A Reflection on Virtual Reality Design for Psychological, Cognitive & Behavioral Interventions: Design Needs, Opportunities & Challenges

Luma Tabbaa[a]*, Chee Siang Ang[a], Panote Siriaraya[b], Wan Jou She[c], and Holly Gwen Prigerson[c]

[a]School of Engineering & Digital Arts, University of Kent, Canterbury, United Kingdom; [b]School of Information and Human Science, Kyoto Institute of Technology, Kyoto, Japan; [c]Weill Cornell Medicine, New York City, New York, United States

*Corresponding Author: Luma Tabbaa, l.a.tabbaa@kent.ac.uk, Jennison Building, School of Engineering & Digital Arts, University of Kent, Canterbury, CT2 7NT, United Kingdom

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Despite the substantial research interest in using Virtual Reality (VR) in healthcare in general and in Psychological, Cognitive, and Behavioral (PC&B) interventions in specific, as well as emerging research supporting the efficacy of VR in healthcare, the design process of translating therapies into VR to meet the needs of critical stakeholders such as users and clinicians is rarely addressed. In this paper, we aim to shed light onto the design needs, opportunities and challenges in designing efficient and effective PC&B-VR interventions. Through analyzing the co-design processes of four user-centered PC&B-VR interventions, we examined how therapies were adapted into VR to meet stakeholders' requirements, explored design elements for meaningful experiences, and investigated how the understanding of healthcare contexts contribute to the VR intervention design. This paper presents the HCI research community with design opportunities and challenges as well as future directions for PC&B-VR intervention design.

Keywords: virtual reality; virtual reality in healthcare; virtual reality design; user experience; user-centered design; co-design process

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Introduction

It is estimated that in 2016, nearly one in 10 (676 million) people suffered from a form of a mental disorder globally (World Health Organization, 2016). In England, one in six adults suffered 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 were 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 suffered from a mental disorder, and additional 4.5% (11.2 million) adults were diagnosed with a serious mental illness where institutionalization and/or pharmacological interventions are required (National Institute of Mental Health, 2017). 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 (Dieleman et al., 2016).

Although there is 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 (Marrero et al., 2020; Wainberg et al., 2017). As such, to address this "last mile" problem, there has been emerging interests in identifying innovative ways to encourage people to actively take part in treatments, assessments, training, and other forms of support related to mental health and wellbeing.

In the HCI community, in particular, there has been a growing body of research on 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 & Kharrazi, 2018), mobile (Baig et al., 2015), augmented reality (Baranowski & Lyons, 2020), and VR (Niki et al., 2019) in a variety of ways, from diagnoses and assessment (Mendez et al., 2015), treatment (Emmelkamp et al., 2001), rehabilitation (Bortone et al., 2018), to self-management (Schroeder et al., 2018). 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 & Yardley, 2009). Thus, it is vital to understand the conventional practices and processes in the therapies when developing technology-based interventions and translating this in-depth understanding in the technology design.

VR is a technological platform that has received significant attention in the field of mental healthcare in the past decades (see a review in (Freeman et al., 2017)). VR for mental health and wellbeing interventions in general and Psychological, Cognitive & Behavioral (BC&B) interventions in specific have shown unique advantages that make VR especially valuable in this domain. Such advantages include its ecological validity, the ability to control the stimuli and expose users to different situations safely in comparison to the unpredictable nature of real-world circumstances (see a summary in (Weiss et al., 2006)).

However, despite emerging literature that supports the use of VR for healthcare and wellbeing, little has been done to understand the design process of translating conventional therapies into VR, meeting the design needs of critical stakeholders such as patients, and clinicians, 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).

Therefore, this paper aims to highlight design needs, opportunities, and challenges in designing PC&B-VR interventions. To this end, we analyzed four user-centered PC&B-VR interventions co-designed by multidisciplinary teams of researchers and healthcare practitioners (addressing (i) behaviors that challenges in dementia, (ii) anxiety disorder, (iii) eating disorders, and (iv) pain management in exercise). We aim to contribute original knowledge to the HCI community by shedding light on the need for drawing coherent design knowledge that ensures successful translation and deployment by designing effective, enriched, and meaningful PC&B-VR interventions which are user-centered and driven by an in-depth understanding of real-world healthcare contexts.

Literature Review

Virtual Reality in Mental Health and Wellbeing

Decades of research demonstrate the efficacy of VR in supporting therapies and interventions in several mental health and wellbeing domains. For instance, VR has been used to facilitate exposure therapy; a well-established treatment for addressing psychological trauma, stress, and anxiety disorders (Rothbaum & Schwartz, 2002). Empirical data from research supports the efficacy of Virtual Reality Exposure Therapy (VRET) in facilitating a variety of treatments such as for acrophobia (i.e. fear of heights) (Freeman et al., 2018), arachnophobia (i.e. fear of spiders) (Lindner et al., 2020), aviophobia (i.e. fear of flying) (Wiederhold & Wiederhold, 2003), social phobia (Sekhavat & Nomani, 2017), Post Traumatic Stress Disorder (PTSD) (Gonçalves et al., 2012) and other stress-related disorders (Guillén et al., 2018) (also see a summary in (Maples-Keller et al., 2017; Parsons & Rizzo, 2008)). In such treatments, VR was used to provide 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.

At the other end of the spectrum, instead of using VR to trigger and arouse certain emotions as part of the therapy, VR has shown potentials in reducing emotional intensity by providing alternative imagery to help users modulate emotional distress caused by the physical reality that the user is experiencing. Such interventions include reducing distress resulting from pain in burns, painful medical procedures for cancer patients, and acute pain in exercise (see a summary in (Matsangidou, Ang, & Sakel, 2017)).

Furthermore, there exist research works in the body of literature; in which, VR was utilized as a modality to promote mental wellbeing practices. For instance, VR has been utilized as a modality to facilitate mindfulness practice; where users capitalize on the sense of presence by using VR to isolate themselves from environmental and personal distractors; hence, engage more deeply in mindfulness practices (Navarro-Haro et al., 2017; Seabrook et al., 2020).

Other forms of treatments involve embodying a visual representation of oneself or others using VR technology. Studies examined the use of body ownership or self-embodiment in VR to help people with Eating Disorders (Riva et al., 2002; Wiederhold et al., 2016). Similarly, researchers explored embodiment as a method to reduce self-criticism for individuals living with depression (Falconer et al., 2016). Another interesting case examined how VR could be 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 visualizing "the other" as a virtual avatar that best resembles the most dominant and distressing person or entity believed to be the source of the malevolent voice (du Sert et al., 2018).

Studies have also examined the use of VR as a tool for clinical assessment or training. For instance, researchers have utilized VR as a tool to train individuals with autism on social cognition (Boyd et al., 2018), assess sexual arousal in paraphilia within forensic settings for offenders (Renaud et al., 2014), and assess or train skills for People Living with Dementia (PWD) that typically degenerate as a result of a dementia diagnosis such as spatial navigation (White & Moussavi, 2016).

Designing Virtual Reality for Mental Health and Wellbeing

Despite the growing attention VR has received in mental health and wellbeing, there are major barriers when it comes to designing VR interventions. When designers translate conventional therapies into VR, very fundamental design questions arise that are 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 HCI research community for other technology platforms, such as those related to games (de Vette et al., 2018; Fanfarelli et al., 2018; Siriaraya et al., 2018), web (Britto & Pizzolato, 2016) and mobile health (mHealth) (Miller et al., 2016; van Dooren et al., 2019) applications for healthcare and wellbeing, little is known about the best-case practices in VR design for this domain. In fact, only some practical guidelines were found that aims to assist clinicians on how to administer VR for therapy[1] such as monitoring additional measures on top of the therapy outcome measures that are related to VR use, including monitoring levels of dizziness or nausea when using VR (Mishkind et al., 2017).

There are some generic design guidelines such as the guidelines laid out in the Oculus[2] 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 the healthcare and wellbeing domain; mainly due to the 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 recognizing the correct navigation path and have less eye/hand coordination when using input devices (i.e. mouse) (Slatin & Rush, 2003). This is why many researchers have explored technology design for users with specific mental and physical needs such as older adults (Kalimullah & Sushmitha, 2017; Kascak et al.,

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[1] ttps://painstudieslab.com/vr-guidelines/

[2] https://developer.oculus.com/design/

2014), people on the autism spectrum (Britto & Pizzolato, 2016), and people with visual impairment (Choo et al., 2019). Given these unique design requirements, designing VR experiences requires us to be sensitive to the design needs of the clinical population for user-friendly and highly engaging yet clinically relevant VR experiences.

Therefore, we aim to highlight design needs, opportunities and challenges in PC&B-VR intervention design through the analysis of the co-design process, development, and evaluation of four user-centered PC&B-VR interventions.

The PC&B-VR Interventions

This study combines a corpus of data collected from four user-centered 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.

Behaviors that Challenges in Dementia (VR-Dementia): 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 behavior that challenges such as physical and verbal aggression (Rose et al., 2019; Tabbaa et al., 2019). The intervention was co-designed with specialists within dementia healthcare across five sessions (see Table 1) to identify suitable VEs that could be therapeutic for this patient-group. PWD (see Table 1) were offered five 360-video-based VEs to choose from and were offered to spend time in VR for a maximum of 15 minutes. PWD explored the VEs (see Figure 1) 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[3], paired with a Samsung S6 phone, was used to stream the audial/visual content.

VR-Anxiety: This VR intervention was designed to reduce the anxiety of students with “Moderate to High” or “High Anxiety” (Otkhmezuri et al., 2019). The intervention was based on the Cognitive Bias Modification of Interpretations approach (CBM-I) (Mathews & Mackintosh, 2000). In collaboration with clinical psychologists (see Table 1), 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 1) engaged in 40 CBM-I scenarios using VR for ~ 45 minutes. Specifically, participants were exposed to VEs during a period where they would typically have high levels of anxiety, i.e. exam hall, 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 audio feedback.

Eating Disorders (VR-ED): 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 1). The co-design sessions aimed to understand how conventional ED therapy sessions could be translated into VR and how the therapist and people with ED could engage in the therapy virtually. The remote VR therapy was constructed by drawing knowledge from Acceptance & Commitment Therapy (ACT) (Hayes et al., 2011), Play Therapy (PT) (Schaefer, 2003), and Mirror Exposure Therapy (MET) (Waller et al., 2016). Therapists and people with ED (see

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

Table 1) logged-in from remote locations without having met each other face-to-face and were presented in the VE as 3D avatars. Participants engaged in a 25-minute training game to familiarize themselves with how VR works. 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 customizable avatar that resembled how participants thought their body looked like (see Figure 1). 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. Therapist and participant avatars included various features to enhance the liveliness of the interaction, including avatar eye animation and blinking, voice processing, and avatar lip-sync in real-time.

Pain Management in Exercise (VR-Pain): This intervention utilized 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 1) (Matsangidou, Ang, Mauger, et al., 2017). Over the span of four design sessions, the intervention was co-designed with experts in exercise and pain (see Table 1) aiming to understand how the parameters of altered visual feedback in VR could prolong exercise. Participants (see Table 1) 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 synchronize the participant-avatar arm using the band's gyroscope.

<< Figure 1 here >>

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, and HCI experts, and twenty-four had intervention-specific clinical expertise (details described in Table 1). Additional 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:

- **Brainstorm Workshops and Co-Design Sessions Notes:** detailed notes were collected during co-design sessions and brainstorm workshops. Each session/workshop was approximately 1-1:30 hours long. 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. The notes per session ranged between 3-8 pages long. 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.

- **User's 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. Each feedback session was approximately 20 – 30 minutes long. In addition, researchers logged hardware issues, (i.e. related to the HMD) and software issues, (i.e. related to usability, blurriness, etc.) that occurred. The lengthiness of the notes ranged between 2-5 pages per test user per iteration session. Overall, the notes aimed to understand the effectiveness of translating traditional 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. Due to the unique layout of the transcription template, the word count is also described alongside the

number of pages. Transcribed interviews with PWD ranged between 4 pages (~480 words) and 13 pages (~1930 words) per PWD per session. Transcribed interviews with caregivers ranged between 7 pages (~1430 words) and 17 pages (~2490 words) per caregiver per session. Open-ended questionnaires (n=21) were answered by people with ED (n=14) and therapists who carried the VR-ED therapy (n=7). Answers to open-ended questionnaires which were answered by people with ED and therapists ranged between 0.5 – 1.5 pages per participant per session. 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 behavioral 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. Observation notes were 5 – 10 pages long per participant per session.

<< Table 1 here >>

The data were retrospectively analyzed using thematic analysis; a method used for identifying, interpreting, and reporting patterns within datasets (Braun & Clarke, 2006). The data were combined and analyzed in NVivo[4] software. We used an inductive approach to the analysis, where codes and themes were developed from the data. Two researchers with HCI expertise reviewed, coded and analyzed the data from initial coding to the final scheme delivery. The data were read and reread several times throughout the process. Initially, data were coded using broad codes. Then, the codes were reviewed to ensure the codes were meaningful to the representative data. Codes were then collated and thoroughly discussed to develop potential themes, and initial themes were evolved from the codes. Finally, the evolving themes were refined further, through critically discussing and reviewing each theme and underlying codes to ensure the fit of themes.

We aim to understand (i) the processes of 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 design.

Findings and Discussion

From the analysis, we identified four key themes relating to the "PC&B-VR design"; (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 summarized in Table 2. In the following, we present each of these themes at depth and discuss the design needs, challenges, and opportunities within each theme.

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[4] https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software

<< Table 2 here >>

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 healthcare is immersion; where users can be fully and deeply engaged within a VR space. As such, the design of the VR experience needs to assist users to “step” into the intervention environment, allowing them to immerse themselves in the therapy, hence, building an 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; we propose the idea of shifting our design thinking from “page” metaphor to “world” metaphor, focusing on building a virtual world that fosters the appropriate therapeutic milieu; where users “step into” the therapy world. Here we highlight key aspects in the design of the following elements: (i) user interfaces in three-dimensional spaces, and (ii) a meaningful clinical space for therapy.

User Interfaces in Three-Dimensional Spaces

Research is emerging looking into how information and UI elements should be organized 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 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 and that there were too many lines for users to read at once. In addition, 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 (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, relies on individual designer's interpretation onto visualizing 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, resulted in highly unsatisfactory user experience, and required a new design paradigm to optimize the content layout and UI that is user-friendly to mobile-web (Chen et al., 2002). We explored different layouts to present critical therapy information in our projects. 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 approach is still limited; as it may be challenging to embed with open or outdoor VEs, when there are no flat spaces to embed the UI within. Another common UI layout modality in VR is floating UI windows. In such layout, we tested two design approaches: (i) a floating UI bounded to the user's head coordinates; always in front of the user, and (ii) a floating UI that is static in place. For the floating UI connected to the participant's head movement, we 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 cause annoyance but also hindered the user's emotional engagement and immersion in VR, which are vital reasons why VR was used in the first place.

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 behavior, emotion, and mental process; thus, such space should be carefully designed in a way that supports effective therapies (Augustin & 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 (Macedonio et al., 2007; Riva et al., 2007). However, in a healthcare context, where delivering emotional experiences that attend to the user's needs and therapy aims is vital, it is unclear on what a "well-designed" VE may look like. Drawing from the wealth of research in games literature, it is suggested 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 & 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 close 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 world. However, in user testing, we 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.

> For a substantial duration of the iteration testing, the test user was not bothered by the dumbbell; instead, she was far more interested in the 3D-VE and its content; she was looking around and moving her head and upper body to see what else there is to see. Throughout the iteration testing, all she commented on was on how realistic the gym looked and made comparisons with her "real" gym. – VR-Pain, Artefact Feedback & Evaluation

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 context; mainly for 360-VEs (Lin et al., 2017; Seabrook et al., 2020). Thus, there exists a need to explore further how to design VEs that does 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 effectivity of the VR intervention.

Our analysis shows that users' perceived control can result in increased engagement and motivation (Peters et al., 2018; Seabrook et al., 2020). The effect of providing autonomous experiences was viewed in the VR-Dementia intervention, where

PWD were drawn to the idea of choosing the experiences and determining the narrative they wanted to construct within VR. This was also recognized by previous research; where users with arachnophobia were drawn to the use of VR because felt they had control over the narrative of the therapy through knowing what is expected; which was found more desirable and less distressing for patients (Lindner et al., 2020). 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 & Banaji, 2001). Thus, we value 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.

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 would be unfamiliar with such interaction modalities. Three aspects related to interaction within the VR space were identified from our data: (i) enabling competence, (ii) mechanics of interaction, and (iii) mechanics of navigation.

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 et al., 2018). In the healthcare and wellbeing context, 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 (Lindner et al., 2020).

> After spending time painting the details of the 3D model's head, she mistakenly paints the entire head with the color 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 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.

> "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." – VR-Dementia, Observations, P08

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 visually impaired users (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 they likely are key targets of many PC&B-VR interventions.

Mechanics of Interactions

In healthcare 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 we 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 gave users 10 seconds to complete the answer for each question; 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, we opted for using voice recognition; as it allows the fulfilment of the interventions' requirement to give quick answers.

> The test user was utterly frustrated by the inability to type the answers in time, especially since the system prompted errors every time the user failed to answer within 10 seconds. Furthermore, since the test user verbalized her answers, the researcher could see that the lengthy typing process gave her more time to change her answers, which defies the purpose of an unconscious bias training. – VR-Anxiety, Artefact Feedback & Evaluation

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

We found that some methods of interactions could get inspirations 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.

This lack of intuitive and closer-to-real-life interaction modalities have been identified by previous literature; the unfamiliarity of VR interaction modalities may hinder the technology acceptance and willingness to use PC&B-VR interventions in the future, by both users and clinicians (Guillén et al., 2018). 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).

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 mental health 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 & 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, we explored how we could deliver comfortable and natural navigation modalities to move within the VE. We explored 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. 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 effect.

Teleportation between VEs is another aspect of designing navigation mechanisms that was 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 healthcare cannot be understated; for example, research has established clear and detailed design guidelines for web applications including colors and navigational path modalities that are friendly to healthcare (Baig et al., 2015; Holzinger & 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 healthcare need to be user friendly and enable users to navigate in a way that suits their abilities. Furthermore, navigation for VR healthcare must not cause unwanted physical side effects such as motion sickness. Such an adverse effect not only is a safety issue for users but also is an identified concern by therapists that discourages them from choosing to use VR (Bush, 2008).

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 healthcare (Fletcher-Tomenius & Vossler, 2009; Leach, 2005). Thus, reflecting such understanding within 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.

Enabling Self through Body Ownership

Body ownership in VR refers to the perceptual illusion that the virtual body is one's own (Petkova et al., 2011). One key aspect which we found to be essential for the users to feel connected to their virtual body is the visual resemblance of the avatar. Users with ED were asked to create an avatar that resembles what they believed they look like. Users were offered pick-and-choose options for skin tone and hair color and style, as well as sliders that modifies body parts independently, where slider's extreme ends go from very slim to very thick (see Figure 2). 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 2 here >>

Research in game design concluded that greater embodiment cultivates greater intrinsic motivation (Birk et al., 2016). In VR-ED intervention, mirror exposure therapy was utilized 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 et al., 2007), or versions that resemble 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, we initially did not anticipate a need for proprioceptive feedback 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 behavior 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.

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 & 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 center 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 PWD 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 realized 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 to the user 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 we need further research to understand the design needs and strategies to support users in this sense.

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 & Zaphiris, 2010; Stenros et al., 2009). In the healthcare 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 health care (Leach, 2005; Norfolk et al., 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 & Doyle, 2002). Similarly, such concerns were raised during the design of the VR- ED.

One design aspect we adopted to address such concerns was by utilizing 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. We 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 with lip-syncing and eye-movement animations to enhance 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 et al., 2019). In the healthcare context, we believe there is a lot to be learnt from literature in clinical psychology that directs clinicians with strategies and behaviors 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). We believe that future research could examine how to embed such characteristics into therapist avatars.

An Enabling Deployment Context

Throughout the co-design process, it became clear that the design of effective VR for healthcare, 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 intervention 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 the 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 et al., 2007; Peck et al., 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. 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 for dementia, PWD residing in the hospital require assistance in most if not all activities of daily living (Garcia et al., 2012); thus, the system was designed to be used together with caregivers who were by PWD's side and provided support and guidance. Finally, many users with ED are hesitant to seek therapy due to the anxiety related to the 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.

Finally, in consistence with the important notion of person-centered care in healthcare practices (Brechin et al., 2020), the study found that 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. These could vary depending on the user's own needs by providing suitable guidance and support modalities.

> "I think if it (the VR session) was happening at a certain time, then we can be chatting to the patient about it. Perhaps [put] some of the pictures (of VEs) up. [Be]cause young man (PWD) has a "memory box" of stuff, so maybe we can have a folder of this. I always use that when starting with activities for him, so he remembers (the activity or its content)". – VR-Dementia, Interviews, P15

Discussions

Through the analysis of the co-design, development, and evaluation process of four user-centered PC&B-VR interventions, we explored the processes of adapting conventional interventions into VR, the usability and acceptance of VR by clinicians and users, the design problems and requirements for PC&B-VR interventions, and how best to incorporate the understanding of the broader healthcare contexts in the design. Here in this section, we summarize key design opportunities and challenges on designing enriched, effective, and meaningful PC&B-VR interventions.

PC&B-VR Design Challenges

- There is clearly a lack of standardized approaches toward VEs design in PC&B-VR. The study concluded that VR healthcare design paradigm is more akin to games than web/mobile design paradigms, where UI in web/mobile design uses a "page" design metaphor. As such the design of VEs for PC&B-VR interventions need to emphasize the understanding of the "world" design metaphor, allowing users to receive critical information (i.e. menus, instructions, questionnaires…etc.) related to the intervention effectively.

- The study outlined a challenge in designing interactions that are balanced with the user's abilities and familiarity with VR interactions when engaging in PC&B-VR interventions. Some interventions could be emotionally stressful by nature (i.e. exposure to frightening events), require a high level of attention (i.e. responding at a timely manner in an assessment), or cause mental or physical exhaustion. All of these could increase cognitive load, which could affect performance and willingness to engage in VR. As such, designing intuitive, smooth, and sensitive interactions in a way that does not unnecessarily add to the cognitive load or emotional distress is fundamental. For example, in the case of the therapeutic game in the VR-ED intervention, the user became frustrated and annoyed when certain actions repeatedly failed to be executed using the interaction method of choice, thus, resulted in emotional distress in the user, undermining the therapeutic activity.

- Interaction mechanisms in VR are mainly designed for gaming and entertainment; therefore, many users within healthcare (including clinicians and patients) may not be familiar with such interaction and navigation mechanisms. Such unfamiliarity may affect the sense of competence and engagement in VR and ultimately, acceptability and desirability of the PC&B-VR intervention.

- Considering the fundamental difference in interaction and navigation mechanisms between VR and other mediums (i.e. PC, mobile), translating

PC&B interventions from 2D space to VR space may be challenging. As such, complying with therapy needs may require further investigation, to ensure that the replacement interaction mechanisms in VR still delivers the therapy goals in a meaningful manner.

- The lack of self-trust; trusting one's own actions and behaviors were observed in most VR interventions investigated in this study. The study found that usability and sociability go beyond the ease of use and interaction within VR.

- Designing PC&B-VR interventions that foster positive and trustful therapeutic connections between the user and the caregiver is still a relatively an unexplored area in VR design. Such design needs is a growing demand in the near future; novel research trends within VR research have begun to explore the usability of PC&B-VR interventions beyond traditional setting (i.e. therapist's office); where therapists do not co-locate with the patient during the PC&B-VR intervention, instead, therapists log on to the PC&B-VR virtually (i.e. such as in VR-ED intervention) or delivered in the form of an automated therapist as part of the VR system (Freeman et al., 2018; Lindner et al., 2020; Miloff et al., 2019).

PC&B-VR Design Opportunities

- Future research could produce design guidelines using the "world" design to deliver standardized and consistent experiences that consider the design needs and requirements for PC&B-VR interventions. Such standardization 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 center of the therapy.

- Considering that many users with cognitive, physical, and mental constraints are likely to be key targets of many PC&B-VR interventions, accessibility design guidelines are still understudied. Future research could consider designing accessibility guidelines to specific user groups to enhance the usability of VR.
- As part of the efforts required to produce familiar and intuitive mechanisms of interaction and navigation, there is a need in developing solutions to mediate intuitive and closer-to-real-life interaction, navigation and teleportation modalities to maximize technology acceptance of VR, ensure user's wellbeing (i.e. avoiding adverse side effects such as motion sickness) and ultimately, deployment of VR.
- Familiarizing users with the etiquette of using VR builds their trust in their actions and the system. Future research could explore further how a design framework can support users "entering" and "exiting" a VR experience and develop an understanding of which usability and social norms are acceptable in VR.
- The present study concluded that the design of virtual therapist avatars needs to adopt characteristics and behaviors that assist real therapists in building therapeutic rapport with their patients. Future research could build on this by exploring how to design such virtual therapist avatars to enhance the therapist-patient therapeutic connection virtually. Furthermore, the study concluded that providing patients and clinicians/therapists with the appropriate tools, activities and environments may assist in fostering therapeutic connections within the VR

space. In such, future research could investigate the type of therapeutic activities suitable for this context and how to deliver such activities in VR.

Conclusion & Future Work

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 paper, four user-centered VR-based PC&B interventions were examined, including the co-design and iterative development processes, and evaluation by representative users and clinicians/caregivers. We explored in-depth how critical design elements of these interventions 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, we presented the results of thematic analysis discussing the design needs, opportunities, and challenges within each theme. A limitation of the results presented here lies in the small number of intervention cases that were examined. This is partially due to the fact that few studies have described the process of translating, designing, and developing therapies in VR. As such, we need to build on this knowledge by exploring the VR design when examining a more comprehensive range of PC&B-VR interventions in mental healthcare. Additionally, all 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. Nonetheless, we hope that this paper shed light on design needs, opportunities, and challenges that could be a useful starting point to collectively, as a research community, harvest knowledge and iterate in building a design framework for developing PC&B-VR interventions.

Disclosure of Interest

No potential conflict of interest was reported by the authors.

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Table 1: Intervention design duration, number of design sessions and expertise profile, participant profile of final prototype evaluation, and type of data used in this study

Study	Design Duration	Design Brainstorm Sessions & Workshops	Representative End-Users Evaluation	Analyzed Data
VR-Dementia	Three months	Five sessions including experts in HCI (n=2), designers & developers (n=2), clinical psychologist (n=1), consultant clinical psychologist (n=1), consultant clinical neuropsychologist (n=1), and workshop attendees (n=15) including psychologists, managers, and nurses within dementia care	PWD with moderate to severe dementia (n=8) and caregivers (n=16); nurses (n=11), occupational therapists (n=3), psychologist (n=1), and physiotherapist (n=1)	• Workshops & sessions notes • Test user's 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	Four months	Five sessions including experts in HCI (n=2), designers & developers (n=2), behavioral psychologists (n=2), cognitive psychologist (n=1), and volunteer test users (n=2)	University students with "moderate to high" and "high" anxiety (n=42)	• Workshops & sessions notes • Test user's artefact feedback (n=3)
VR-ED	Six months	Eight sessions including an expert in HCI (n=1), designers & developers (n=2), cognitive psychologist (n=1), clinical psychologists (n=2), and volunteer test users (n=4)	Individuals deemed at high risk of developing ED (n=14) and clinical psychologists (n=7) whom each carried the therapy for two sessions	• Workshops & sessions notes • 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	Four months	Four sessions including an expert in HCI (n=1), designers & developers (n=4), cognitive psychologist (n=1), sports and pain in exercise consultant (n=1), and volunteer test users (n=2)	Healthy participants (n=120)	• Workshops & sessions notes • Test user's artefact feedback (n=2)

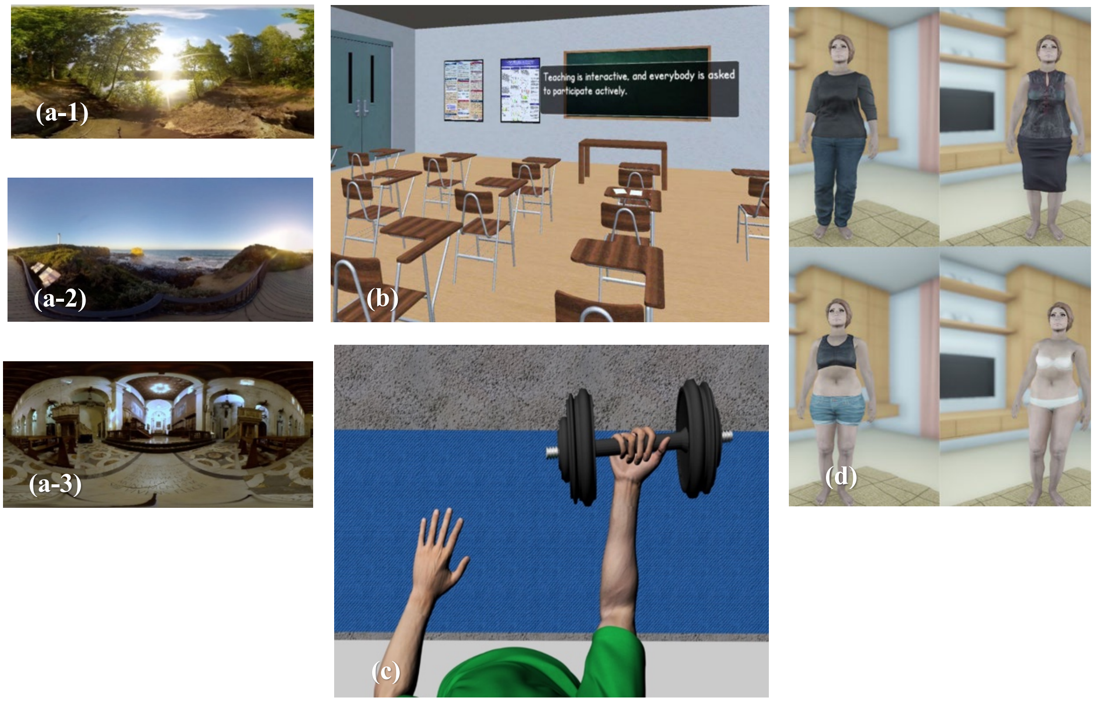
Table 2: Summary of Thematic Scheme

Theme	Sub-theme	Description	Example
Building a virtual therapeutic milieu	User interfaces in three-dimensional spaces	Designing UI elements using the "world" metaphor rather than the "page" metaphor to better fit the user needs and experience within PC&B-VR interventions.	"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
	A meaningful clinical space for therapy	Building VEs that fosters the appropriate therapeutic milieu and addresses the user's emotional needs; where users "step into" the therapy and emotionally engage in its content.	"For a substantial duration of the iteration testing, the test user was not bothered by the dumbbell; instead, she was far more interested in the 3D-VE and its content; she was looking around and moving her head and upper body to see what else there is to see. Throughout the iteration testing, all she commented on was on how realistic the gym looked and made comparisons with her "real" gym." – VR-Pain, Artefact Feedback & Evaluation
Interactions that fit	Enabling competence	Enabling the user to feel capable, effective and competent to maintain engagement in therapy and maximize the acceptability of the PC&B-VR interventions.	"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." – VR-Dementia, Observations, P08
	Mechanics of interactions	Designing intuitive, closer-to-real-life and natural interaction mechanisms to deliver PC&B-VR interventions in a meaningful manner.	The test user was utterly frustrated by the inability to type the answers in time, especially since the system prompted errors every time the user failed to answer within 10 seconds. Furthermore, since the test user verbalized her answers, the

			researcher could see that the lengthy typing process gave her more time to change her answers, which defies the purpose of an unconscious bias training. – VR-Anxiety, Artefact Feedback & Evaluation
	Mechanics of navigation	Designing navigation mechanisms that are natural, fit to the user's abilities and does not trigger unwanted adverse effects.	"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
Designing therapeutic connections with self & others	Enabling self through body ownership	Maintaining the sense of suspension from reality and empowering the sense of presence in PC&B-VR interventions through body ownership.	"'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
	Etiquette and trust in virtual worlds	Designing protocols that can help users reduce their self-awareness and hesitation during interaction with PC&B-VR interventions.	Dear God, something is talking to me! Oh God! Do I have to reply to this? – VR-ED, Observations, P10
	Therapeutic rapport in co-presence	Designing PC&B-VR experiences that fosters a positive, constructive and authentic therapeutic relationship between the therapist and the user.	"The fact that she [therapist] was a cube made me feel safe to talk about myself." – VR-ED, Questionnaire, P13
An enabling deployment context		Develop a deeper understanding of the real-world healthcare contexts in which the PC&B-VR intervention will be used, to enhance the deployability of VR.	"I think if it (the VR session) was happening at a certain time, then we can be chatting to the patient about it. Perhaps [put] some of the pictures (of VEs) up. [Be]cause young man (PWD) has a "memory box" of stuff, so maybe we can have a folder of this. I always use that when starting with activities for him, so he remembers (the activity or its

		content)". – VR-Dementia, Interviews, P15

(1)


(a-1)
(a-2)
(a-3)
(b)
Teaching is interactive, and everybody is asked to participate actively.
(c)
(d)

(2)


Μαλλιά (Hair style)
Δέρμα (Skin tone)
Μπλούζες (Tops)
Παντελόνια (Bottoms)
Σώμα (Body)
Πόδια (Legs)
Χέρια (arms)
Στέρνο (chest)

(1)

Figure 1: (a) Three of the offered VEs in the VR-Dementia intervention; (b) One of the CBM-I scenarios (classroom VE) in the VR-Anxiety intervention; (c) User lifting the visually altered dumbbell in the VR-Pain intervention; (d) Varied stages of Mirror Exposure Therapy

(2)

Figure 2: 3D Avatar with Customization UI Used in the ED-VR Intervention for the Mirror Exposure Therapy

Luma Tabbaa: Luma Tabbaa is a PhD candidate and a Lecturer in Digital Media at the School of Engineering & Digital Arts, University of Kent – UK. Her research interests include exploring the use of digital media and immersive technologies such as virtual reality in the field of mental health and wellbeing.

Chee Siang Ang: Chee Siang Ang is a Senior Lecturer in Multimedia and Digital Systems at the School of Engineering & Digital Arts, University of Kent – UK. His main research is in digital health, where he investigates, designs and develops technologies (i.e. immersive and sensing technologies) which provides treatment and self-management of health conditions.

Panote Siriaraya: Panote Siriaraya is an Assistant Professor at the Faculty of Information and Human Science, Kyoto Institute of Technology – Japan. His main research interest is in the field of Human-Computer Interaction and Machine learning, which includes topics such as Virtual Environments, Recommender Systems and Designing Technologies for the Aging population.

Wan Jou She: Wan Jou has an interdisciplinary background in Human-Computer Interaction and Designed Intelligence, specializing in developing internet-based bereavement resources for individuals who wish to manage their grief and maintain continuing bonds with the deceased. She has a research interest in preventing the development of Prolonged Grief Disorder through technology.

Holly Gwen Prigerson: Holly Prigerson is an Irving Sherwood Wright Professor in Geriatrics in Weill Cornell Medicine, Cornell University – USA and has published over 300 research articles. Her current research lies in automated approaches to detect suicide attempt risk among bereaved individuals as well as exploring immersive technologies in supporting treatment and management.