaires, watch a video, and then fill out some questionnaires again. We prepared twelve videos to be viewed as a total, and each video is a maximum of three minutes long. After each video, you will have time to rest.

What are the possible benefits?

We hope that you enjoy watching 360-degree videos. Also, you will receive a 10 pounds Amazon Gift Card voucher upon completion of participation in this study.

For how long the study requires me to volunteer for?

The session at the laboratory is expected to take approximately 2 hours.

What do I need to know, and what are the possible disadvantages and risks in taking part?

There are a few things we would like you to know before deciding to take part in the study; first, we will use a camera that will video and audio record the session from beginning to end. We want you to know that these recordings will be kept at a very secured drive, that is protected by a firewall and password, and we guarantee you that only the research members body mentioned above will have access to it.

Secondly, we will collect and record physiological measures, this means we would like to continuously record throughout the session physiological information like your Galvanic Skin Response (skin sweat measure), and Electrocardiography (electrical activity of the heart). Due to the nature of placing the physiological data capture equipment, some things that are important for you to know before coming into the lab. As we will be attaching three small electrodes to your calf, we ask that you wear suitable clothes (i.e. loosely fitted). If the clothing was not suitable, we regret to ask you to withdraw from the study. We will also ask you to wear a watch on your right hand and some electrodes on your fingers, on the same hand. We might need to use rubbing alcohol to place the electrodes on a clean area or to clean the watch after use. Therefore, we exclude potential participants who are not tolerant of rubbing alcohol or non-precious metal, as some get a rash from them. We want to assure you that the procedure is not painful or scary; also, there are no negative effects that would be a concern.

We will also use eye-tracking technology to track your eyes movement. We do not foresee any risks associated with eye-tracking technology as it does not affect you; in fact, you will not notice that the equipment is recording.

Some videos may be distressing, some of which will contain emotional content (i.e. fake blood). We made sure there are breaks between the videos for you to rest; however, if you do not wish to view such content, we strongly advise that you do not participate in this study.

Can I refuse to take part, withdraw after I gave my consent at any time?

Your participation in the study is fully voluntary, and you can withdraw from this study at any time without negative consequences. On the experiment day, we provide you with a unique participant ID that is only known to you, if you decided to withdraw at any point, you would need to provide the researchers or the departmental office with the ID and indicate your wish to withdraw from the study. You can contact the Departmental Office at *[contact number]*.

What will happen to the results, and how will you protect my confidentiality and anonymity?

Your information will be immediately anonymised by creating a participant ID. Ownership of the data generated from this study remains with the University of Kent, including the research team. Access to the data is restricted, and no information will be disclosed that may identify you. The results serve exclusively academic purposes. The information generated from this study may be published, but no details will be disclosed from which your identity could be traced back. Any findings which are published may contain extracts of anonymous data. All data will be stored and kept safely in line with the Data Protection Act. The data will be saved on a hard drive that has a firewall for virus protection, and access with a password for information protection.

Has anyone reviewed the study?

This study is reviewed and approved by the ethics committee of the Psychology Research Ethics. If you have any serious concerns about the ethical conduct of this study, please inform the Chair of the Psychology Research Ethics panel (via the Psychology Departmental Office) in writing, providing a detailed account of your concerns.

Thank you for reading this information sheet and considering taking part in the study “Stepping Into The Virtual World: A Study of Immersive 360-Degree Videos”. If you wish to receive additional information later, or you want to contact the researchers, please also refer to the contact details given below.

Yours sincerely,

[contact information]

Appendix–C: Informed Consent Form (Chapter 3)

Participant Identification Number (ID):		Sign Initials Below
I confirm I have read and understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.		
I understand that my participation in this study is voluntary and that I can change my mind and withdraw from the study at any point. I confirm that I've been provided with the necessary information related to contact details and the procedure to follow if I wished to withdraw at any point.		
I have been guaranteed that access to the data is restricted and that no personal data will be kept; therefore, all my responses are anonymous. I understand that no personally identifiable data will be recorded.		
I understand that the experiment session will be video and audio recorded. I give permission to record video and audio of the session.		
I give permission for the members of the research team to collect and record my physiological signals like Galvanic Skin Response, and Electrocardiogram.		
I give permission for the members of the research team to collect and record eye-tracking information.		
I give permission for members of the research team to have access to my anonymised responses. I understand that this study will be published in a journal or conference, but no information will be disclosed from which my identity could be traced back.		
I am aged 18 or above and consent to participate in this study.		

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

Appendix–D: Debriefing Sheet (Chapter 3)

Thank you very much for your participation. We would like to give you a little background on the study.

This study examines the psychological and physiological effect of presence and immersion in emotional elicitation using Virtual Reality (VR). We are examining a range of different emotions, aiming to understand whether 360-degree video-based VR experiences can elicit the range of emotions intensely. We are also looking into whether the physiological measures would be more or less intense depending on the emotion we are trying to elicit, and the stimuli were used.

We expect that 360-degree video-based VR experiences will elicit high and deep emotions in all emotional categories that we examined (high arousal positive, low arousal positive, high arousal negative, and low arousal negative). Also, we expect that such an emotional reaction would be reflected in the eye-tracking, electrocardiogram, and galvanic skin response data.

We would like to remind you that your participation in the study is fully voluntary, and you can withdraw from this study at any time without negative consequences. The participant identification number stated above is only known to you, if you decided to withdraw at any point, you would need to provide the researchers or the departmental office with this ID and indicate your wish to withdraw from the study. You can contact the Departmental Office at *[contact information]*.

If you have any further questions, please use the contact details given below. You can also contact us to obtain a summary of the results once the study is completed.

Again, thank you very much for your assistance.

[contact information]

Appendix–E: Participant Information & Pre-Exposure Questionnaire (Chapter 3)

- This questionnaire is meant to be delivered digitally, where individuals fill this questionnaire using a laptop/PC and touchpad/mouse.
- Please note that any instructions addressing the experimenter are underlined.
- Please note that any written instructions addressing the participating individual are in *italic*.
- Please note that some questions pose as inclusion criteria and may exclude the individual from participation in this study if such criteria are not met. Please note instructions to the experimenter regarding exclusion criteria are underlined and should not be included in the actual questionnaire. If the participating individual does not meet the inclusion criteria, the digital questionnaire should not allow them to proceed to the next sections and flag the item(s) that the individual failed to meet as it can help the experimenter explain why the individual cannot proceed any further.
- Please read this in conjunction with the "Verbal Instructions Protocol" document as some instructions may need to be verbally communicated to the participant.
- Please note that the titles in this questionnaire are only indicative for the experimenter's use. On the questionnaire itself, please have each section set on an individual page with no headline.

Section Zero – Generic Information Related to the Experiment

Insert participant ID and any general relevant information (date/time… etc.). Click next.

Section One – Participant Profile

Please refer to the "Verbal Instructions Protocol" document where you will find instructions related to this section that needs to be verbally communicated to the participating individual filling this questionnaire.

What is your biological sex?

Question format: drop-down list
Female
Male

What is your sexual orientation?

Question format: drop-down list
Bisexual
Gay
Heterosexual
Lesbian
Others
Prefer not to disclose

Which hand do you consider your dominant hand (which hand do you use to write with)?

Question format: drop-down list
Right
Left

Which hand do you use to navigate using a mouse?

Question format: drop-down list
Right
Left

How old are you?

Question format: insert integer number

Individuals who are younger than 18 years old should be excluded from participation in this study.

At what age did you learn English?

Question format: drop-down list
The drop-down list ranges from zero (Native Speaker) to 80 years.

How do you assess your English language proficiency?

Question format: drop-down list
Native or bilingual proficiency.
Full professional proficiency, or "fluent".
Professional working proficiency, or "intermediate".
Limited working proficiency, or "lower intermediate".
Elementary Proficiency, or "beginner".

Individuals who rate themselves as "Limited working proficiency, or lower intermediate" or "'Elementary Proficiency, or beginner" should be excluded from the participation in this study.

Using the British government's survey categories from the 2001 census, which ethnic origin or descent describes you best? Please tick one of the boxes below:

Question format: drop-down list			
Indian	Asian - Other	Black - Other	White – UK/Irish
Pakistani	Black – Caribbean	Mixed Race	White - Other
Bangladeshi	Black – African	White – European	Prefer not to disclose
Chinese			

Press "next" to proceed to the next section.

Section Two – Health & Wellbeing

Please choose the appropriate answer to the following questions:

Question format: multiple choice question			
Have you ever worn a virtual reality headset (HMD)?	Yes	No	
If yes, did you have any problems (nausea, dizziness, etc.)?	Yes	No	Not Applicable

Individuals responding "yes" to the second question should be excluded from participation in this study.

How easily do you get motion or carsick? (please choose the number corresponding to your answer)

Question format: Likert scale

1	2	3	4	5	6	7

Never been motion sick — Get motion sick very easily

Individuals responding 6 or 7 should be excluded from participation in this study.

Please choose the appropriate answer to the following questions:

Question format: multiple choice question		
Do you now or have you ever had a seizure disorder or epilepsy?	Yes	No
Have you ever had a seizure?	Yes	No
Do you have a heart condition?	Yes	No
Do you have heart arrhythmias?	Yes	No
Do you suffer from hypertension?	Yes	No
Do you have a vestibular (balance) disorder?	Yes	No
Do you have any medical conditions affecting balance?	Yes	No
Do you frequently experience headaches, lightheadedness, or dizziness?	Yes	No
Are you hearing impaired?	Yes	No
Are you visually impaired?	Yes	No

Individuals responding "yes" to any of these questions should be excluded from participation in this study.

Which best describes you right now?

<u>Question format: drop-down list</u>
I have a perfect or close-to-perfect vision.
I sometimes wear glasses or contacts, but I don't have to wear them all the time, and I see okay without them.
I must wear glasses or contacts to correct my vision to perfect or close-to-perfect.
I wear glasses or contacts, but even with them, my vision is less than perfect.

<u>Individuals responding "I wear glasses or contacts, but even with them, my vision is less than perfect" should be excluded from participation. Also, individuals wearing corrective glasses frames should be excluded from the study if the VR headset cannot contain and fit the corrective glasses.</u>

Please choose the appropriate answer to the following questions:

Do you have any medical condition, or are you taking any medication that would make you susceptible to experiencing dizziness, disorientation, or nausea?	Yes	No
Have you had a head injury in the past year?	Yes	No
Do you have a neurological disease?	Yes	No
Do you have a learning disability?	Yes	No
Do you have any psychological disorders?	Yes	No
Are you diagnosed with clinical depression?	Yes	No
Do you use any medication for psychological or emotional problems?	Yes	No
Do you get skin rash from wearing non-precious metal or rubbing alcohol?	Yes	No

<u>Individuals responding "yes" to any question here should be excluded from participation in this study.</u>

Please notify your experimenter that you are ready to proceed and press "next" and proceed to the next set of questions.

Part Three – Immersive Tendencies Questionnaire

Indicate your preferred answer by clicking on the appropriate circle of the seven-point scale. Please consider the entire scale when making your responses, as the intermediate levels may apply. For example, if your response is once or twice, the second circle from the left should be marked. If your response is many times but not extremely often, then the sixth (or second circle from the right) should be marked.

Do you easily become deeply involved in movies or tv dramas?

NEVER OCCASIONALLY OFTEN

Do you ever become so involved in a television program or book that people have problems getting your attention?

NEVER OCCASIONALLY OFTEN

How mentally alert do you feel at the present time?

NOT ALERT MODERATELY FULLY ALERT

Do you ever become so involved in a movie that you are not aware of things happening around you?

NEVER OCCASIONALLY OFTEN

How frequently do you find yourself closely identifying with the characters in a storyline?

NEVER OCCASIONALLY OFTEN

Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?

NEVER OCCASIONALLY OFTEN

How physically fit do you feel today?

NOT FIT MODERATELY FIT EXTREMELY FIT

How good are you at blocking out external distractions when you are involved in something?

NOT VERY GOOD SOMEWHAT GOOD VERY GOOD

When watching sports, do you ever become so involved in the game that you react as if you were one of the players?

NEVER OCCASIONALLY OFTEN

Do you ever become so involved in a daydream that you are not aware of things happening around you?

NEVER OCCASIONALLY OFTEN

Do you ever have dreams that are so real that you feel disoriented when you awake?

NEVER OCCASIONALLY OFTEN

When playing sports, do you become so involved in the game that you lose track of time?

NEVER OCCASIONALLY OFTEN

How well do you concentrate on enjoyable activities?

NOT AT ALL MODERATELY WELL VERY WELL

How often do you play arcade or video games? (OFTEN should be taken to mean every day or every two days, on average.)

NEVER OCCASIONALLY OFTEN

Have you ever gotten excited during a chase or fight scene on TV or in the movies?

NEVER OCCASIONALLY OFTEN

Have you ever gotten scared by something happening on a TV show or in a movie?

NEVER OCCASIONALLY OFTEN

Have you ever remained apprehensive or fearful long after watching a scary movie?

NEVER OCCASIONALLY OFTEN

Do you ever become so involved in doing something that you lose all track of time?

NEVER OCCASIONALLY OFTEN

Please notify your experimenter that you are ready to proceed and press "next" and proceed to the next set of questions.

Section Four – Pre-Exposure Affective Measures (VAS)

Please refer to the "Verbal Instructions Protocol" document where you will find verbal instructions related to this section that needs to be verbally communicated to the participant. All questions in this section utilise the Visual Analog Scale (VAS) to measure the participant's emotional state.

Please drag the sliders on the line below to indicate the best describes the greatest amount of each emotion you feel right now. On this scale, the far left means you do not feel even the slightest bit of the emotion and far right is the most you have ever felt in your life. All you have to do is to make sure you rate the correct emotion the way you feel right now as accurate as you can, there are no right or wrong answers, just honest answers. Note that if you needed to place a zero at any point, you can't leave the slider as it is, you need to press and drag to towards the left end of the slider.

To what extent do you feel joyful right now?

Not joyful at all	As joyful as I can be

To what extent do you feel angry right now?

Not angry at all	As angry as I can be

To what extent do you feel calm right now?

Not calm at all	As calm as I can be

To what extent do you feel sad right now?

Not sad at all	As sad as I can be

To what extent do you feel disgusted right now?

Not disgusted at all	As disgusted as I can be

To what extent do you feel relaxed right now?

Not relaxed at all	As relaxed as I can be

To what extent do you feel happy right now?

Not happy at all	As happy as I can be

To what extent do you feel fearful right now?

Not fearful at all	As fearful as I can be

To what extent do you feel excited right now?

Not excited at all	As excited as I can be

To what extent do you feel anxious right now?

Not anxious at all	As anxious as I can be

To what extent do you feel dizzy right now?

Not dizzy at all	As dizzy as I can be

Please notify your experimenter that you are ready to proceed and press "next" and proceed to the next set of questions.

Part Five – Pre-Exposure Affective Measures (SAM)

<u>Please refer to the "Verbal Instructions Protocol" document where you will find verbal instructions related to this section that needs to be verbally communicated to the participant. In conjunction with the original questionnaire's format, all questions are in visual (SAM) Likert scale format.</u>

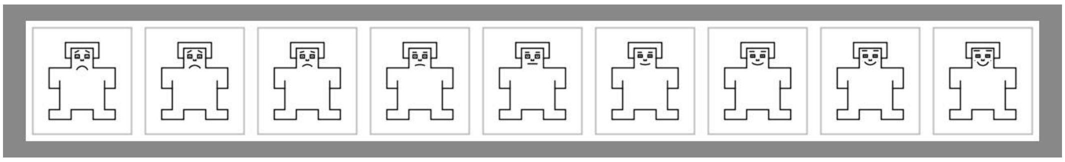
Happy vs Unhappy:

This SAM scale is the happy-unhappy scale, which ranges from a smile to a frown. Notice that on one side, SAM is frowning, on the other side, SAM is smiling, and in the middle, SAM is not smiling or frowning.

- *At one extreme of the happy vs unhappy scale, you feel happy, glad, cheerful, pleased, good, pleased, satisfied, contented, or hopeful. You can indicate feeling completely happy by choosing this figure on the far right of the scale here.*
- *The other end of the scale is when you feel completely unhappy, annoyed, unsatisfied, melancholic, despaired, bored, scared, angry, bad, or anxious. You can indicate feeling completely unhappy by choosing this figure on the far left of the scale.*
- *If you felt completely neutral, neither happy nor unhappy, choose this figure in the middle that is not smiling nor frowning.*

- *The figures also allow you to describe intermediate feelings of pleasure by choosing any of the other pictures in between.*

Using the happy vs unhappy SAM, please rate your emotions based on how you ACTUALLY FEEL RIGHT NOW, AT THIS MOMENT:

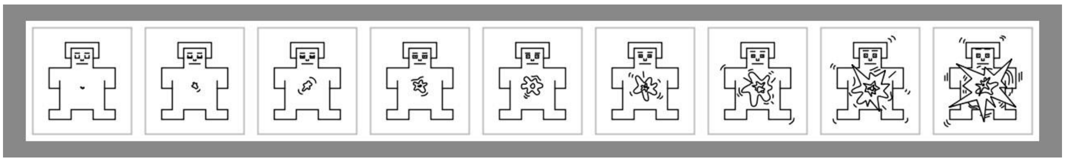


Excited vs Calm:

This SAM scale is excited vs calm scale. Notice that on one side, SAM is very still, and his eyes closed, on the other side, SAM is jumping up, and his stomach is excited. Note that excitement or calmness doesn't necessarily mean excitement or calmness positively nor negatively as we have the happy vs unhappy SAM above to express that.

- *At one extreme of the scale, you feel stimulated, excited, frenzied, jittery, and wide-awake, or aroused. You can indicate feeling completely excited by choosing this figure on the far-right side of the scale. Notice how it looks like SAM is jumping up and down, and his stomach is excited. This is like when you get excited and can't sit still or like you have butterflies in your stomach when you are very nervous.*
- *On the other hand, at the other end of the scale, you feel completely relaxed, calm, sluggish, dull, sleepy, unaroused. If you feel completely calm, you can choose this figure on the far-left side of the scale.*
- *If you are not at all excited nor at all calm, choose this figure the figure in the middle of the row.*
- *The figures also allow you to describe intermediate feelings of pleasure, by choosing any of the other pictures in between.*

Using the excited vs calm SAM, please rate your emotions based on how you ACTUALLY FEEL RIGHT NOW, AT THIS MOMENT:



This is the end of this questionnaire; please notify the experimenter that you're ready to proceed, thank you.

Appendix–F: Post-Exposure Questionnaire (Chapter 3)

This questionnaire is meant to be delivered digitally, where participants fill this questionnaire using a laptop/PC and touchpad/mouse.

- Please note that any instructions addressing the experimenter are underlined.
- Please note that any written instructions addressing the participant are in *italic*.
- Please read this in conjunction with the "Verbal Instructions Protocol" document as some instructions may need to be verbally communicated to the participant.
- Please note that the titles in this questionnaire are only indicative for the experimenter's use. On the questionnaire itself, please have each section set on an individual page with no headline.
- At the beginning of the questionnaire per participant, the experimenter may need to insert relevant information such as participant ID.
- This questionnaire is meant to be filled after watching each video.

Section Zero – Video Information

This section is only meant to be filled by the experimenter. Insert relevant information about the video that is about to be viewed. For example, insert video code and video viewing order.

Press next to proceed to the participant's section.

Section One – Self Assessment Manikin (SAM)

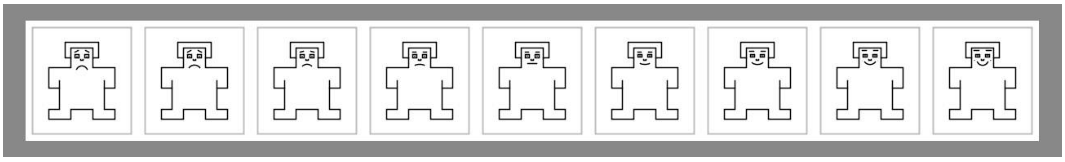
Please refer to the "Verbal Instructions Protocol" document where you will find instructions related to this section that needs to be verbally communicated to the participant filling this questionnaire.

Happy vs Unhappy:

This SAM scale is the happy-unhappy scale, which ranges from a smile to a frown. Notice that on one side, SAM is frowning, on the other side, SAM is smiling, and in the middle, SAM is not smiling or frowning.

- *At one extreme of the happy vs unhappy scale, you feel happy, glad, cheerful, pleased, good, pleased, satisfied, contented, or hopeful. You can indicate feeling completely happy by choosing this figure on the far right of the scale here.*
- *The other end of the scale is when you feel completely unhappy, annoyed, unsatisfied, melancholic, despaired, bored, scared, angry, bad, or anxious. You can indicate feeling completely unhappy by choosing this figure on the far left of the scale.*
- *If you felt completely neutral, neither happy nor unhappy, choose this figure in the middle that is not smiling nor frowning.*
- *The figures also allow you to describe intermediate feelings of pleasure, by choosing any of the other pictures in between.*

Your rating of each video should reflect your immediate personal experience and no more. Using the happy vs unhappy SAM, please rate your emotions based on how you ACTUALLY FELT WHILE YOU WATCHED THE VIDEO.



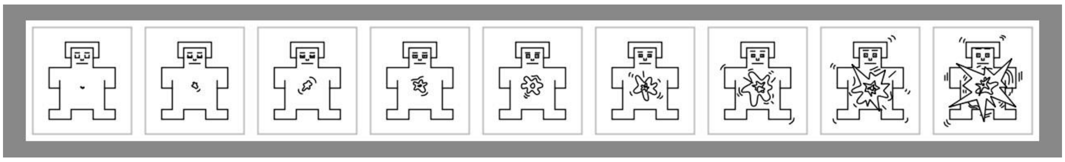
Excited vs Calm:

This SAM scale is excited vs calm scale. Notice that on one side, SAM is very still, and his eyes closed, on the other side, SAM is jumping up, and his stomach is excited. Note that excitement or calmness doesn't necessarily mean excitement or calmness positively nor negatively as we have the happy vs unhappy SAM above to express that.

- *At one extreme of the scale, you feel stimulated, excited, frenzied, jittery, and wide-awake, or aroused. You can indicate feeling completely excited by choosing this figure on the far-right side of the scale. Notice how it looks like SAM is jumping up and down, and his stomach is excited. This is like when you get excited and can't sit still or like you have butterflies in your stomach when you are very nervous.*

- *On the other hand, at the other end of the scale, you feel completely relaxed, calm, sluggish, dull, sleepy, unaroused. If you feel completely calm, you can choose this figure on the far-left side of the scale.*
- *If you are not at all excited nor at all calm, choose this figure the figure in the middle of the row.*
- *The figures also allow you to describe intermediate feelings of pleasure, by choosing any of the other pictures in between.*

Your rating of each video should reflect your immediate personal experience and no more. Using the excited vs calm SAM, please rate your emotions based on how you ACTUALLY FELT WHILE YOU WATCHED THE VIDEO.



Section Two – Visual Analog Scale (VAS) of Emotions

Please refer to the "Verbal Instructions Protocol" document where you will find instructions related to this section that needs to be verbally communicated to the individual filling this questionnaire.

Please drag the sliders on the line below to indicate the best describes the greatest amount of each emotion you ACTUALLY FELT WHILE YOU WATCHED THE VIDEO. On this scale, the far left means you do not feel even the slightest bit of the emotion and far right is the most you have ever felt in your life. All you have to do is to make sure you rate the correct emotion the way you ACTUALLY FELT WHILE YOU WATCHED THE VIDEO as accurate as you can, there are no right or wrong answers, just honest answers. Note that if you needed to place a zero at any point, you can't leave the slider as it is, you need to press and drag to towards the left end of the slider.

To what extent do you feel joyful while you watched the video?

Not joyful at all	As joyful as I can be

To what extent do you feel angry while you watched the video?

Not angry at all	As angry as I can be

To what extent do you feel calm while you watched the video?

Not calm at all	As calm as I can be

To what extent do you feel sad while you watched the video?

Not sad at all	As sad as I can be

To what extent do you feel disgusted while you watched the video?

Not disgusted at all	As disgusted as I can be

To what extent do you feel relaxed while you watched the video?

Not relaxed at all	As relaxed as I can be

To what extent do you feel happy while you watched the video?

Not happy at all	As happy as I can be

To what extent do you feel fearful while you watched the video?

Not fearful at all	As fearful as I can be

To what extent do you feel excited while you watched the video?

Not excited at all	As excited as I can be

To what extent do you feel anxious while you watched the video?

Not anxious at all	As anxious as I can be

To what extent do you feel dizzy while you watched the video?

Not dizzy at all	As dizzy as I can be

Section Three – Presence

Indicate your preferred answer by clicking on the appropriate circle of the seven-point scale. Please consider the entire scale when making your responses, as the intermediate levels may apply. There are no right or wrong answers, just honest answers.

In the video, I had the sense of "being there" ...

Not at all — Very much

During the video, how often did you think of the room you are in and your surroundings?

Not at all — All the time

How flat and missing in depth did the video appear?

Not at all — Very much

Do you think of the video as…?

Something I saw — Somewhere I visited

How disturbing was the lag or delay between the navigation and the response of the video?

Didn't notice it — Completely putting off

Whilst you watched the video, music played in the background. How much attending did you pay to it?

None at all — A great deal

The video became more real or present to me compare to the 'real world'

At no time — All the time

How natural did your interactions with the environment seem?

Not at all Very High Degree

This is the end of this questionnaire for this video; please notify the experimenter that you're ready to proceed, thank you.

Appendix–G: Verbal Instructions Protocol (Chapter 3)

- Verbal instructions to the participant are written in *italic*. Please read all instructions in bold out aloud to the participant.
- Instructions to the experimenter are underlined. Please read all underlined instructions silently to yourself.
- References to materials are shaded in grey, such as document materials, i.e. consent form. List of used materials is provided at the end of the document.

Stage One – Introduction, Participant Information Sheet & Consent

The experimenter meets the potential participant and introduces themselves. Say nothing about the study and walk them to the laboratory. Once the individual is seated, they are expected to read the "Participant Information Sheet", ask questions if any, and if they are happy to participate, sign the consent form.

Read instructions: *Welcome to this laboratory. We would like to thank you for coming here today. Here is an information sheet* (hand the "Participant Information Sheet") *that I would like you to read it through, if you have any questions or concerns, please do not hesitate to ask. If all your questions are addressed, or you have no questions, and you are happy to participate, please read this consent form* (hand the "Consent Form") *and sign your initials* (point with your finger on where the individual is expected to sign) *here, here, and here, and write your full name, date and signature here. Please fill all original copies of this form; one original copy will be given to you, and two original copies are for our records. After you are done, please let me know that you are ready.*

Have the potential participant read the "Participant Information Sheet", allow time for questions, and have the three original copies of the "Consent Form" signed. Make sure that the consent forms are correctly filled and signed, keep one copy for the participant, and file the other two in the appropriate file storage.

Stage Two – Participant Profile & Exclusion Criteria

The "Participant Profile Questionnaire" consists of five parts. The online questionnaire is meant to take the user step by step through all parts, as they cannot proceed to the next part until the current part is completed.

These two parts cover general information related to the individual's profile and health & wellbeing state. There are excluding criteria in parts one and two of the questionnaire that results in terminating the participation in the study. These excluding criteria were already asked when the timeslot for participation was booked; however, these questions are asked again to reconfirm.

Part one includes information about the participant profile, such as age, sex, ethnicity…etc. Herein, only two parameters can exclude an individual from participating: 1. Age: if they are younger than 18 years old. 2. English Language Competency: if they score their English language competency as "limited working proficiency, or lower intermediate" or "elementary proficiency, or a beginner".

Part two contains all items that are related to the individual's health & well-being. In all YES/NO questions, if the individual answers "yes" to any of them, they should be excluded from the study. Furthermore, if they respond to question 15 (if they had felt dizzy whilst using VR before) as yes, indicating they have had problems with using VR before, they are excluded from participation. If the user answered five or greater at the "motion sickness" question, indicating they can "get motion sickness very easily" they should be excluded from participation. Finally, if they answered "wearing glasses or contacts, but even with them my vision is less than perfect" in the "what best describes you" question, they should be excluded from participation.

Read instructions: *This laptop will be used throughout this study to fill all the questionnaires that I will ask you to fill today. You can use the mouse or the touchpad to help you fill the questionnaires. I will ask you now to fill this questionnaire* (open the "Participant Profile Questionnaire"). *This* *questionnaire is divided into five parts. In here, the first and second parts consist of questions that are related to your profile, including health history. It is vital that you answer all the questions truthfully and to the best of your knowledge. If you have any questions, please don't hesitate to ask. If for any reason you failed to meet our eligibility criteria, the survey will let you know by preventing you from proceeding to the next step and flag a red comment or comments on which part or parts you failed to meet our criteria. If that happened, I ask you to let me know, and I would have to regret that we would not proceed further with the study. Otherwise, if you successfully complete parts one and two, the questionnaire will remind you that you need to let me know. Please let me know when you are done before we proceed to parts three, four, and five.*

<u>If the participant failed to meet the criteria, read the instructions:</u> *I regret to tell you that your answer* <u>(read the item(s) that are red-flagged)</u> *does not qualify you to proceed in this study, I apologise to let you know that we will not proceed any further now. Thank you for your time and interest.*

<u>If the participant successfully meets the criteria:</u> *Thank you, now we will proceed to the third part of this questionnaire. In here, I ask you to read the questions and then indicate your preferred answer by clicking on the appropriate circle of the seven-point scale. Please consider the entire scale when making your responses, as the intermediate levels may apply. For example, if your response is once or twice, the second circle from the left should be marked. If your response is many times but not extremely often, then the sixth (or second circle from the right) should be marked. Please let me know when you are done and ready to proceed.*

<u>Await for the participant to fill this part and be notified when they are ready.</u>

<u>Read instructions:</u> *Thank you, the fourth part of this questionnaire is here, as you can see, these questions ask you to rate certain emotions based on how you feel right now. We will use this tool to express how you feel after watching every video; therefore, it is crucial that you understand how to use this tool, so you will be able to fill accurate answers later. Please drag the sliders on the line below to*

indicate the best describes the greatest amount of each emotion you feel right now, at this moment. On this scale, the far left means you did not feel even the slightest bit of the emotion and far right is the most you have ever felt in your life. All you have to do is to make sure you rate the correct emotion the way you feel right now as accurate as you can, there are no right or wrong answers, just honest answers. Note that if you needed to place a zero at any point, you can't leave the slider as it is, you need to press and drag to towards the left end of the slider. Again, once you are done and ready to proceed, please notify me.

<u>Await for the participant to fill this part and be notified when they are ready.</u>

<u>Read instructions:</u> *Thank you. This is the last part of this questionnaire is here. If you look at the two questions below, you will see two sets of nine figures, each arranged along a continuum. We call this set of figures SAM, and you will be using these figures to rate how you feel right now at this moment, and then later how you felt while watching each video. Therefore, it's very important that understand how to use this tool so you will be able to answers this question later on accurately. SAM shows two different kinds of feelings: Happy vs Unhappy, and Excited vs Calm. Later on, you will see lots of videos and different things that may make you feel happy or unhappy, excited or relaxed, or maybe even angry, scared, or thrilled. Every person will feel differently about each video. There are no wrong answers, so simply respond as honestly as you can. Whatever you feel is the right answer to put on the rating scale.*

<u>Now you will explain Happy vs Unhappy SAM; read instructions:</u> *This SAM scale is the happy-unhappy scale, which ranges from a smile to a frown. Notice that on one side* <u>(point with your finger)</u>, *SAM is frowning, on the other side, SAM is smiling, and in the middle, SAM is not smiling or frowning.*

- *At one extreme of the happy vs unhappy scale, you feel happy, glad, cheerful, pleased, good, pleased, satisfied, contented, or hopeful. You can indicate feeling completely happy by choosing this figure* <u>(point at the happy SAM)</u> *on the far right of the scale here.*

- *The other end of the scale is when you feel completely unhappy, annoyed, unsatisfied, melancholic, despaired, bored, scared, angry, bad, or anxious. You can indicate feeling completely unhappy by choosing this figure* (point at the frowning SAM) *on the far left of the scale.*
- *If you feel completely neutral, neither happy nor unhappy, choose this figure* (point at the neutral SAM in the middle) *in the middle that is not smiling nor frowning.*
- *The figures also allow you to describe intermediate feelings of pleasure, by choosing any of the other pictures in between* (point at all the figures in between).

Now you will explain Excited vs Calm SAM; read instructions: *This SAM scale is excited vs calm scale. Notice that on one side* (point with your finger), *SAM is very still, and his eyes closed, on the other side, SAM is jumping up, and his stomach is excited. Note that excitement or calmness doesn't necessarily mean excitement or calmness positively nor negatively as we have the happy vs unhappy SAM above to express that.*

- *At one extreme of the scale, you feel stimulated, excited, frenzied, jittery, and wide-awake, or aroused. You can indicate feeling completely excited by choosing this figure* (point at the excited SAM) *on the far-right side of the scale. Notice how it looks like SAM is jumping up and down, and his stomach is excited. This is like when you get excited and can't sit still or like you have butterflies in your stomach when you are very nervous.*
- *On the other hand, at the other end of the scale, you feel completely relaxed, calm, sluggish, dull, sleepy, unaroused. If you feel completely calm, you can choose this figure* (point at the calm SAM) *on the far-left side of the scale.*
- *If you are not at all excited nor at all calm, choose this figure* (point at the neutral SAM in the middle) *the figure in the middle of the row.*
- *The figures also allow you to describe intermediate feelings of pleasure, by choosing any of the other pictures in between* (point at all the figures in between).

Do you have any questions? Is SAM happy vs unhappy and calm vs excited clear for you?

Await response, answer questions if there any, if not, proceed.

Read instructions: *Great, so I'd like you to use SAM to describe how you feel right now, at this moment. Once you're done and ready to proceed, please notify me so that we can move to the next step.*

Stage Three – Equipment Setup

Now you will set up the physiological equipment and test them, making sure they are recording correctly and record a baseline. Read instructions: I will now be applying the physiological recording equipment. *I will place this electrode on your left calf here, and here* (point at your own calf), *then I will place another two electrodes on your fingertips of your right arm here, and here* (point at your own fingers), *and one last electrode on your forearm of the right arm here* (point at your own arm). *I also might use rubbing alcohol to clean the equipment like the watch or clean the skin area before applying the electrodes. Is that okay with you?*

Await response, if okay, then proceed to place all equipment as follows:

- ECG Left Leg: middle of the calf, on the side (red electrode).
- ECG Right Arm: middle of the forearm (white electrode).
- GSR: place one electrode on the index finger, and another one on the middle finger.

Read instructions: *Throughout the study, it is extremely important that you do not move your right arm and fingers as the equipment is very sensitive to movement. This includes any repetitive movements like tapping or shaking. I will use this Velcro to strap your arm, and it will not be tight, it is only there to remind you not to move your arm, is that okay for you?* Await response, of okay, proceed to apply the strap. *I would also ask you to please not move your left leg as this equipment are also very sensitive to movement, this includes any movement like restless shaking.*

Now you will test the equipment; read instructions: *Now I'm going to test the equipment. In a minute, I will ask you to take a deep breath and hold, count a slow 5, then release. Is that okay with you?* Awaits response, check that GSR signal responds to the breath-hold and release and that both ECG/GSR signals are recording as expected. If the experimented is satisfied, they can proceed; if not, they must detect and resolve the issue before proceeding any further.

Read instructions: *Okay, thank you. Now I would like to record 3 minutes of pure relaxation. I would like to ask you to relax and sit quietly. Please do not move both arms, your head, adjust seating, tremble your fingers, or shake your legs. Feel free to close your eyes. Please try not to move or think or anything exciting or stressful. Are you ready?* Await response then record 3 minutes as a baseline. If the participant spoke, laughed or did anything that might compromise the reliability of the baseline data, the timer should reset and record new 3-minute baseline.

Now the VR headset will be introduced, and eye-tracking will be calibrated. Read instructions: *This is the Virtual Reality headset we will use to view the videos we have for today. As you can see* here (point at the three straps on the VR headset) *using these straps, you can adjust the headset so that it can suit you. Once you put on the headset, I ask you to watch the video from beginning to end. The videos you will be watching are 360-degree videos. Please feel free to navigate through the 360-degree world the way you like or enjoy by rotating your head and upper body. In order for the headset to work properly, we will need to calibrate it, meaning, the headset needs to identify your eyes movement. Let's put on the headset first and then we'll proceed to the calibration instructions, don't worry, we will only have to do this once.* Await and assist the participant in putting on the headset. *The program will now start. You will see a grey screen and a green dot. I will ask you to follow the green dot with your eyes and not your head. Are you ready?* Await response and activate calibration, then wait until calibration is successfully done if not, repeat the process.

Stage Four – Exposure

Read the instructions: *Fantastic. You can remove the headset now. Along with this headset, these are the headphones we will use to listen to the audio/music in the videos, the audio levels should be loud to a limit where you can't hear your surroundings, but also not painfully loud. If the sound is too low or annoyingly loud, please let me know so that we adjust it. We will play one video, fill some questionnaire, have two minutes rest that is purely dedicated for you to relax and get ready for the next video, and so on. Is that okay with you?* Await response. *Great, thank you. We will start the video in a bit. I'm going to be in the other room the entire time and will come around when the video ends. If there are any problems with the video or you needed me, please wave at this camera with your left hand* (point at the camera)*. Please put your headphones and headset on.* Await until the participant puts on the headphones and VR, assist if needed. *I also would like to remind you not to move your right hand or leg as much as possible and to watch the video from beginning to end. I will play the video whenever you're ready, are you ready?* Await response, play video.

Stage Five – Post Exposure

The "Post-Exposure Questionnaire" per one video exposure consists of questions regarding emotional effect and presence while watching the video. The online questionnaire is meant to take the user step by step through all parts, as they cannot proceed to the next part until the current part is completed.

Once the video is done, read instructions: *You can remove the headphones and VR headset now. Thank you for watching the video. I would like you to fill this questionnaire now. This questionnaire consists of various questions regarding how you felt while watching the video, please read the instructions of each part carefully and provide an answer that is as accurate and honest as you can. There are no right or wrong answers, just honest answers. If you felt unsure about how to answer a question or you have any questions at all, please do not hesitate to ask, as it is very important that you fully understand every question. I will be waiting for you here. Also, I would like to remind you that your rating of this* *video should reflect your immediate personal experience and no more. Please rate each one AS YOU ACTUALLY FELT WHILE YOU WATCHED THE VIDEO. Lastly, please notify me when you've completed the questionnaire and ready to proceed to the next step.*

Await until the participant completes the questionnaire and ready to proceed, then read instructions: *Okay, thank you. Now I would like to have two minutes of pure relaxation. I would like to ask you to relax and sit quietly. Please do not move both arms, your head, adjust seating, tremble your fingers, or shake your legs. Feel free to close your eyes. Please try not to move or think or anything exciting or stressful. Are you ready?* Await response then record 2 minutes as a baseline. If the participant spoke, laughed or did anything that might compromise the reliability of the baseline data, the timer should reset and record new 2-minute baseline.

Repeat stages four and five for all videos.

Stage Six – Completion

Read instructions: *This is the end of the study now. First of all, I would like to remove the electrodes and the Velcro wrap, are you okay for me to do that?* Await response, then proceed to remove all equipment. *Great, thanks. I would like to thank you for your time. Your participation is very valuable to us. This sheet ("Debriefing Sheet") provides further information about the study purpose and details. Please feel free to read* (hand the "Debriefing Sheet").

Read instructions: *Now, I'm pleased to present a £10 Amazon Voucher as a token of appreciation for participating in this study. First, I would like you to fill in this sheet to confirm that you have received the voucher* (provide the "Participant Payment Sheet" and allow the participant to fill in the relevant information, after signing, hand in the "£10 Amazon Voucher").

Read instructions: *Thank you, please make sure you take the consent form, participant information sheet, and the debriefing sheet. Please don't hesitate to contact us in the future if you had any questions or concerns, thanks again.*

The experimenter takes the participant outside the laboratory to the hall.

List of Referenced Materials

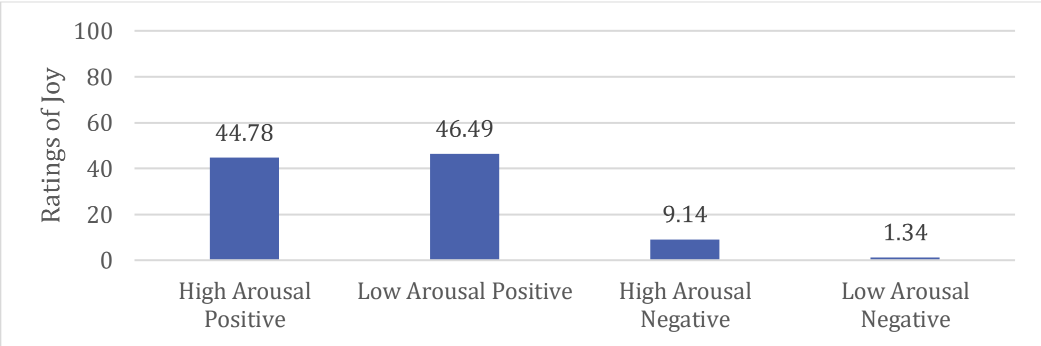
- Participant Information Sheet.
- Consent Form.
- Participant Profile Questionnaire.
- Post-Exposure Questionnaire.
- Debriefing Sheet.
- £10 Amazon Voucher.

Appendix–H: Statistical Analysis of Emotional Elicitation Per Emotion Descriptor (Chapter 3)

This analysis was aimed to evaluate the emotional effects of engaging in 360-VEs over ten Visual Analog Scales (VAS) of emotions (see sections 3.4.6 and 3.5.2).

VAS Ratings of Joy

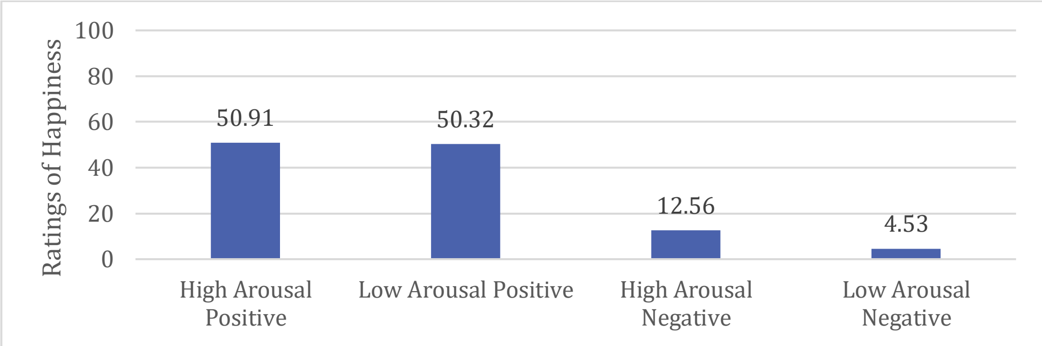
The below figure describes the mean ratings of joy in each CMA quadrant.



The two-way repeated-measures ANOVA showed no significant interaction between valence and arousal over ratings of joy, $F(132, 2)=2.70$, $p=.10$. Tukey's HSD test indicated that the mean value of joy over low arousal ($M=23.58$, $SD=27.97$) did not significantly differ from high arousal ($M=26.69$, $SD=24.69$), $t(132, 2)=-1.05$, $p=.30$. However, the mean value of joy over low valence (negative) ($M=5.24$, $SD=10.52$) was significantly lower than high valence (positive) ($M=45.64$, $SD=21.53$), $t(132, 2)=-13.96$, $p<.001$; meaning, positive VEs received significantly higher ratings of joy than negative VEs.

VAS Ratings of Happiness

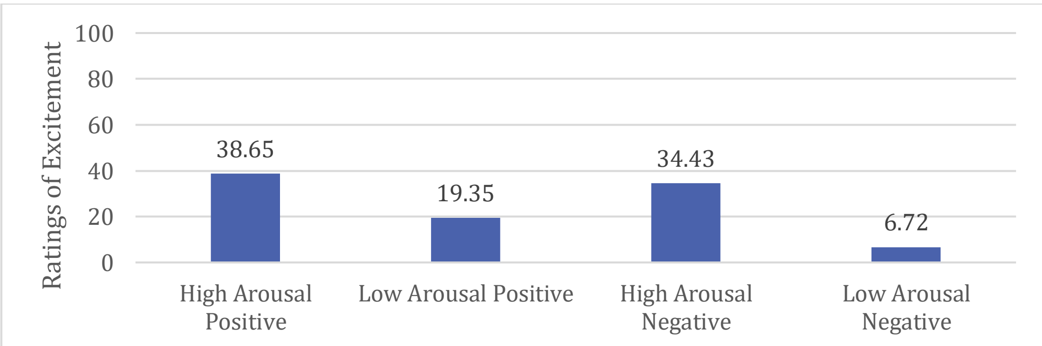
The below figure describes the mean ratings of happiness in each CMA quadrant.



The two-way repeated-measures ANOVA showed no significant interaction between valence and arousal over ratings of happiness, $F(132, 2)=1.72$, $p=.191$. Tukey's HSD test indicated that the mean value of happiness over low arousal ($M=27.08$, $SD=26.53$) did not significantly differ from high arousal ($M=31.45$, $SD=27.03$), $t(132, 2)=-1.52$, $p=.131$. However, the mean value of happiness over low valence (negative) ($M=8.54$, $SD=14.02$) was significantly lower than high valence (positive) ($M=50.62$, $SD=18.76$), $t(132, 2)=-14.85$, $p<.001$; meaning, positive VEs received significantly higher ratings of happiness than negative VEs.

VAS Ratings of Excitement

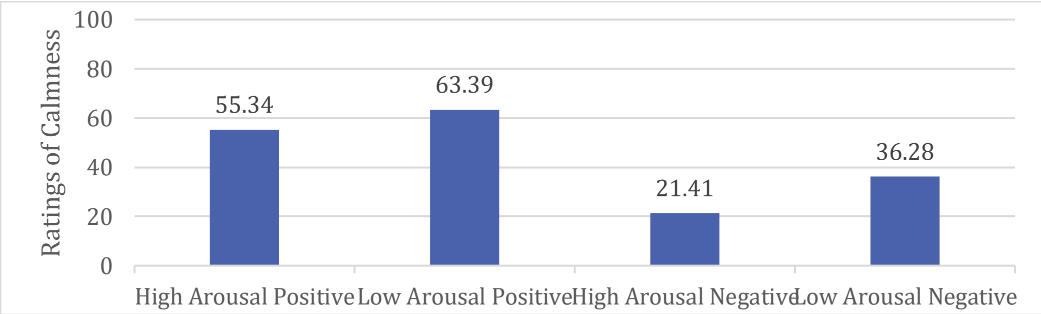
The below figure describes the mean ratings of excitement in each CMA quadrant.



The two-way repeated-measures ANOVA showed no significant interaction between valence and arousal over ratings of excitement, $F(132, 2)=1.55$, $p=.215$. Tukey's HSD test indicated that the mean value of excitement over low arousal ($M=12.94$, $SD=14.82$) was significantly lower than high arousal ($M=36.51$, $SD=24.04$), $t(132, 2)=-6.96$, $p<.001$; meaning, high arousal VEs received significantly higher ratings of excitement than low arousal VEs. Similarly, the mean value of excitement over low valence (negative) (*M*=20.57, *SD*=22.92) was significantly lower than high valence (positive) (*M*=29.00, *SD*=22.77), *t*(132, 2)=-2.49, *p*=.014; meaning, positive VEs received significantly higher ratings of excitement than negative VEs.

VAS Ratings of Calmness

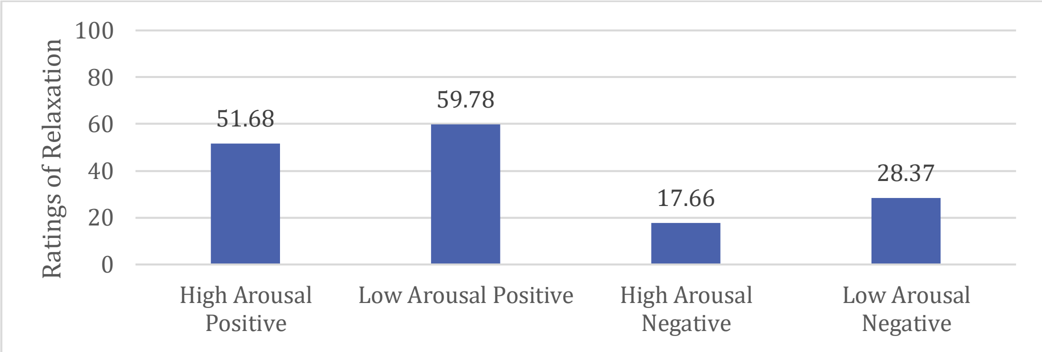
The below figure describes the mean ratings of calmness in each CMA quadrant.



The two-way repeated-measures ANOVA showed no significant interaction between valence and arousal over ratings of calmness, *F*(132, 2)=0.79, *p*=.375. Tukey's HSD test indicated that the mean value of calmness over low arousal (*M*=49.64, *SD*=25.54) was significantly higher than high arousal (*M*=38.12, *SD*=28.21), *t*(132, 2)=2.99, *p*=.003; meaning, low arousal VEs received significantly higher ratings of calmness than high arousal VEs. Similarly, the mean value of calmness over low valence (negative) (*M*=28.85, *SD*=23.11) was significantly lower than high valence (positive) (*M*=59.37, *SD*=22.54), *t*(132, 2)=-7.96, *p*<.001; meaning, positive VEs received significantly higher ratings of calmness than negative VEs.

VAS Ratings of Relaxation

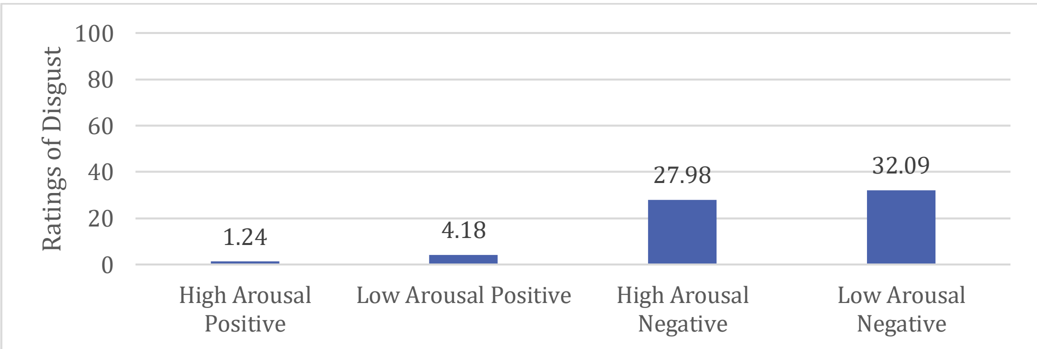
The below figure describes the mean ratings of relaxation in each CMA quadrant.



The two-way repeated-measures ANOVA showed no significant interaction between valence and arousal over ratings of relaxation, $F(132, 2)=0.11$, $p=0.739$. Tukey's HSD test indicated that the mean value of relaxation over low arousal ($M=43.84$, $SD=28.35$) was significantly higher than high arousal ($M=34.41$, $SD=27.34$), $t(132, 2)=2.41$, $p=.017$; meaning, low arousal VEs received significantly higher ratings of relaxation than high arousal VEs. Similarly, the mean value of relaxation over low valence (negative) ($M=23.01$, $SD=21.40$) was significantly lower than high valence (positive) ($M=55.73$, $SD=24.44$), $t(132, 2)=-8.37$, $p<.001$; meaning positive VEs received significantly higher ratings of relaxation than negative VEs.

VAS Ratings of Disgust

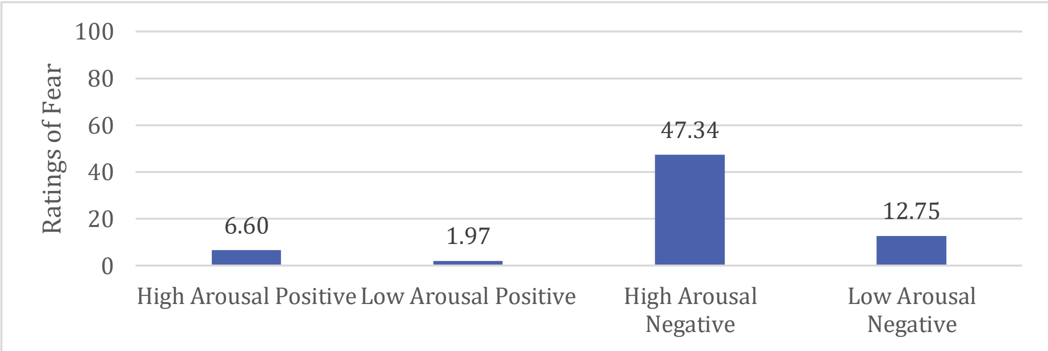
The below figure describes the mean ratings of disgust in each CMA quadrant.



The two-way repeated-measures ANOVA showed no significant interaction between valence and arousal over ratings of disgust, $F(132, 2)=0.04$, $p=.85$. Tukey's HSD test indicated that the mean value of disgust over low arousal ($M=18.34$, $SD=24.21$) did not significantly differ from high arousal ($M=14.81$, $SD=19.68$), $t(132, 2)=1.17$, $p=.24$. However, the mean value of disgust over low valence (negative) (*M*=30.03, *SD*=23.69) was significantly higher than high valence (positive) (*M*=2.71, *SD*=5.63), *t*(132, 2)=9.1, *p*<.001; meaning, negative VEs received significantly higher ratings of disgust than positive VEs.

VAS Ratings of Fear

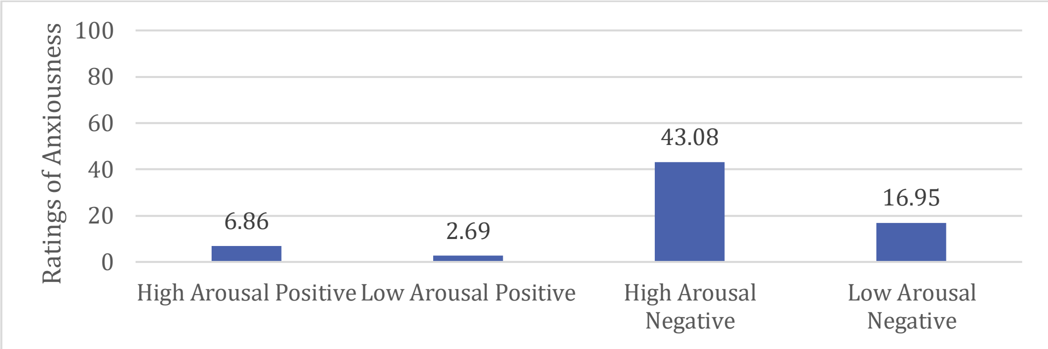
The below figure describes the mean ratings of fear in each CMA quadrant.



The two-way repeated-measures ANOVA showed a statistically significant interaction between valence and arousal over ratings of fear, *F*(132, 2)=30.31, *p*<.001. Tukey's HSD test indicated that the mean value of fear over low arousal (*M*=7.44, *SD*=14.66) was significantly lower than high arousal (*M*=27.28, *SD*=26.9), *t*(132, 2)=-7.21, *p*<.001; meaning, high arousal VEs received significantly higher ratings of fear than low arousal VEs. Similarly, the mean value of fear over low valence (negative) (*M*=30.05, *SD*=27.26) was significantly higher than high valence (positive) (*M*=4.29, *SD*=6.93), *t*(132, 2)=9.47, *p*<.001; meaning, negative VEs received significantly higher ratings of fear than positive VEs.

VAS Ratings of Anxiousness

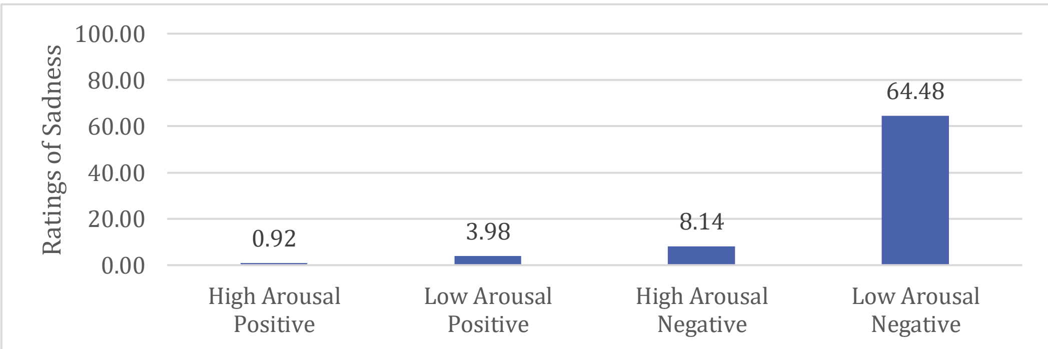
The below figure describes the mean ratings of anxiousness in each CMA quadrant.



The two-way repeated-measures ANOVA showed a statistically significant interaction between valence and arousal over ratings of anxiousness, $F(132, 2)=15.65$, $p<.001$. Tukey's HSD test indicated that the mean value of anxiousness over low arousal ($M=9.92$, $SD=16.35$) was significantly lower than high arousal ($M=25.24$, $SD=25$), $t(132, 2)=-5.46$, $p<.001$; meaning, high arousal VEs received significantly higher ratings of anxiousness than low arousal VEs. Similarly, the mean value of anxiousness over low valence (negative) ($M=30.01$, $SD=24.73$) was significantly higher than high valence (positive) ($M=4.77$, $SD=8.25$), $t(132, 2)=9.1$, $p<.001$; meaning, negative VEs received significantly higher ratings of anxiousness than positive VEs.

VAS Ratings of Sadness

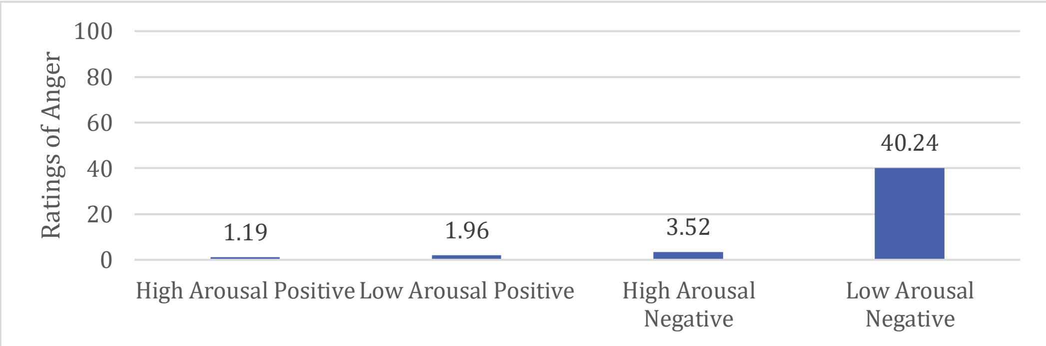
The below figure describes the mean ratings of sadness in each CMA quadrant.



The two-way repeated-measures ANOVA showed a statistically significant interaction between valence and arousal over ratings of sadness, $F(132, 2)=113.23$, $p<.001$. Tukey's HSD test indicated that the mean value of sadness over low arousal ($M=34.68$, $SD=35.75$) was significantly higher than high arousal ($M=4.58$, $SD=8.78$), $t(132, 2)=11.86$, $p<.001$; meaning, low arousal VEs received significantly higher ratings of sadness than high arousal VEs. Similarly, the mean value of sadness over low valence (negative) (*M*=36.31, *SD*=34.44) was significantly higher than high valence (positive) (*M*=2.45, *SD*=5.46), *t*(132, 2)=13.52, *p*<.001; meaning, negative VEs received significantly higher ratings of sadness than positive VEs.

VAS Ratings of Anger

The below figure describes the mean ratings of anger in each CMA quadrant.



The two-way repeated-measures ANOVA showed a statistically significant interaction between valence and arousal over ratings of anger, *F*(132, 2)=52.02, *p*<.001. Tukey's HSD test indicated that the mean value of anger over low arousal (*M*=21.39, *SD*=27.44) was significantly higher than high arousal (*M*=2.37, *SD*=5.52), *t*(132, 2)=7.52, *p*<.001; meaning, low arousal VEs received significantly higher ratings of anger than high arousal VEs. Similarly, the mean value of anger over low valence (negative) (*M*=21.88, *SD*=26.91) was significantly higher than high valence (positive) (*M*=1.57, *SD*=4.75), *t*(132, 2)=8.15, *p*<.001; meaning, negative VEs received significantly higher ratings of anger than positive VEs.

Appendix–I: Consent to be Approached (Chapter 4)

Contact details: *[names and contact information]*

Please ensure that you have read and understood the proposed research as outlined on the participant information form before you make a decision about being approached to take part in this research.

Clinical Researchers' briefing and undertaking

I am happy to answer any general questions you have about this research. I agree to abide by the British Psychological Society's Code of Conduct and Ethical Guidelines for Research with Human Participants and will work within the research guidelines mandated by the Mental Capacity Act (2005).

Name of Researcher	Date	Signature

Participants' briefing and undertaking

I have agreed to be approached to take part in this research on the basis of the information made available to me by the researchers outlined above.

I understand the purpose of the research and give my informed consent to be approached. I understand that signing and returning this form does not commit me or the individual I will be representing to take part in this research, and that if I do choose to represent I will be asked to give my consent on behalf of the identified individual as a representative and I understand that I can change my mind and withdraw before or on the day of the study by contacting the researcher with my unique number (you will be given this following the process of informed consent).

Name of Participant	Date	Signature

In the case of a consultee or a representative

Name of Representative	Date	Signature
Relationship to person you will be representing:		

Appendix–J: Participant Information Sheet (Chapter 4)

Invitation and brief summary

This study aims to see whether virtual reality is well received amongst individuals living with dementia. The individual will have the opportunity to experience a virtual environment.

What is involved?

Individuals living with dementia will have up to 15 minutes to engage with the virtual world within the headset. They will be given a choice of different environments to choose from. Individuals will be supported by care staff, and, where appropriate, will be interviewed for their feedback. Care staff will also have the opportunity to experience virtual reality for a short period and will be interviewed for feedback regarding their views on the virtual reality experience. Participants will be video recorded in order to analyse their engagement with virtual reality and interviews audio recorded. If virtual reality is well received it will help inform its potential use in the service in the future as an activity.

What is Virtual Reality?

Virtual reality is a technology designed to provide a simulated environment the user can explore and interact with. It aims to create a sense of "presence" which means the user may feel as though they are experiencing the environment in real life. A headset will be worn, and the headset virtual environment will be played through the headset. The image below demonstrates someone wearing a virtual reality headset.

Background

Research indicates that virtual reality is viewed as a positive distraction from everyday activities or during times of distress. There is also evidence of increased pleasure and alertness in individuals living with dementia whilst using virtual reality.

What happens to the data?

Audio recordings will be transcribed for analysis then deleted. Videos will be analysed using a scoring system then deleted. All analysed raw data will remain anonymous and participants will not be identifiable.

What are the potential benefits of taking part?

- The opportunity to take part in a meaningful activity.
- Experience an environment otherwise not accessible within the ward environment.
- The potential of feeling more pleasure and alert.
- The opportunity to maximise wellbeing and minimise ill-being.

What re the potential risks of taking part?

- There are no known significant risks of taking part in this study.
- Known side effects have included disorientation and nausea.
- There are have been complaints of discomfort from the equipment.

Minimising risk of harm

- If the individual taking part in this study has history of motion sickness, they should declare this and not take part in the study, to reduce the risk of harm to them.
- Disorientation, as a result of virtual reality, will be minimised by using season neutral environments to support the individual's orientation back to the "real" environment following the virtual reality experience
- We will orientate the individual, where possible, to time and place before and after the virtual reality experience.

- The study will be carried out in an environment familiar to the individual.
- The equipment will be padded to support with comfort.

Will anyone need to be informed about taking part in this research?

The responsible clinical of the individual with dementia will be informed about their participation in this research.

Consent process

If you are interested in taking part, please provide your consent to be approached where you will be provided with the opportunity to ask any questions and discuss your involvement further should you wish too. You can then give your consent to take part in the study. And be provided with the timeframe of your involvement.

[Contact information]

Appendix–K: Information for Consultee Sheet (Chapter 4)

We feel your relative/friend is unable to decide for himself/herself whether to participate in this study.

To help decide if he/she should join the study, we would like to ask your opinion whether or not they would want to be involved. We would ask you to consider what you know of their wishes and feelings, and to consider their interests. Please let us know of any advance decisions they may have made about participating in research. These should take precedence.

Please read the information sheet provided. If you decide your relative/friend would have no objection to taking part we will ask please sign and return the consent to be approached form if you would like to be approached. If you have read the information and consent to participation and have no further questions please sign and return the consultee declaration form, also enclosed. This provides consent on behalf of your relative/friend to take part in this study. We will keep you fully informed during the study, should you wish, so you can let us know if you have any concerns or you think your relative/friend should be withdrawn.

If you decide that your friend/relative would not wish to take part it will not affect the standard of care they receive in any way.

If you are unsure about taking the role of consultee you may seek independent advice or contact us with your queries.

We will understand if you do not want to take on this responsibility.

The information in the participant information sheet is the same as would have been provided to your relative/friend.

Appendix–L: Participant Consent Form (Chapter 4)

Please 'tick' each box	
I confirm that I have read the information sheet dated.................................... for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected.	
I understand that the information collected about me may be used to support other research in the future and may be shared anonymously with other researchers. I understand the information may be published anonymously to a journal and/or conference including the use of anonymous quotes from the study.	
[applicable to participating patients only] I agree to my responsible clinician being informed of my participation in the study.	
I agree to take part in the above study.	

Name of Participant	Date	Signature
Lead Researcher	Date	Signature

Appendix–M: Consultee Declaration Form (Chapter 4)

Please 'tick' each box	
I ________________ have been consulted about __________________'s participation in this research project. I have had the opportunity to ask questions about the study and understand what is involved.	
In my opinion he/she would have no objection to taking part in the above study.	
understand that I can request he/she is withdrawn from the study at any time, without giving any reason and without his/her care or legal rights being affected.	
I agree to their responsible clinician being informed of their participation in the study.	
I understand that the information collected about this individual may be used to support other research in the future, and may be shared anonymously with other researchers. I understand the information may be published anonymously to a journal and/or conference including the use of anonymous quotes from the study.	

Name of Consultee	Date	Signature
Relationship to Participant		
Lead Researcher	Date	Signature

Appendix–N: Debrief Sheet (Chapter 4)

Thank you for taking part in this research, your time is very much appreciated!

Summary of research and aims

St Andrews are working in collaboration with The University of Kent to explore the use of virtual reality (VR) with individuals living with dementia. The purpose of this research was to explore whether individuals living with dementia can use VR. Particular interest was paid to exploring the potential benefits of using VR including the individual's wellbeing during and immediately after using VR. We hope this research can inform future practice in finding innovative ways to increase opportunities of wellbeing for individuals living with dementia. The research may be published in a peer reviewed journal and/or presented at a conference level.

What if there is a problem?

If you feel distressed as a result of taking part in the study, or observe the presentation of individuals who have participated to be out of their usual presentation, please contact a member of the research team using the contact details below.

Changing your mind

During your participation you can withdraw from this research without the need for any explanation. Any data collected from yourself or the individual you were representing will be withdrawn and disposed of confidentially. Please keep a note of your unique number and present this if you would like to withdraw from the study. You will have up until 1 week following the completion of your participation to withdraw your data.

Contact details

[contact information]

Complaints

If you have any complaints before, during or after this research, they can be directed to: *[contact information]*

Appendix–O: Interview Transcript Template – Patient Participants (Chapter 4)

<table>
<tr><td colspan="3">Participant Related Background (information to take into consideration that might have affected the interview)</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Interview Information</td></tr>
<tr><td>Week: 00</td><td>Day: 00</td><td>Session: 00</td></tr>
<tr><td>Date:
Day
00th of Month, Year</td><td>Total VR immersion time: 00:00 min</td><td>Virtual Environments Viewed:</td></tr>
<tr><td colspan="3">Codes and Keywords:
CR: Clinical Researcher (Interviewer).
TR: Technical Researcher (Interviewer).
SP: Caregiver (Support Member).
ID00: Patient ID (Participant, Interviewee).
(.) Pause in speech.
(-) Break in speech.
(Rep/Conf): When any of the researchers or caregiver verbalize or confirm what the participant says/does.
(Demo): When SP, CR, or TR demonstrates or explain to the participant by doing.
(CommSheet): An A4 laminated sheet with two large boxes on each end (right/left) with a YES/NO in each box. This communication sheet is used to aid participants to answer interview questions only if needed.
(VEMenu): An A3 laminated sheet that contains a snapshot of every virtual environment we offer and its title. The virtual environments are Woodland, Country Side, Sandy Beach, Rocky Beach, and Cathedral.
(VRHSet): VR headset or sometimes referred to as goggles.</td></tr>
</table>

Line #	Verbatim	Transcriber's Comments
1		
2		
3		
4		
5		
6		
7		
8		
9		

Appendix–P: Interview Transcript Template – Caregiver Participants (Chapter 4)

Interview Information		
Week: 00	Day: 00	Session: 00
Date: Day, 00th of Month, Year		
Codes and Keywords: CR: Clinical Researcher (Interviewer). TR: Technical Researcher (Interviewer). SP: Caregiver (Support Member, Interviewee). ID00: Patient ID (Participant). (.) Pause in speech. (-) Break in speech. (Rep/Conf): When any of the researchers or caregiver verbalize or confirm what the participant says/does. (Demo): When SP, CR, or TR demonstrates or explain to the participant by doing. (CommSheet): An A4 laminated sheet with two large boxes on each end (right/left) with a YES/NO in each box. This communication sheet is used to aid participants to answer interview questions only if needed. (VEMenu): An A3 laminated sheet that contains a snapshot of every virtual environment we offer and its title. The virtual environments are Woodland, Country Side, Sandy Beach, Rocky Beach, and Cathedral. (VRHSet): VR headset or sometimes referred to as goggles.		

Line #	Verbatim	Transcriber's Comments
1 2 3 4 5 6 7 8 9 10		

Appendix–Q: Observations Template (Chapter 4)

Observation Session for Participant: ID_0 in Phase 00

General Information

Day/Date	Day, 00th of Mon 2018
Time	
VR Session(s) Duration	
VE Name	00:00:00 min
VE Name	00:00:00 min
Total Session Duration	00:00:00 min
Attendees	
Participant ID	ID_0
Caregiver ID (SP – Support)	ID_00 (Coded here as SP)
Clinical Researcher (CR)	Present
Technical Researcher (TR)	Present (author, may refer to myself as I)
Notes	

Set Up (Pre-Session)

Reminder Points: • Notes from myself as a technical researcher. • Notes from the caregivers if any. • Remarks on how it is easy/hard to set up. • Remarks on the general workflow to set up in a clinical setting.	
Total Setup Time	00:00:00 min
Issues Faced	
Incomplete Items	
Notes	
Notes for the future	

Observations (During the Session)

Reminder Points:

- What happened?
- What the caregiver/patient said.
- What the caregiver/patient did.
- How the caregiver/patient reacted (including gestures).
- How the patient behaved and how the caregiver responded.
- What went right/wrong?
- Dynamics of interaction between the patient and the caregiver.

- Dynamics of interaction between the caregiver and the hardware/software.
- Dynamics of interaction between the patient and the hardware/software.
- Reaction and feasibility of using technology.
- NOTE: Coloured in grey, are the observations when the participant has the headset on and interacting/watching.

Session started at 00:00 AM,

Room setting:

About the participant:

Participant walk in and first impression:

(End of session)

Reflection (Post-Session)

Reminder Points:

- What was the aim and what was the results?
- How was the audial and visual interaction?
- What are the pros and cons to the execution?
- What are the pros and cons to the experiment set up?
- How was the engagement in terms of the device and the content?
- What could have been done better?
- Combine theories with thoughts?
- Reflect on the protocol itself: what worked and what didn't?
- Technical interaction/set up in relation to the clinical/medical environment.
- Next session's recommendations.
- Generalize themes/patterns.
- How the design of the hardware and the software affected the experiment?

- How the used technology affected the implementation in a clinical setting?
- Connect research questions to the reflections based on the observations.

Appendix–R: Participant Interview Questionnaire (Chapter 4)

Semi-structured interviews aimed to explore the perceptions of individuals with dementia (where possible) regarding the feasibility of the VR equipment and the overall VR experience. Since the interviews are semi-structured, the interviewer will not strictly follow this formalized list of questions. The interviewer will ask more open-ended questions, in order to allow a discussion with the interviewee rather than a straightforward question and answer. Usability questions are based on a well-established System Usability Scale (SUS) (Brooke, 1996). Presence and Immersive experience questions are based on a well-established instrument (Nichols, Haldane & Wilson, 2000).

Individuals with Dementia Interview Questionnaire (Elaborate)

- Usability Questions:
  - Would you like to use this system frequently? If yes: How frequently and why?
  - Did you find the system unnecessarily complex? If yes: what troubled you more?
  - Was the system easy to use? Can you tell us more?
  - Do you think that you will need the support of a technical person to be able to use this system? If yes: Why? What needs to be done to ensure the easy use of the system?
  - Did you find the various functions in this system were well integrated?
  - Was there too much inconsistency in this system? If yes: Can you give us an example?
  - Would you imagine that most people would learn to use this system very quickly? Can you tell us more?
  - Was the system very cumbersome to use? If yes: Why? What needs to be done to ensure the easy use of the system?
  - Did you feel very confident using the system? If yes: What do you think made you feel that way?

- Did you need to learn a lot of things before you could get going with this system? If yes: Can you tell us a couple of things you feel needed to learn?

- Presence and Immersion Questions:
  - In the computer-generated world, did you have the sense of "being there"? If yes: Can you tell us more? How exactly did you feel?
  - During the VR session, did you think of the other person(s) in the room (e.g., the caregivers)? If yes: how often did you think of them?
  - Did you feel that the VE was flat and missing in depth? If yes: How flat and missing in depth did the VE appear?
  - Was the VE a picture or more like a place you could have been? Can you tell us more?
  - Will it be more enjoyable to use the VE with no-one else in the room? If yes: How much more? Why?
  - Was there a lag or delay between your movements of the controls and the response in the computer-generated world? If yes: How disturbing was it?
  - Whilst you used the game, music played in the background. How much attention did you pay to it? {This question will be adjust based on the VE}
  - At the time you used the VR, did you feel like the VE was more real or present to you than the real world? If yes: How real?
  - Can you tell us how it felt? Did you feel exhilarated after the experience? If yes: How much?

Questionnaire for Individuals with Dementia (Simplified)

- Usability:
  - Was it easy or hard to look around?
  - Would you want to try it again later?
  - Did you want to take it off?

    - Do you prefer using these goggles or TV?
    - Do you prefer watching this video using these goggles or TV?
    - Did it make you feel dizzy?
    - Is it exciting or boring?
    - Is it comfortable?
- Likability and emotional impact:
    - Did you like it?
    - Was it fun or scary?
    - Did it make you feel happy or sad?
    - How do you feel now after watching this video?
- Immersion:
    - Did it feel like you were at the …? What else did you see?
    - Did you listen to the sounds of the …? What else did you hear?
    - Did you forget that you were with … (mention people in the room)?
    - Did it feel real? Like you were really there?
    - Did you forget that you were in this room?
    - Is it annoying to look at when you turn around your head? (lag or delay)

Appendix–S: Caregiver Interview Questionnaire (Chapter 4)

Semi-structured interviews will explore the perceptions of caregivers regarding the feasibility of the VR equipment and the overall VR experience. Bellow you can find some questions. However, these questions are not exhaustive. Since we are aiming for a semi-structured interview, the interviewer will not strictly follow this formalized list of questions. The interviewer will ask more open-ended questions, in order to allow a discussion with the interviewee rather than a straightforward question and answer. Usability questions will be based on a well-established System Usability Scale (SUS) (Brooke, 1996). Presence and Immersive experience questions will be based on a well-established instrument (Nichols, Haldane & Wilson, 2000).

- Usability Questions:
    - Would you like to use this system frequently? If yes: How frequently and why?
    - Did you find the system unnecessarily complex? If yes: what troubled you more?
    - Was the system easy to use? Can you tell us more?
    - Do you think that you will need the support of a technical person to be able to use this system? If yes: Why? What needs to be done to ensure the easy use of the system?
    - Did you find the various functions in this system were well integrated?
    - Was there too much inconsistency in this system? If yes: Can you give us an example?
    - Would you imagine that most people would learn to use this system very quickly? Can you tell us more?
    - Was the system very cumbersome to use? If yes: Why? What needs to be done to ensure the easy use of the system?
    - Did you feel very confident using the system? If yes: What do you think made you feel that way?

    - Did you need to learn a lot of things before you could get going with this system? If yes: Can you tell us a couple of things you feel needed to learn?
- Clinical Use in the Locked Psychiatric Hospital:
    - Please tell us your general impression on using the VR headset with the patients.
    - What do you see as benefits of using VR for people with dementia? o Can you tell us more?
    - What do you think are challenging issues of using VR in a clinical environment involving people with dementia, and why?
    - What can we change to improve the technology for clinical use?
    - Are you keen to see this technology adopted in dementia management in St Andrews? If yes: what needs to be done to ensure the successful adoption?
    - How else do you think VR can be used in St Andrews?