Creation of VR Stimuli Checklist Based on Systematic Literature Review of Immersive Psychological VR Interventions

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Abstract

The current literature on psychological VR interventions lacks methodological rigour in terms of including all information regarding the creation and use of the VR environments. Therefore, the following literature review identified trends across categories and all types of information reporting regarding the content of the virtual reality utilised within these interventions. The dataset was taken from Elsevier's Scopus and after the screening procedure included 61 reports of psychological immersive VR interventions. The inclusion criteria were limited to reports of psychological VR interventions whose VR environment presentation was considered fully-immersive. The initial results gathered consisted of trends across all included studies, including but not limited to types of VR stimuli, VR interaction, and VR presentations. The reports were further categorised by the author based on the type of therapy utilised or the goal of the particular intervention. These categories and the data gathered regarding important factors of VR environments were utilised for the creation of a checklist aimed at future VR researchers. Specifically, the created checklist poses questions regarding different aspects of VR, including but not limited to interact-ability, sensory feedback and amount of detail, in order to help future researchers enhance their psychological VR interventions and their subsequent reporting.

Introduction

Recent scientific and technological developments give rise to new technological advancements, such is the case with Extended reality, the appeal of which started as a source of entertainment and developed into uses within the field of psychology. Extended reality (XR) is considered an umbrella term for all immersive technologies, including Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) (Marr, 2019). AR combines the real world with the virtual by taking virtual information and objects and overlaying them in the real world. This virtual information can range from camera filters to additional text, images, or animations (Marr, 2019). VR, on the other hand, creates a fully immersive digital environment using a head-mounted display which allows for 360-degree view of the virtual environment (Marr, 2019). Finally, MR is the most recent technological advancement in terms of XR and encompasses both VR and AR. Simply put, MR allows you to interact with your real environment using digital objects, for instance allowing you to place a digital object on a real table (Marr, 2019). This rise of new XR technologies resulted in a spike in research concerning the use of XR for psychological interventions, reflected in the rise of published articles within this field in recent years. This research is expansive in terms of types and variety of interventions created within VR, including psychological interventions aimed at particular target groups, including but not limited to people with autism spectrum disorder (ASD) (Bekele et al., 2014), posttraumatic stress disorder (PTSD) (Beidel et al., 2019), phobias (Banos et al., 2002) and social anxiety disorder (SAD) (Beidel et al., 2021).

The advantages that Virtual reality interventions may provide for psychology range from cost-effectiveness to control of variables. Namely, for certain types of therapies, the creation and use of VR interventions solve issues of cost and availability due to a lack of therapeutic staff (Riva, 2022). Furthermore, the very nature of VR interventions allows for a high amount of control regarding all variables as well as safety thanks to the ability to leave the VR environment at any point (Riva, 2022). Virtual Reality can transcend not only geographical constraints but also reality through the creation of

environments beyond real-life. Exposure to feared stimuli, for instance for individuals with phobias, is also able to bypass social stigma by allowing individuals to conduct exposure in VR instead of in public. Certain types of therapies can benefit from these advantages more than others, for instance, Exposure therapy, Reminiscence therapy, or natural relaxation interventions.

Exposure therapy is used as a treatment program for different types of phobias, PTSD, SAD and more. In Exposure therapy, the psychologist creates a safe environment for the patient to gradually expose the individual to whatever they fear or are trying to avoid (American Psychological Association, 2017). The form of exposure therapy depends on the problems being treated, namely what the patients are going to be exposed to and how they will be exposed to it. Several variations of exposure therapy exist, however, in vivo exposure also known as direct exposure, is the main form that can benefit from being transported to VR as it encompasses direct exposure to the feared stimulus (American Psychological Association, 2017). Certain forms of in vivo exposure therapy, for instance, ones aimed at aerophobia (fear of flying), can be very costly and difficult to administer (Banos et al., 2002). Furthermore, VR has been tested for its fear-inducing abilities and found can activate several fears, including claustrophobia (Botella et al., 1998) and acrophobia (Freeman et al., 2018). Utilization of VR in these cases would allow for a cost-effective solution to interventions that might otherwise not take place due to the difficulty of maintaining constant exposure levels and guaranteeing the safety of the patients. Another exposure intervention that would benefit from being conducted in VR is one aimed at combat-related PTSD, which is characterized by unwanted memories, nightmares, and psychological distress (Beidel et al., 2019). Due to the types of events that create combat-related PTSD, it is impossible to ethically conduct in vivo exposure therapy. Hence, there is a great potential benefit in VR exposure programs such as Virtual Iraq, which uses visual, auditory, olfactory, and tactile cues for exposure therapy (Beidel et al., 2019). The results of trials for Virtual Iraq revealed statistically significant improvements across a range of symptoms (Beidel et al., 2019).

Reminiscence Therapy is a form of psychotherapy in which individuals, mostly the elderly or patients with dementia, recall past events and pleasurable memories to enhance their sense of well-being (Field, 2023). Virtual Reality allows Reminiscence therapy to become more complex than simple talk therapy by for instance, exposing the patient to photos from their life along with music reminding them of that time-period. Furthermore, VR allows the participant to explore different virtual environments, relevant to the specific participant, to enhance the reminiscence experience (Khirallah Abd El Fatah et al., 2024). The very nature of VR allows not only for the creation of different environments that can enhance reminiscence therapy but also to able to overcome mobility limitations of the patients.

Nature relaxation interventions are not considered an official form of therapy, however, in this paper, they encompass all interventions whose method is the exposure of participants to natural environments to achieve relaxation, reduce stress or enhance well-being. An extensive literature review found strong evidence of an association “between exposure to nature and improved cognitive function, brain activity, blood pressure, mental health, physical activity, and sleep” (Jimenez et al., 2021, p. 13). Due to geographical and personal limitations, certain individuals are unable to experience ‘in vivo’ nature exposure, hence virtual reality can provide immersive exposure to natural environments. The amount of control over VR enables patients to experience fantastical realities as well as giving them the ability to change certain aspects of the environment themselves, to enhance the experience for their personal relaxation.

The above-mentioned VR therapies represent a small number of therapies which can be directly translated into VR. However, many different types of therapies cannot be conducted using VR, and many therapies surface with VR and can only be conducted using this technology. As research into psychological intervention using VR is new, the need for a recognized standardized methodology arises to allow for analysis and comparison of the different VR environments created for psychological

interventions. Multiple literature reviews conducted on VR psychological interventions focused on a specific domain such as promoting positive mental health (Li Pira et al., 2023) or managing pain and anxiety in children (Ahmadpour et al., 2020). Another literature review focusing on the outcomes of VR psychological interventions outlined the main result as the need for VR intervention studies to improve their methodological rigor (Turner & Casey, 2014). These interventions highlight the gap within the VR intervention field, regarding the guidelines and guidance for intervention creation, as well as lack of clear reporting of these interventions. Due to this, the current paper will focus on creating a checklist aimed at VR researchers to provide them with all the necessary aspects of VR environment that they must consider during intervention creation. The checklist will include information and questions regarding all sensory factors, interactivity, immersion and other important factors found in VR interventions through a systematic literature review. Due to the current state of VR intervention literature lacking methodological rigor, the author anticipates lacking information regarding certain aspects of the VR environment. Hence, the checklist created will be aimed at posing main and follow-up questions, regarding all VR factors identified in the literature review, to have the researcher consider the given factor and its presentation, rather than providing clear guidelines. The usefulness of this checklist lies with giving researchers ideas on how to enhance their intervention, for instance by addition of a specific sensory input, providing thinking questions regarding the presentation and consequence of the addition of certain factors, and highlighting the necessity of including all used factors in the written report. The checklist will emphasize the need for methodological rigor to enhance the replicability and credibility of future VR interventions.

The following paper contains a systematic literature review of studies that were concerned with creation and/or testing immersive psychological VR interventions. This paper has been focused only on psychological interventions which are deemed as immersive, due to the extensive number of elements required for the creation of an immersive VR environment as well as the fact that VR programs rely on

immersion to trigger emotional, psychological, and/or physical reactions (Martens et al., 2019). The following paper identified key elements of VR interventions, namely elements of interactivity, sensory feedback, and use of avatars, to use the information for the creation of the checklist that will guide future researchers in the creation and reporting of new immersive psychological VR interventions. Therefore, the Research question which will drive the following literature review is:

What factors and stimuli of virtual environments are associated with VR-based immersive psychological interventions?

This research question will be answered to use said findings for creation of a checklist aimed at guiding researchers in the creation and reporting of future VR interventions.

Methods

The methodology of the following paper was designed to encompass the latest developments in psychological VR interventions with attention put on transparency of the review process to allow for replication. The following sections will elaborate on the key steps of this paper, including defining key words and search strings, establishing inclusion and exclusion criteria, conducting data extraction, employing a selection process, finalizing paper selection, and extracting critical findings regarding set-up and creation of XR interventions. The following study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) (Moher, 2009) framework for reporting methodology. PRISMA consists of a 27-item checklist and a four-phase flow diagram aimed at helping researchers improve the reporting of systematic reviews (Moher, 2009).

Eligibility Criteria

Before the search strategy could be established, the eligibility criteria were created for the screening of reports. The inclusion criteria contained VR psychological interventions which utilized immersive virtual reality. The immersion of a given intervention was determined by the way the environment was presented to the participant. Specifically, all interventions utilizing a head-mounted

display were considered to be immersive, with other types of presentation being judged on one-to-one basis to determine the level of immersion. As the research questions is focused on immersive VR interventions, all other types of extended reality interventions were excluded, including AR and MR. Other types of exclusion criteria included studies which did not use VR, were not psychological interventions or interventions at all, studies that were not published in English or were inaccessible through the UT library, duplicates, other literature reviews and grey literature papers (e.g. conference papers, study proposals and case studies). Studies were deemed as medical (not psychological) interventions when they included samples of individuals with specific medical conditions (for instance, dementia or traumatic brain injuries). The distinction between psychological and medical conditions was based on the definition of mental disorders provided by the Diagnostic and Statistical Manual of Mental Disorders, which defines it as "a syndrome characterized by clinically significant disturbance in an individual's cognition, emotion regulation, or behavior that reflects a dysfunction in the psychological, biological or developmental processes underlying mental functioning" (American Psychiatric Association, 2013, p. 20). Hence, all studies which included samples of individuals with specific conditions were compared to this definition to determine if they were eligible for inclusion, except for dementia which was identified as a neurocognitive disorder and was hence excluded (American Psychiatric Association, 2013). The identification of a paper as an intervention depended on the research question which had to focus on the feasibility or effectiveness of the intervention, rather than focusing on a third variable that is explored using VR.

Search Strategy

The papers selected for this review were selected from an extensive iterative process of search string creation using Elsevier's Scopus. Due to time constraints, it was not feasible to include more than one database within this literature review. Elsevier's Scopus was chosen based on being one of the most extensive databases when it comes to the scope of different fields and not being an

exclusively medical database. The search strings were created to limit the number of studies to about 600 by including and excluding specific keywords to find studies that meet the specific inclusion criteria.

The preliminary search string creation involved the identification of inclusion and exclusion key words. Due to the specificity of the current research question, the search string was focused on identifying psychological immersive VR interventions of all kinds. Therefore, most key words are focused on excluding medical interventions and other literature reviews. Each key word was used in combination with the search string 'TITLE-ABS-KEY' to ensure that the search engine looked for the key word within the title, abstract or key words of each study. The *inclusion key words*, each connected by AND are as follows: *psychology OR psychological, virtual AND reality, Intervention*. The *exclusion key words* were all connected by the search term AND NOT and included *medical, meta AND analysis, orthopedic, cancer OR cardiovascular OR stroke OR cardiac OR covid * OR respiratory, review OR critique, spinal OR birth OR tumor, pain AND management*. The above-mentioned key words were combined in the Scopus search engine and the * sign was used to exclude all words which contain *covid* within them.

Even though all studies were extracted from Scopus, during the screening process, the reports' DOIs were used to find further information about each study, hence multiple different websites were used for in-depth analysis of the reports. This search was conducted on the 20th of February 2024 and yielded 614 studies.

Review Procedure

To continue with the review process, the full list of extracted studies was transported to Ray.Yan. Ray.Yan is a literature screening software which allows for systematic screening of study titles and abstracts as well as their categorisation into included and excluded groups. The program identified 4 duplicates within our studies, after which 2 studies were removed, leaving 612 studies for the review process. The screening process consisted of 2 steps which are described below. First, the author and another researcher split the studies in half and each of them assessed each study's title and abstract in

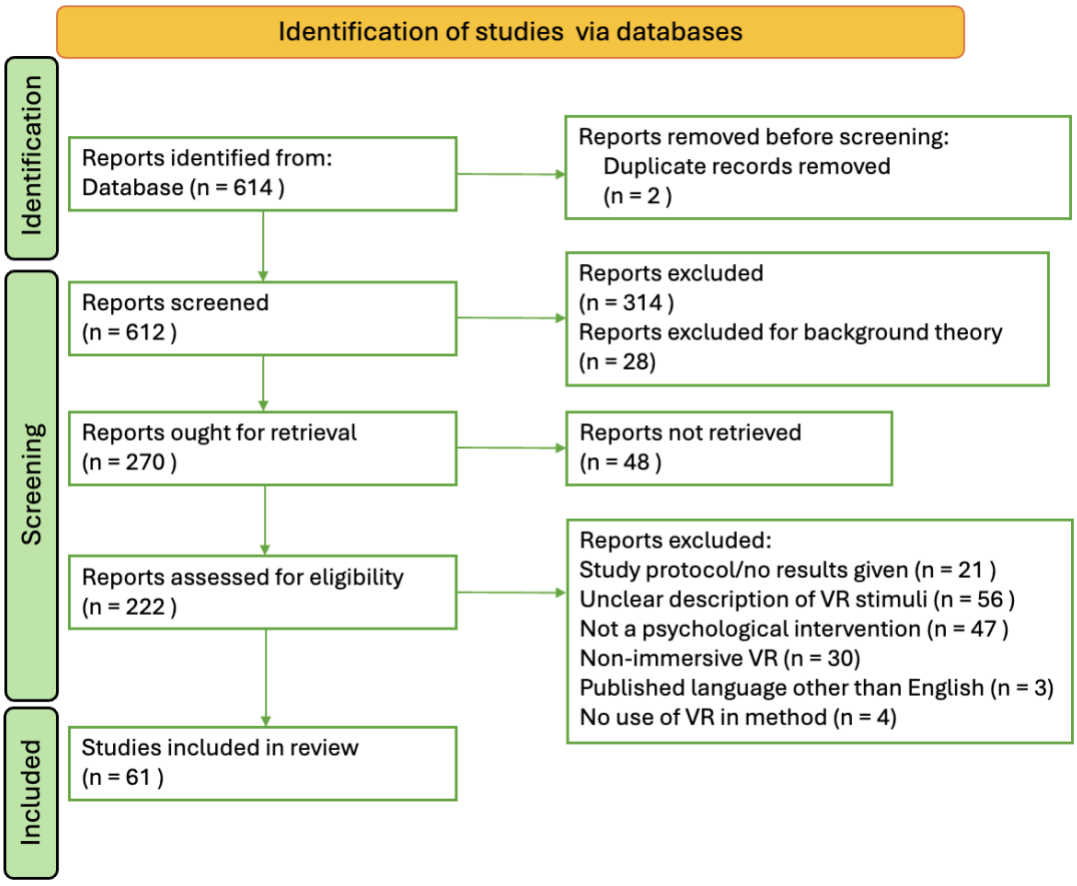
their half of the sample. Each study was then marked as 'included/eligible', 'excluded/not eligible', or 'maybe included/maybe eligible'.

After the first stage of review, 223 were excluded and 110 were identified as 'maybe included'. About 40 studies identified as 'maybe included' were then screened by the first supervisor, with the rest being screened by the author and another researcher based on the feedback received from the first supervisor. After screening of all studies in the maybe category, 314 were excluded, leaving 298 in the dataset. The studies excluded using Ray.Yan were excluded with reasons, which are as follows: studies did not use XR (n = 81), studies were not psychological interventions (n = 151), studies who's reports could not be retrieved (n = 9) and studies excluded for other reasons (n = 73). Studies excluded for other reasons, were excluded based on the exclusion criteria outlined above, however due to procedural failures, the reasonings behind their exclusion were not noted during the process. Furthermore, 33 studies were excluded from the dataset as their relevance was limited to providing general background theory rather than directly addressing our research focus, leaving 270 for the full-text examination. The full graphic representation of the screening procedure as well as its description, can be found below in Figure 1.

After the initial screening of titles and abstract, the studies that met the eligibility criteria (n = 270) were downloaded from Ray.Yan and summarized in a Microsoft Excel table for detailed data extraction. The author and another researcher separated this table into 2, with each containing about half of the eligible studies. Afterwards, they each analyzed the full texts of their half of the studies and summarized the relevant information in an Excel table. During this step, 48 studies were removed due to the inability to retrieve the full text documents, mainly due to pay-walls and differing languages. To ensure that only studies pertaining to immersive VR psychological interventions were included, the Excel table was screened once more.

Figure 1

PRISMA Flowchart of The Study Selection and Screening Process



During this step, 48 studies were removed due to the inability to retrieve the full text documents, mainly due to pay-walls and differing languages. To ensure that only studies pertaining to immersive VR psychological interventions were included, the Excel table was screened once more. During the review of the full reports, one more exclusion criterion was created which removes studies which lack significant information regarding VR stimuli. Studies excluded due to this exclusion criterion usually either referenced another paper which included the in-depth description of VR stimuli, or simply included information regarding study procedure, but no information on VR stimuli. During the final screening, studies were removed, due to being study protocols (n = 21), not being immersive (n = 30), containing unclear descriptions of the VR programs (n = 56), not being psychological interventions (n =

47), being in a different language (n = 3), or not using VR (n = 4). Any uncertainties regarding inclusion/ exclusion of studies and their categorization in further steps were resolved by the first supervisor. After the full-text screening, 61 studies were identified as eligible. The PRISMA flowchart, provided in Figure 1, is a clear graphic representation of the procedure from the search results to the final number of included studies.

Data Extraction

To answer the research question, we gathered information from each study. This information included the number of participants (total and per group, where applicable), any important demographic information and any relevant diagnostic information. We identified how participants were separated into the different conditions. For general information, we also included the most important information regarding the research question, procedure and findings of each study. Furthermore, to answer the research question, we also gathered information regarding the type of VR used as well as the specific program used. We identified any information regarding the VR stimuli, and all the sensory effects used for the creation of the virtual environment. Finally, we gathered information about the experimental task and any priming or pre-exposure to stimuli that occurred during the procedure. To find all this relevant information, the full text of each study was assessed, particularly the methods and results sections to gather relevant information, as well as section on the description of the intervention, which is the most relevant for this paper. Due to the extensive amount of information gathered required for proper screening of studies, only the most relevant information regarding the research question will be included in the results tables.

The information gathered from all the included studies, was used for the creation of a checklist intended for the support of the creation of future VR interventions. The checklist was created based on the information regarding VR stimuli and their sensory feedback(s) and contains questions that are meant to guide future researchers through VR intervention creation by providing questions for the

researchers to think about regarding their design decisions. The checklist was created using the Mind-mapping tool, Miro. The full checklist will be presented and explained in the following results section.

Results

After all the screening procedures, 61 articles were included in the final dataset. The following results section will first present trends found across all interventions regarding types of interactions and stimuli presented in VR. Afterwards, the categorization of the different interventions will be presented and explained. Finally, the created checklist will be discussed and explained in detail.

Trends across categories

The results tables, presented in the Appendix B, were used for the identification of trends across all categories. The trends that were identified are regarding Type of stimuli in VR, the type of VR interaction, how the VR was presented, freedom of movement in VR, presence of interactable elements/objects, and the ability to change elements of the environment. The following section will present the distribution of all studies across these trends and their detailed descriptions.

Types of Stimuli in VR

The types of stimuli in VR refers to the main elements of the VR program, namely personal stimuli, direct avatar interaction, background avatars, and environment only. Personal stimuli refer to interventions in which all content of the intervention is personalized to each participant, such as in Reminiscence Therapy. Direct avatar interaction describes VR interventions of which a key part is a direct conversation with a virtual avatar. The background avatars describe interventions in which avatars are present as part of the environment, meaning no interaction with avatars is present. Finally, environment only refers to interventions which contain no avatars, meaning only the environment is present. These different elements of VR, except for personal stimuli, overlap in one direction. More specifically, if a study is identified as having direct avatar interaction, it is implied that it also contains a general environment and may contain background avatars. Studies labeled as background avatars also

contain an environment. The final distributions are as follows with the graphical representation being presented below in Figure 2: Direct avatar interaction (n = 14), background avatars (n = 13), environment only (n = 28), and personal (n = 6).

Types of VR Interaction

The trend of Type of VR interaction refers to hardware that the participant used to interact with the VR program. The types of interaction within this category are exclusive, meaning each intervention could only be placed in one category. The results are as follows, with the graphical representation shown below in Figure 3: No interaction (n = 26), VR controllers (n = 28), treadmill (n = 3), exercise bike (n = 2), and other (n = 2). The no interaction category refers to intervention in which participant were unable to interact with the VR environment, meaning they merely experienced it. The category of VR controllers encompasses interventions that utilized VR controllers in the forms of buttons and joysticks, as well as interventions that used VR controllers to simulate movement of VR activities, such as gardening or fishing. Categories of treadmill and exercise bike used either of the exercise equipment during their VR procedures. Finally, the category of Other encompassed studies utilizing a unique type of interaction. One study utilized a driving console to simulate driving under the influence to achieve behavior change (Vankov et al., 2021), while another study utilized hand gestures to enhance social functioning of children with autism (Cai et al., 2013).

Types of VR Presentations

The Types of VR presentations refer to how the participant experienced the VR environment. More specifically, out of the 61 included studies 59 used head-mounted displays (HMD) for their VR presentations. This may be because this study only included immersive VR interventions, which were determined by the way they were presented. Due to this, only two studies included used a different form of presentation. One study utilized projectors to create wall projections across three of the four walls in a room, enabling the participant to still be immersed (Cai et al., 2013).

Figure 2

Bar Graph of the Distribution of Interventions across VR stimulus types

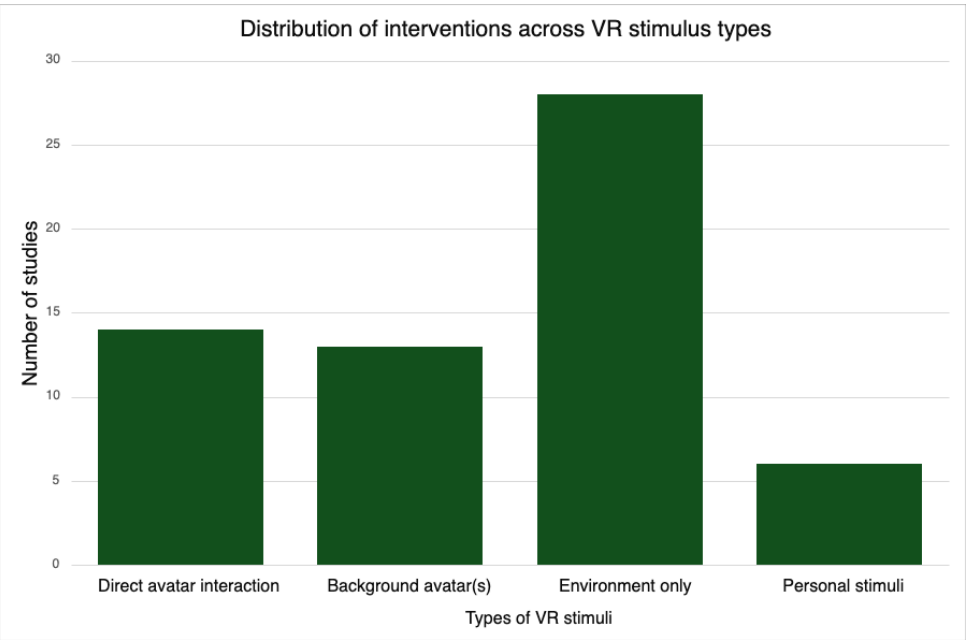
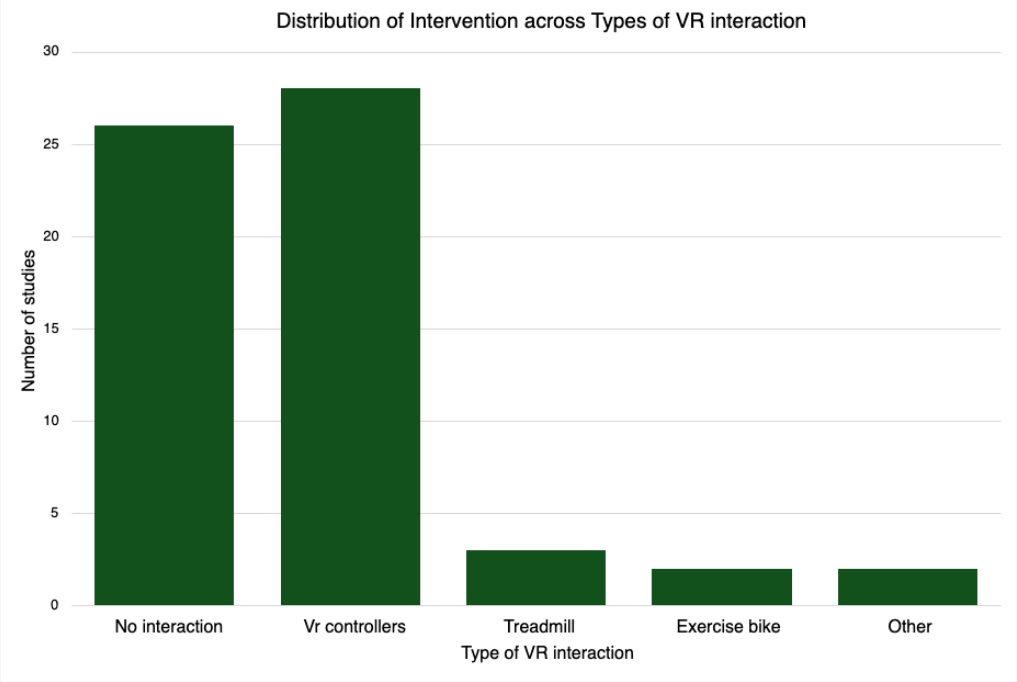


Figure 3

Bar graph of Distribution of interventions across Types of VR interaction



The second study, which did not make use of HMD, utilized three computer screens which were presented so the participants saw what was right in front of them in the environment as well as to their right and left (Schwebel et al., 2014).

Types of Sensory Feedback in VR

This trend category refers to the different senses stimulated by the VR environment and outside environmental factors that were kept constant. The sensory factors include Visual, Audio, Tactile, Haptic, Olfactory, Proprioceptive and Exteroceptive. In terms of constant environmental variables, they included temperature, humidity and PM concentrations. The trend will be presented by reporting the number of studies that utilized specific sensory feedback out of the entire dataset, for every sensory feedback. As may be evident, all 61 interventions utilized visual feedback, while 44 also used audio feedback. The 17 studies which did not use auditory feedback were mostly concerned with natural environment exposure or relaxation interventions. Two studies used tactile feedback and two studies used haptic feedback. One of the interventions reported as haptic feedback, identified their own sensory feedback as tactile, however as they used a rumble platform to recreate shaking of the ground, the author believes that reporting this intervention as haptic feedback is more accurate (Brito et al., 2021). Three studies utilized olfactory feedback. Only one study utilized proprioceptive feedback, the form of which was not specified, and exteroceptive feedback, received via a giant fan to increase the immersion of a free fall scenario (Brito et al., 2021). Finally, in terms of constant variables, only three studies kept the temperature constant throughout the intervention. One of these studies not only controlled temperature but also humidity and particle matter concentration using a real-time sensor package (Yin et al., 2019).

Other VR Trends

The rest of the trends found within this literature review are concerned with the ability to move in VR, the presence of interactable elements/objects and the ability for the participant to change

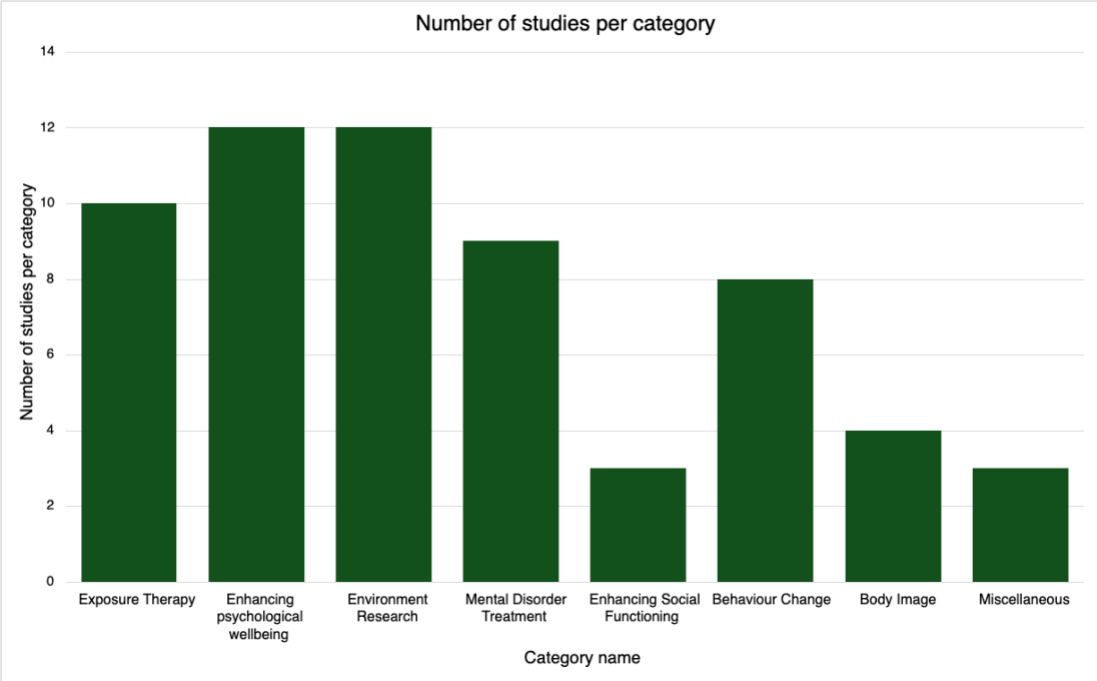
aspects of the environment. Due to each of these trends either being present or not, the use of graphical representations can be considered unnecessary. In terms of freedom of movement, it refers to the participant's ability to freely move or teleport across the VR environment. From the included studies, 23 included Freedom of movement in their intervention, while 38 did not. The presence of interactable elements/objects refers to any aspects of the VR that the participants were able to 'physically 'interact with, like certain activities (e.g. fishing) or picking up objects. 17 studies utilized interactable elements in their program, while 44 did not. Finally, changing aspects of the environment refers to the ability of the participant to change the environment to suit their needs or preferences, for instance changing the time of day or weather. 57 interventions did not include any change-able elements, while four studies, focusing on exposure or relaxation interventions, included the ability to change the environment.

Report Categorization

To allow for the comparison of the intervention stimuli, the author first categorized the studies based on the type of therapy utilized or based on the specific aim of the interventions. All the 61 included articles were separated into eight categories based on the aims of the interventions. Figure 4, below, shows the graphical representation of these categories. The studies in category, 'Exposure Therapy' (n = 10) utilized VR for the creation of Exposure Therapy interventions. The category 'Enhancing Psychological Wellbeing' (n = 12) encompassed studies whose focus was on improving well-being or lowering stress in general populations. 'Environment Research' (n = 12) focused on interventions which utilized exposure to natural environments to achieve different goals. The category of 'Mental Disorder Treatment' (n = 9) also focused on improving well-being, however the interventions were aimed at individuals with specific mental health disorders. Studies found in the category, 'Enhancing Social Functioning' (n = 3) were concerned with enhancing the social skills of individuals who might struggle with social situations, such as people with autism.

Figure 4

Bar Graph of the number of studies per category



Interventions within the category ‘Behavior Change ’(n = 8) mainly focused on different types of behavior changes, including but not limited to pro-environmental behavior or smoking cessation. The category of ‘Body Image ’(n = 4) included interventions whose aim was to change the participants ’body image, to improve well-being, eating and exercise habits. Finally, the ‘Miscellaneous ’(n = 3) category encompasses three studies whose aim did not match any of the previously mentioned categories and which will be described individually.

Using the categories created above, certain similarities and unique stimuli surfaced within each category. These environmental properties of the intervention will be presented in the text below, separated by the created categories. The full results of each category are presented in Appendix B, with the description of the results tables found in Appendix A.

Exposure Therapy

The category of *Exposure Therapy* was made to include all articles which utilized Exposure Therapy in VR. These studies were namely concerned with treating different phobias (n = 2), PTSD (n = 4) and anxiety (n = 2), but also include gambling (n = 1) and obsessive-compulsive disorder (OCD) (n = 1). The following section will present the descriptions of all the key information gathered from VR exposure therapy intervention, with the full results presented in Table B1, at the end of this paper.

Exposure Therapy is defined by gradual and repeated exposure to a fearful stimulus or situation, hence all the studies in this category contained leveled hierarchies of exposure. The interventions aimed at phobias, focused on aerophobia and claustrophobia, respectively. Both interventions used more than one VR environment for exposure and allowed the participant to freely move around. (Botella et al., 2000; Banos et al., 2002). In terms of sensory feedback, both interventions utilized both visual and auditory stimuli, enhancing the immersion of the exposure scenarios. The aerophobia intervention included multiple interactable elements across all three environments, such as the window and tray on the airplane (Banos et al., 2002). No interactable objects were present in the claustrophobia intervention, but the participants were able to change certain aspects of the virtual environments to change their level of exposure (Botella et al., 2000). Finally, unlike the claustrophobia intervention, the aerophobia study included not only the airplane environment but also environments associated with airplane travel, such as the airport or the participant's room while they pack for the flight (Banos et al., 2002).

The Category of Exposure Therapy included 4 interventions on combat-related PTSD or treatment-resistant PTSD. The difference between exposure therapy for PTSD and other forms is that the VR stimuli for PTSD interventions must be tailored to the traumatic events of the participant. Due to the specificity of VR environments in PTSD interventions, only information regarding sensory feedback was included in the final table. One article focusing on combat-related PTSD created personalized

exposures for each participant that not only included visual and auditory stimuli but also delivered scents associated with the traumatic scene through a scent machine and tactile feedback through a rumble platform (Beidel et al., 2019). The other 3 interventions on PTSD all used a form of virtual reality and motion-assisted exposure therapy, called 3MDR (van Gelderen et al., 2020; Tang et al., 2021; Smith-MacDonald et al., 2023). 3MDR involves the participant being put on a treadmill in VR, where they are exposed to a pre-selected image that is related to the participant's traumatic memory. 3MDR uses a number recall task after each exposure, music inducing traumatic events and relaxation music to desensitize the participant to the memory.

Both interventions aimed at social or public speaking anxiety utilized social interactions with avatars in their exposures. Specifically, the self-guided anxiety intervention exposed the participants to a visual-only environment containing multiple avatars. As the intervention was self-guided, participants were able to modify aspects of the environment on 3 levels (low, moderate and high), including audience size, audience reaction, speaker's distance from audience, number of speech prompts and salience of self (Premkumar et al., 2021). The second VR intervention on social anxiety focused on making the exposures more personalized to the participant by creating a hierarchy of virtual visuo-auditory social situations according to the participant's anxiety levels (Kampmann et al., 2016). This allowed the participants to experience a hierarchal exposure to fearful situations tailored to their individual fears. However, this also meant that the study included little information regarding stimuli due to the large variety of virtual environments created.

Finally, Exposure Therapies for gambling and OCD both included being immersed in virtual environments with triggering stimuli. The gambling intervention utilized a timed exposure to specific triggering VR stimuli, such as video lottery terminals, along with ambient music and sounds to decrease the primed urge to gamble (Giroux et al., 2013). The OCD intervention exposed participants to a visual-

only contaminated area with various degrees of filthiness which were ordered from medium intensity to the most distress-provoking stimulus (Miegel et al., 2022).

Enhancing Psychological Well-being

The Category titled *Enhancing Psychological Wellbeing*, focused on interventions that aimed at improving the general well-being of people in different contexts. More specifically, it involves studies that do not focus on individuals with mental health problems but rather on improving the general well-being of for instance, university students, people receiving an operation or community-dwelling older adults. The articles in this category can be separated based on the VR content and target group as follows: four articles utilizing exercise in VR, three articles using natural environments, two interventions aimed at self-compassion and self-statements, two interventions aimed at reducing preoperative anxiety, and one study utilizing VR drawing programs. The full descriptions of the articles in this category are presented in Table B2.

One study out of four focusing on exercise in VR, aimed its intervention at enhancing the effectiveness of exercise through VR (Farrow et al., 2018). The intervention using High intensity interval training focused on improving performance by utilizing VR to motivate participants (Farrow et al., 2018). Participants exercised on a stationary bike while leaning their head to the side to avoid collisions in the visual-only VR. Motivation was increased via the presence of a 'ghost' representing the participant's previous performance, as well as switches from a day environment to a night environment when switches occurred between low and high intensity, respectively (Farrow et al., 2018).

The other three interventions involving exercise focused on introducing VR exercises into the participants' lives to increase their general well-being (Brito et al., 2021; Basharat et al., 2023; Shaw & Lubetzky, 2021). The sensorimotor rehabilitation intervention used various environments, including urban and natural settings, a high-rise building and a free fall simulation (Brito et al., 2021). Just like the exercise intervention described above, the sensorimotor rehabilitation intervention used a stationary

bike for its exploration scenario (Farrow et al., 2018; Brito et al., 2021). The VR environments of this intervention featured visual and auditory feedback with certain scenarios also including olfactory, proprioceptive, tactile and temperature stimuli. For instance, giant fans were used to help increase the immersion of the free fall scenario (Brito et al., 2021). Another exercise intervention, Seas the Day, created a VR environment of an animated island with simple shapes and saturated colors, where participants could interact with the environment through activities like Tai-chi, boat rowing and fishing, using controllers to simulate the movements of these activities (Basharat et al., 2023). Finally, an intervention focusing on reducing stress and anxiety utilized upper body movements in a visual-only VRs environment to play dodgeball (Shaw & Lubetzky, 2021).

Three studies focusing on improving psychological well-being used natural VR environments to induce relaxation and mindfulness in participants (Cawley & Tejeiro, 2024; Chan et al., 2020; Naylor et al., 2019). Both interventions on mindfulness and pre-operative anxiety utilized exposure to natural environments to reduce stress, with the mindfulness intervention using varied animated environments, while the pre-operative anxiety intervention used real-life 360-degree recordings of natural environments (Cawley & Tejeiro, 2024; Chan et al., 2020). Both interventions also encompassed breathing exercises in VR, with the pre-operative anxiety intervention being accompanied by relaxing music (Chan et al., 2020). Finally, the SoundSelf intervention immersed individuals in a world of colorful lights and relaxing music, using a program that creates unique visual effects based on the input music (Naylor et al., 2019).

Two studies from this category focus on raising self-compassion and well-being through positive statements and reflection (Hidding et al., 2024; Kim et al., 2020). The first intervention utilized a microphone with voice morphing for the creation of a virtual avatar, which was able to react to the participant through voice, movement and facial expressions (Hidding et al.). After the perspective change occurred, the intervention used the voice recording of the participant as the voice of the virtual

avatar. The second intervention also utilized virtual avatars but within 3 different environments, an office, a lecture room and radio station (Kim et al., 2020). Participants were able to interact with certain objects, namely books, in two of the three scenarios, which each represented a different domain of life, acting as a guide for conversations with virtual avatars. In the 2nd scenario, the books transport the participant to the lecture room environment, which differs based on the book chosen by presenting different images relevant to the domain in the background of the environment (Kim et al., 2020).

Within the category of *Enhancing psychological wellbeing* two studies focused on lowering pre-operation anxiety in children using virtual cartoon characters (Chamberland et al., 2023; Han et al., 2019). The first intervention utilized visuo-auditory augmented reality (AR) to add cartoon characters into the real-life environment of the waiting room. (Chamberland et al., 2023). The intervention used progressive muscle relaxation and breathing exercises guided by the cartoon characters, to reduce pre-operative anxiety. Both interventions adopted the cartoon characters to have them explain the importance and process of the operation (Chamberland et al., 2023; Han et al., 2019). Instead of employing augmented reality, the second intervention utilized a 360-degree 3D virtual operating room in which all equipment and machines required for radiography were rendered graphically (Han et al., 2019).

The final intervention present in this category involved the investigation of the effect of VR art programs on physiological and psychological stress measures (Richesin et al., 2021). Specifically, participants in the experimental group received 15 minutes in the VR application, Google Tilt Brush, in which they were free to use any virtual equipment to draw freely. The unique part of a VR drawing application is that it allows one to draw in 3D space, creating an immersive environment.

Environment Research

The category of *Environment Research* was created to encompass all articles whose intervention stimuli include natural environments. More specifically, interventions in this category were focused on

exposing participants to different types of natural environments to achieve their aim. The final articles in this category can be separated into two subcategories based on the form of the environmental stimuli: Virtual environments (n = 6) and real-life recordings/images (n = 6). The full descriptions of all articles in this category are in Table B3, at the end of this paper.

The six interventions using virtual environments all created their own animated natural environments using different graphics programs (Ilioudi et al., 2023; Yin et al., 2019; Wang et al., 2022; Riches et al., 2023; Lau et al., 2010; Batistatou et al., 2022). The VR calm room intervention created a virtual beach with mountains and trees in which participants were able to change certain aspects of the environment, including time of day, types of weather and enabling/disabling animal sounds while other aspects changed to match, such as sounds of rain when selecting rainy weather (Ilioudi et al., 2023). Another intervention aimed at decreasing anxiety and depression symptoms, created a VR environment of an animated park, where participants could walk around and interact with the environment through activities such as flying a kite, watering vegetables, fishing and feeding birds, using controllers to simulate the movements of these activities (Wang et al., 2022). Just like in the previous study, the relaxation intervention for acute psychiatric services created an audio-visual environment of a beach island which the participants were free to explore and interact with through different activities such as meditation, scuba diving with dolphins and relaxation exercises (Riches et al., 2023). Two interventions focused on the influence of greenery in different urban environments on emotions and stress reactions (Yin et al., 2019; Batistatou et al., 2022). Yin and others (2019), focused on natural elements and natural analogues in different office environments, while Batistatou and others (2022) created a virtual university campus with and without greenery. The difference between these interventions lies not only with the environment that was used, but also in the fact that the office intervention utilized a real-time sensor package to keep environmental conditions, including temperature, relative humidity and PM concentrations, stable across conditions and participants (Yin et al., 2019). Finally, the Virtual psychiatric

ward intervention created a virtual environment replicating the real-life ward in which participants were free to explore and interact with certain objects, with specific places triggering the appearance of a pop-up message which explained the important aspects of the ward, such as the locked-door policy (Lau et al., 2010).

The other six interventions in this category used real-life 360-degree recordings or panoramic images to expose participants to natural environments (Zhang et al., 2023; Ho et al., 2023; Theodorou et al., 2023; Browning et al., 2023; De Jesus Junior et al., 2023; Woo et al., 2024). Two of these interventions have chosen the specific natural environments used based on having no evidence of human activity (Zhang et al., 2023; Browning et al., 2023). The natural environment used in Zhang and other's (2023) intervention was also chosen by the diversity of vegetation and included environmental sounds. Browning and others (2023) used many environments, including forests, beaches, rainforests and waters, which all included a mixture of three components of natural landscapes, plants, water and rocks/minerals. Another intervention aimed at enhancing subjective vitality, made use of panoramic photos of four different environments, urban, park, lake and arctic which were all taken by the researchers to ensure that they were semi-open spaces with no humans and comparable lighting (Theodorou et al., 2023). Another article was aimed at lowering physiological and psychological stress of factory workers through exposure to 360-degree recordings of real-life environments including parks, hiking trails, forest paths and bikeways recorded during sunny afternoons (Ho et al., 2023). A relaxation intervention aimed at individuals in palliative care, FLOW-VRT, encompassed relaxation coaching in combination with eight 360-degree real-life recordings which were selected based on the following criteria: a serene environment with comforting sounds and visuals, filmed on stationary cameras to minimize motions, low visual disturbances and allowed focusing on a singular point (Woo et al., 2024). The final intervention aimed at individuals with PTSD utilized three virtual audio-visual environments of

an in-mountain lake, Canadian beach and rocky seaside, some of which contained natural sounds and odors, breathing exercise or audio-guided meditation (De Jesus Junior et al., 2023).

Mental Disorder Treatment

The *Mental Disorder Treatment* category includes VR interventions targeted at individuals with a specific mental disorder and whose intervention procedures do not fit to other established categories. Due to the variety and specificity of all articles within this category, no sub-categories can be established. The full description of all studies within this category can be found in Table B4.

The fear of darkness intervention utilizes mobile-assisted VR with five scenarios of increasing difficulty (Paulus et al., 2019). Participants navigate through an animated forest with varying light conditions and torch distances, as well as auditory stimuli like bird and door sounds to enhance immersion.

The intervention aimed at refractory auditory verbal hallucinations made use of a virtual avatar customization procedure, in which participants created avatars embodying their hallucinations (du Sert et al., 2018). The immersiveness of the participant-avatar conversation was enhanced by real-time simulation of the avatar's voice using a microphone with voice transformer and lip-synchronization.

Freeman and others (2018) created an automated VR intervention aimed at fear of heights, which involved a virtual coach created through motion-capture and voice recordings. The virtual coach accompanied the participant through all 10 levels of exposure, each consisting of a different audio-visual environment with certain scenarios being engaging, like rescuing a cat from a tree.

The VR acceptance and commitment therapy intervention utilized audio-visual real-life recordings of five environments, empty desk, lake scene, one person behind a desk, three people behind a desk and a lecture room full of people, accompanied by audio instructions to conduct in vivo exposure (Gorinelli et al., 2023).

An intervention targeted at individuals with borderline personality disorder used an animated VR environment resembling riding a rollercoaster inside of one's brain, with different neurons spanning all over the environment (McLachlan et al., 2021). The intervention utilized gamified elements by having the participants 'pacify' red neurons by pointing the controllers in its general direction, followed by auditory feedback if the neuron was hit.

Kim and Lee (2022) created an intervention aimed at individuals with sluggish cognitive tempo which utilized an animated VR environment of a car driving down a winding mountain road. Different fixations appear above or around the virtual car with audio-visual feedback indicating whether the fixation was faster or slower than the previous one, by tinting the screen green with an alarm or red with a warning sound, respectively.

The Psychedelic replication intervention created a VR environment which simulates psychedelic experiences through visuals and audio (Kaup et al., 2023). The visuals mostly encompass geometric patterns and abstract shapes accompanied by specific soundtracks, created with varying intensities to match the visuals of each level.

The intervention aimed at subjective tinnitus, created participant-specific avatars which recreated the subjective tinnitus sounds of the participants by including five types of sounds, whistling, hissing, roaring, humming and ringing, matched on frequency and loudness (Park et al., 2022). The intervention included four animated audio-visual environments, living room, bedroom, a restaurant and city street, each of which contained a noisy part of the environment, like TV for living room environment, in which the participant was meant to drown out the noise of the tinnitus avatar.

Finally, the alcohol use disorder intervention created a VR environment of an animated city with several areas, a mini market, pharmacy, art gallery and an interactive home, where participants were guided by a therapist to walk around freely while interacting with certain objects to accomplish certain tasks, such as buying groceries (Gamito et al., 2021).

Enhancing Social Functioning

The category *Enhancing Social Functioning* encompasses VR interventions aimed at improving the social functioning of individuals who might otherwise struggle in social situations. The final number of articles included in this category is three, with each intervention focusing on a different target group, specifically people with autism, a psychotic disorder or social anxiety disorder. The full descriptions of all the articles in this category can be found in Table B5.

The intervention aimed at individuals with autism created a virtual dolphinarium displayed via three projectors aimed at 3 walls of the lab (Cai et al., 2013). The environment involved an animated dolphinarium with a glass covering a side of the pool, allowing the participants to directly interact with the dolphins in water. The participants were unable to move within the environment but were able to interact with the dolphins using hand gestures with the correct hand gestures eliciting an audio-visual response from the dolphins of them doing the correct trick and producing noises.

The psychotic disorder intervention, DiSCoVR, utilized three animated environments including a shopping street, a caffe and a supermarket which included different non-player characters, namely people walking down the street, two people interacting together and an NPC interacting with the participant directly, respective to each environment (Nijman et al., 2022). The characters on the shopping street exhibited multiple facial expressions that were to be identified by the participant, while the two individuals in conversation in the caffe used voice recordings to allow the participant to observe a personal conversation. The character interacting with the participant directly was controlled and spoken for by a therapist using a voice morphing program.

Finally, the social anxiety intervention, Pegasys-VR, created a VR environment of an animated school with non-player characters for the participant to interact with (Beidel et al., 2021). The participants interacted with different characters to conduct peer generalization exercises. The environment also includes gamified elements which support the practice of social skills, such as

identifying open-ended questions. Finally, the in vivo exposure of Pegasys-VR was customized to everyone's unique fear, such as giving a speech or reading aloud.

Behaviour Change

The category of *Behavior Change* includes interventions focused on achieving behavior or attitudes changes in their participant to enhance their personal wellbeing or the wellbeing of others. Due to the variety and specificity of each intervention in this category, no sub-categories were identified. The full descriptions of all studies within this category are in Table B6, at the end of this paper.

The first intervention, focusing on pro-environmental dietary change, created three animated environments of a living room and a Swedish and US mountain, depending on condition (Plechatá et al., 2022). The living room included an interactable tablet, showcasing images of different types of foods which the participant was expected to select. Both mountain environments were meant to represent nature 30 years into the future and because of that two versions of each environment were created to reflect the environmental effects of the participant's food choice. One environment was covered in brown smog with dying trees and no grass or animals, while the second environment showed the exact opposite, a green flourishing mountain. The participants also received either normative feedback, showing the KG of CO^2 consumed and compared to the average Scandinavian, or generic feedback which included only KG of CO^2, both of which were presented via a pop-up message, along with an environmental impact food pyramid, after exposure to the mountain environment (Plechatá et al., 2022).

Another intervention aimed at lowering hot water use utilized a virtual animated shower with a window showcasing different stimuli, depending on the condition (Bailey et al., 2014). The vivid conditions showed two tables outside of the window, with one containing a pile of coal which was one by one transported to the other table to indicate energy consumption. The vivid personal condition also

included a virtual avatar, created using pictures of the participants, which would eat every piece of coal transported to the second table, which was accompanied by auditory feedback of crunching sounds and haptic feedback to increase immersion of the avatar chewing on coal. The non-vivid conditions showcased simple posters hanging on the wall outside the window, stating either "You have used 1 piece of coal." or "1 piece of coal was consumed.", respectively (Bailey et al., 2014, p. 579).

An intervention enhancing peace promoting attitudes and emotions, utilized a real-life 360-degree visuo-auditory recording along with imagined and immersive perspective-change procedures (Hasson et al., 2019). The recording showcased a Palestinian couple approaching a military roadblock where they are stopped by soldiers who begin inspecting them, with the video ending once the Israeli soldiers point their rifles at the couple. The recording contained two versions, one with the camera on the side of the Israeli soldiers and one with the camera placed on the other side, to enhance the immersive perspective-change conditions.

Ingram and others (2019) created an intervention aimed at bullying prevention which encompassed three VR bullying-relevant animated scenarios along with perspective-change instructions. The first scenario involved a virtual character getting bullied by their peers, after the character's best friend starts to get bullied too, the character joins the bullies to regain their social standing. The second scenario involves multiple ineffective responses to bullying from a teacher, such as "It's not a big deal." (Ingram et al., 2019, p. 76). The final scenario transported participants into a future where no bullying exists, and the avatars present explain how that was achieved.

Another intervention focused on reducing driving under the influence by having the participants experience what it is like to drive under the influence in a VR environment (Vankov et al., 2021). The first animated environment created for this intervention was a night club environment where participants were to decide what substance they'd like to experience, alcohol, marihuana, mushrooms or ecstasy. In the second animated environment, participants were placed into a driving simulator console before

experiencing a winding road with trees along its side. The alcohol condition reduced the participant's field of vision and created a delay between the participants command and the vehicle's response. In the ecstasy condition, everything moved at an increased pace with sharpened sensors and intervals of colorful, blurry and flashy colors. When selecting marihuana, the environment would be slowed with a reduced vision field and mutated colors. Finally, the magic mushroom condition changed the environment to an unrealistic and imaginary scene with characters, while also switching the console inputs to their opposites, meaning if the participant wanted to turn right, they had to turn the wheel left.

The intervention for bystander helping behavior, created a VR animated bar environment including a bar, a wall of alcohol bottles and three by-stander non-player characters present in the environment (Rovira & Slater, 2022). In the VR environment, the participant conversed with an avatar, wearing a football uniform, before being approached by a different avatar, wearing a different football uniform, who proceeded to start an altercation between two non-player characters. The speech of both avatars was presented via pre-recorded voice lines done by two different actors.

An intervention aimed at teaching children to safely cross the street, created a virtual animated environment of a midblock crosswalk across a bidirectional two-lane road (Schwebel et al., 2014). The intervention is presented using three computer screens to allow viewing of the crosswalk and cars arriving from both directions. The virtual environment is detailed and contains background stimuli of suburban houses with trees and different cars passing by. Once the participant decides to cross the street, the environment switches to a 3rd person view to show a race- and gender-matched avatar crossing the street to see if it was safe or not.

Nowak and others (2020) created an intervention aimed at increasing intentions to get the influenza vaccine. The intervention involved multiple animated environments, namely, a restaurant in which the participants transferred influenza to avatars, inside-body environment in which participants

were to send immune cells after the influenza virus using VR controllers, a hospital environment with the infected avatar, a doctor's office in which participants were administered influenza vaccine, and the restaurant environment without the coughing stimuli (Nowak et al., 2020). Transferring of influenza virus was indicated by coughing noises and animations of particles travelling through the air.

Body Image

The Category of *Body Image* includes interventions whose aim is to improve the participants' body image disturbance and body satisfaction. Four studies were included in this category, with two of them using multiple models of different sizes which were to be identified and judged by the participant. The full descriptions of all four studies within this category can be found in Table B7.

The body image intervention, Resize Me!, created two virtual animated environments, one replicating the lab which was used for character creation and one simulating a typical therapeutic office with indoor plants and a mirror which was used for the body weight estimation procedure (Döllinger et al., 2022). The researchers created an avatar based on the scans and measurements of the participants after which the size of the avatar was edited so that nine weight-different models were created which were gradually replacing the original avatar throughout the procedure, while the participant estimated their body weight.

The second intervention which used multiple models of different weights, created a visual-only virtual animated environment of an office including planters and bookshelves, in which participants were presented with individual models that they had to identify as either thin or fat (Irvine et al., 2020). The researchers created an avatar matched by height, gender and baseline measurements which was then edited into 15 models ranging in BMI from 15.45 to 33.70

The body image satisfaction intervention created two visual-only virtual animated environments, differing on conditions, in which participants were expected to approach three groups of three people in order of their preference (Purvis et al., 2015). The first environment created for the low

body salience condition involved an indoor university building in which avatars wore long-sleeved shirts and long pants. The second environment created for high body salience encompassed a beach scenario with avatars wearing different swimsuits. In both environments, the three groups of three avatars, each with different body weights.

Finally, the full body illusion intervention created a virtual animated environment of an empty room in which participants focused on the naked abdomen of their avatar (Keizer et al., 2016). During this, a researcher uses a brush to stroke the participant's abdomen, which also contains a movement sensor to allow the simulation of the movement of the brush in VR, creating visuo-tactile feedback.

Miscellaneous

The Category of Miscellaneous contains interventions which are completely unique in their design and hence do not fit into any other established categories. The three interventions present in this category focus on reminiscence therapy, increasing empathy in informal caregivers of people with dementia and organizational training, respectively. The full descriptions of all three interventions can be found in Table B8.

The reminiscence therapy intervention utilized interviews to gather personal information regarding participant's key memories and elements associated with those memories, such as music, to create a virtual environment as well as slideshow of pictures and videos (Khirallah Abd El Fatah et al., 2024). Due to the specificity of the VR environments and other stimuli in reminiscence therapy interventions, only information regarding sensory feedback and types of stimuli was included in the final table. The stimuli included exposure to a slideshow containing old photos along with audio descriptions of the important memories associated with those pictures. VR Wander was also used for re-creation of participant's hometown in the VR environment accompanied by music from participant's early lives.

The second intervention, D'mentia, used a shipping container which was furnished as a living room with a kitchen along with projections across the room to help simulate what it is like to have

dementia (Wijma et al., 2017). The projections encompassed different audio-visual animated movie scenes that the participants watched, including a person with dementia struggling to find the fridge to clear the groceries and realizing they bought the groceries twice, a person with dementia being confronted by their informal caregiver about where the TV remote is before complaining about the situation to someone on the phone, and the person with dementia celebrating their birthday with other people but they do not understand why there is cake and have a strong feeling that they want to go home even though they already are.

Finally, the organizational training intervention created a virtual animated visuo-auditory environment of a biotech laboratory including virtual scientists which guided the participant through the organizational training (Baceviciute et al., 2021). The virtual laboratory presents the participants with different information in different forms, namely conceptual information presented through exercises requiring body movements that simulate conducting lab experiments, factual information presented via static posters around the lab, and spatial knowledge presented in the same way as conceptual knowledge with more emphasis on spatial visual representations.

Checklist

The following section will introduce and explain all sections of the checklist created using the information gathered in this literature review. The checklist was created with the main aim of enhancing the creation and reporting of VR interventions, by providing future researchers with brainstorming ideas. Specifically, the checklist is separated into multiple sections based on content, each of which presents the researcher with questions that guide the structure of the checklist and follow-up questions meant to initiate the consideration of different aspects of the VR environment. Due to the limitations of the found evidence, presented in detail in the discussion section, this checklist cannot be considered fully complete due to missing valuable information regarding other aspects of VR interventions which were not explicitly described in the journal used in this review. However, the main use of this checklist

would be to be publicly available for researchers intending to create VR interventions in order to have them consider and think about all different aspects of VR environments and how they are able to enhance their intervention goals with their addition. The checklist is intended to be used in early stages of VR intervention development as it mostly concerns the inclusion of different environmental aspects, how they are presented, and how the decisions regarding this aspect my affect the participant experience and the effectiveness of the intervention, hence making it the most beneficial during the planning of the creation of the intervention.

For the clarity of the organization of the checklist as well as the ability to skip irrelevant questions of the questionnaire, the checklist was separated into different sections by the author, based on content of the questions and their relevance to other questions or a specific topic. The different sections created for the checklist are as follows: *General questions*, *VR program Interaction*, *Sensory Feedback*, *VR avatars*, *real-life recordings/panoramic images*, *Digital graphics*, and *Exposure Therapy*. The checklist will be described below and presented as a mind-map along with textual explanations, separated by the different sections. Mind-maps are a form of diagram that visually organize different pieces of information and indicate their relationship to one another. The mind-map was selected as the best way of presenting the checklist due to being able to show the connection between all questions and answers within one section. The mind maps of the created checklist are separated into different colors to enhance the reader's understanding in terms of the different types of questions and information given by the questionnaire. The following section will briefly explain the meaning behind the use of different colours within the mind-map diagrams. Each new section starts with its title in a black box. The main questions on the checklist are presented in red. For most of them, the answers can only be yes or no, which are presented in dark blue squares. The turquoise squares, always connected to the yes/no answers, are follow-up questions or statements, aimed having the researcher consider all the related aspects and elements. Finally, green squares are presented in certain sections and indicate if

they should be skipped. For instance, the section *VR avatars* begins with the question, "Does your intervention make use of virtual characters or avatars?" and if one answers no, the entire section can be skipped. The arrows connecting each square are colored according to the square that they point to. The colors are also meant to help represent how the checklist would look like in the intended survey-format. The blue questions are to be presented as the main questions of the survey, with a multiple-choice answer. Depending on which answer is chosen, the researcher is then presented with the follow-up questions/statements relevant to their answer. At the end of the survey, the researchers would be presented with all the follow-up information, essentially receiving a list of suggestions and questions that they may further consider regarding their intervention. Before the researcher is presented with the different questions in the checklist, they are first introduced to the checklist via an introductory paragraph found in Appendix C.

General Question Section

The section on *General Questions*, presented below in Figure 5, encompasses questions regarding the VR program which do not specifically fit into any of the other established categories and are important to consider for all types of VR interventions. The questions presented in this section encompass freedom of movement, interact-ability of objects, participant's ability to change the environment, constant environmental variables and motion sickness. The follow-up statements presented for each question are tailored to the answer given (either yes or no) and provide either advice or more questions for the researcher to consider before full implementation of the subject in question. These questions were picked based on encompassing general information relevant for all interventions.

VR Program Interaction Section

The *VR program Interaction* section contains questions about the types of interactions available to the participants. The full mind map is presented below in Figure 6. Specifically, this section of the checklist focuses on the hardware used for the interaction between the participant and VR environment.

This section's main concern is raising questions about participant safety and how natural the interaction feels for the participants.

Figure 5

Mind map of the checklist section 'General Questions'

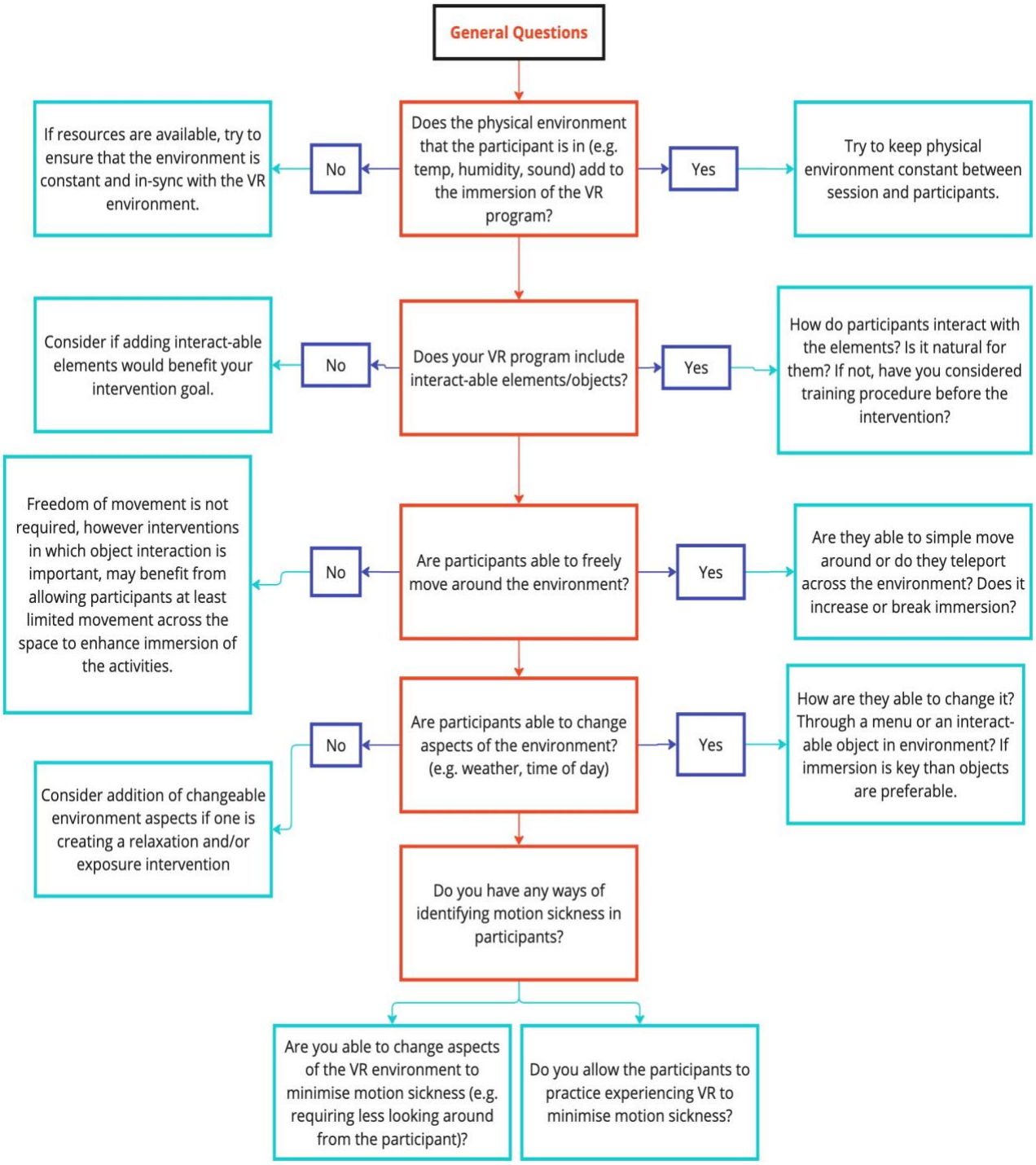
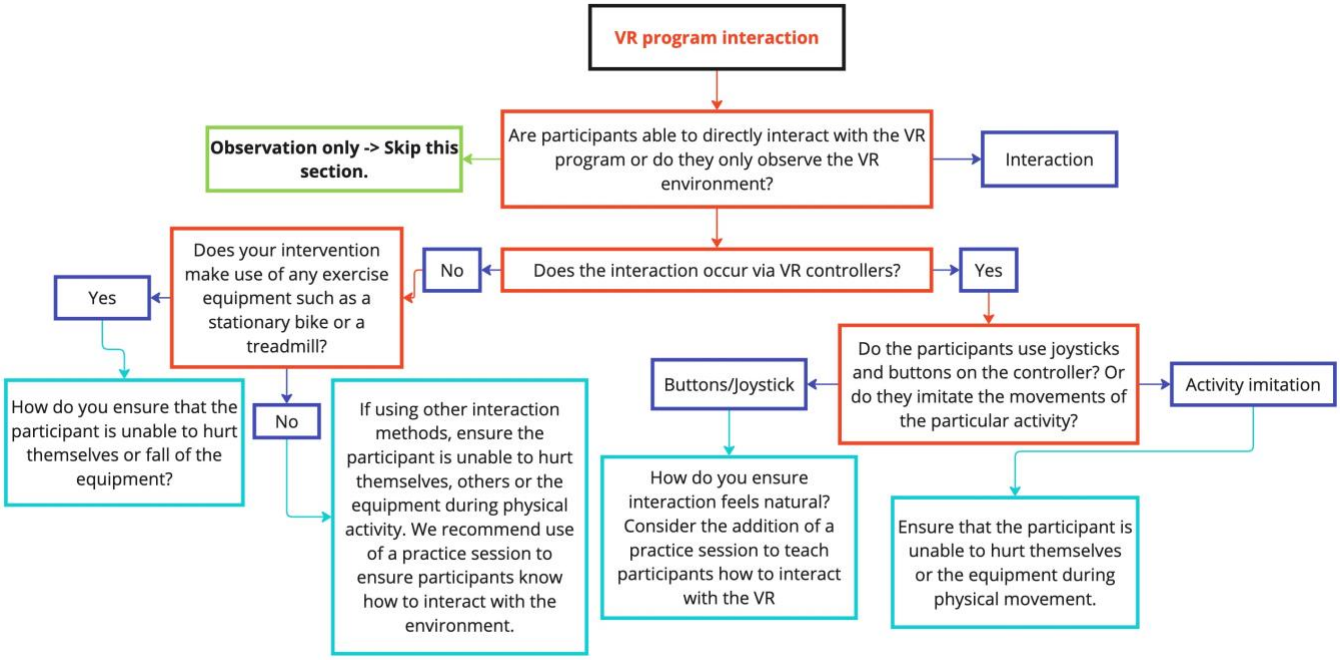


Figure 6

Mind map of the checklist section 'VR program Interaction'



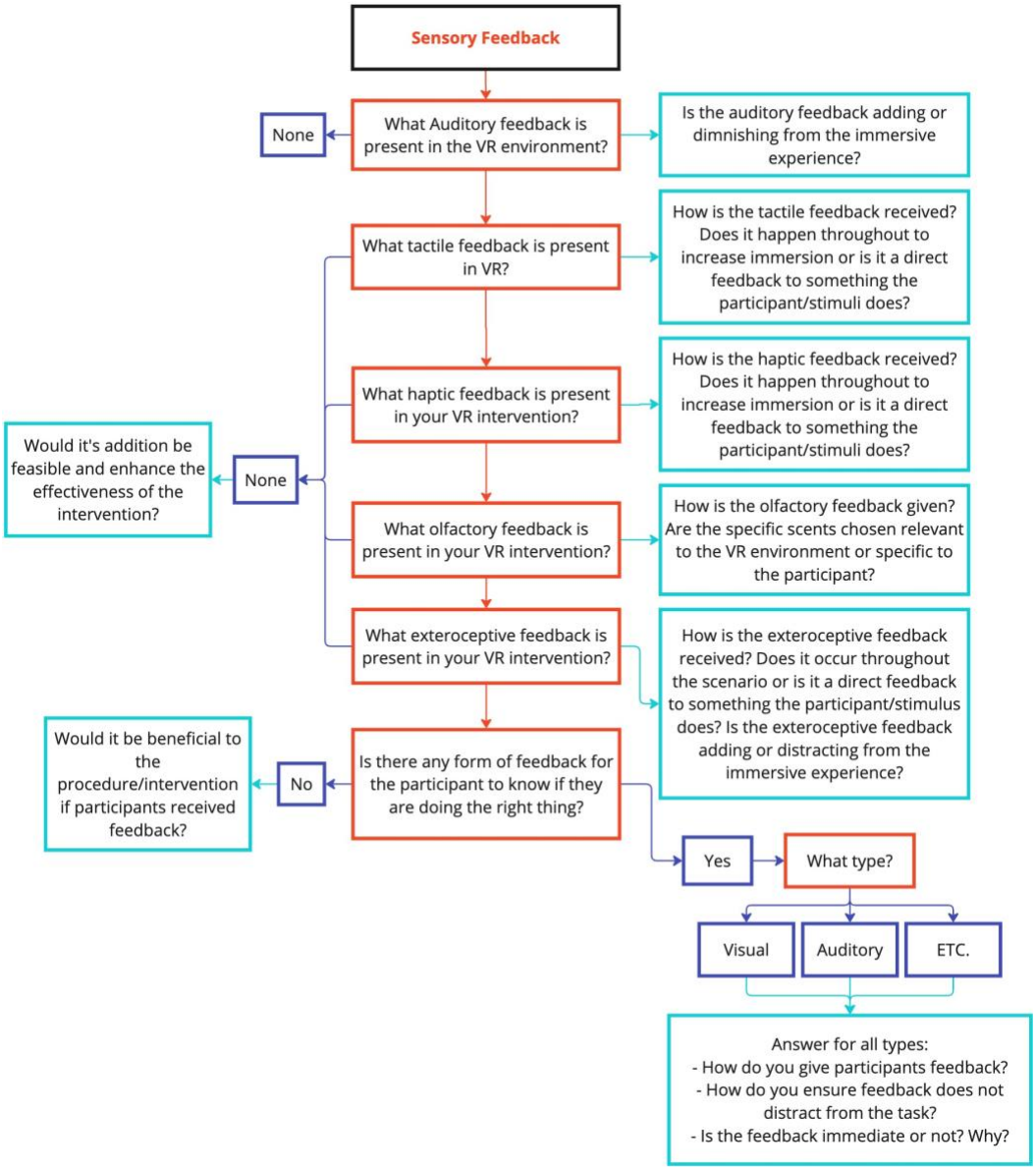
Sensory Feedback Section

The section on *Sensory Feedback* was partially focused on any forms of direct feedback that the participants received for doing the correct or incorrect thing, and partially focused on the general sensory feedback that the participants received within the VR environment. The full mind map of the checklist can be found below, in Figure 7.

The focus of this section is to have the researcher consider all types of sensory feedback and whether their addition and implementation can be considered beneficial for the intervention and immersion, in the current stage. The follow-up questions are aimed at identifying the ways the feedback is presented, if it is beneficial and whether their addition could enhance the intervention.

Figure 7

Mind map of the checklist section 'Sensory Feedback'

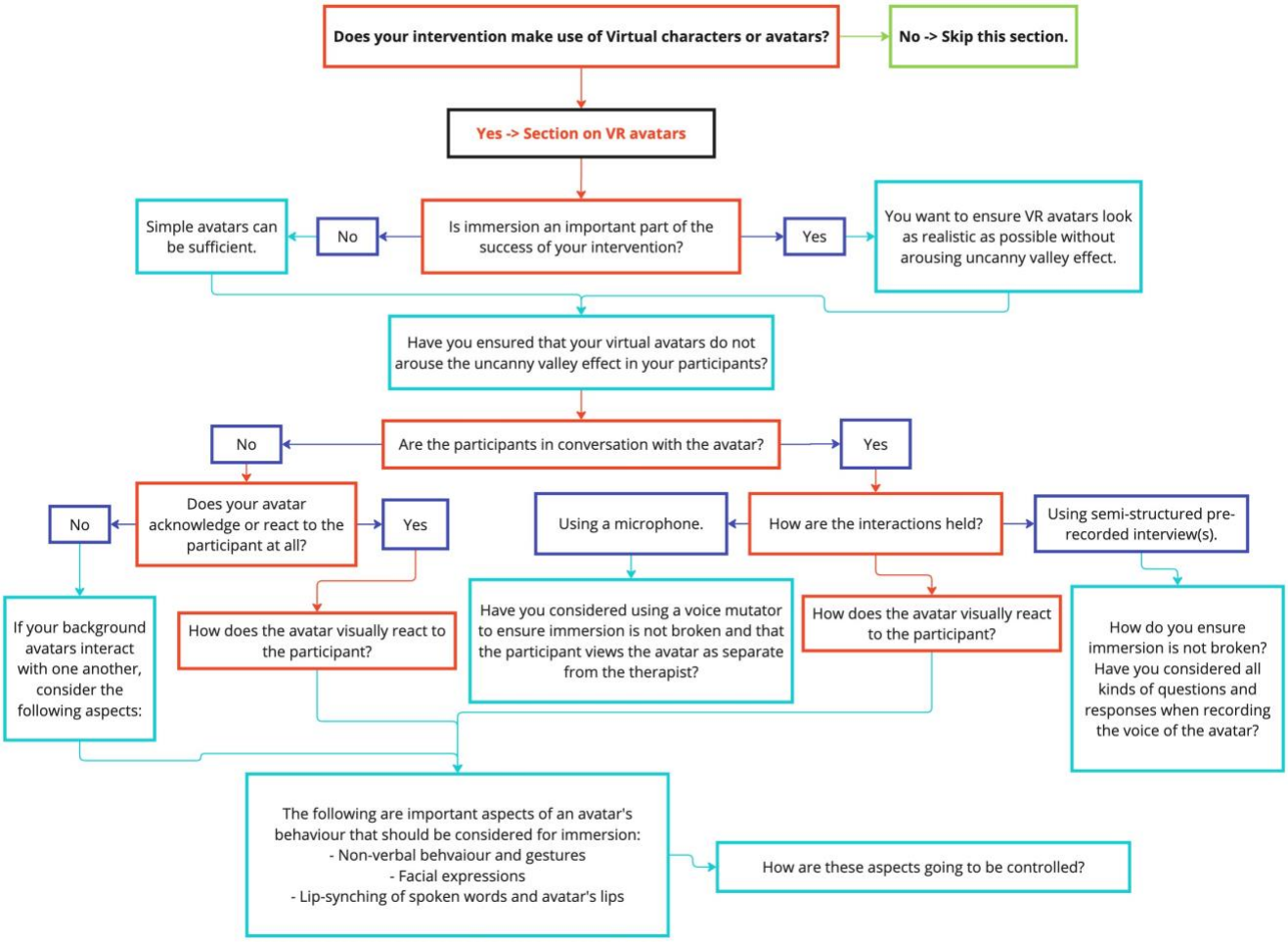


VR Avatars Section

The checklist section on *VR avatars* begins by asking the researcher if their intervention contains any virtual characters or avatars and if the answer is no, the entire section can be skipped. Otherwise, the section contains questions regarding the type of interaction and how they are being held. The full checklist can be found below, in Figure 8.

Figure 8

Mind map of the checklist section 'VR avatars'



The questions found in this section mostly focus on the level of interaction between the participant and the VR avatar, how this interaction is conducted, and the level of detail in the creation of the avatars. The suggestions given focus on testing the avatars for the uncanny valley effect, highlighting all forms of communication that can be utilized, and enhancing immersion through the way the interactions are being held.

Real-life Recordings/Panoramic Images Section

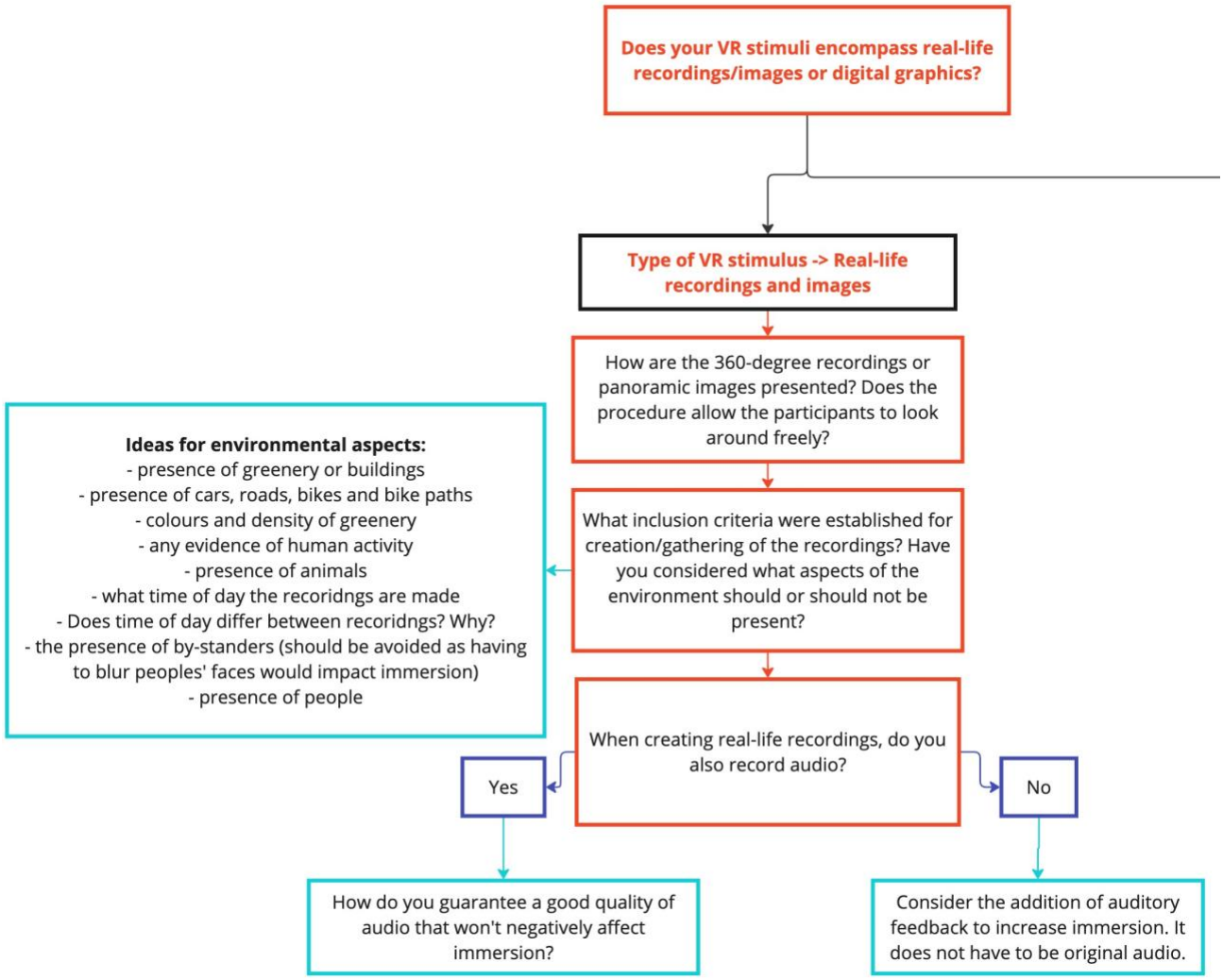
The checklist section on *Real-life recordings and panoramic images* is connected to the Digital graphics section via the first question which asks the researcher to identify which of the two types of

environments are utilized in their intervention. Meaning if the participant selects real-life recordings/panoramic images, they will be presented with this section, otherwise they'll receive the Digital Graphics section. The full mind map of this checklist section can be found below in Figure 9.

This section of the checklist focuses on interventions which utilize real-life recordings for their environments and specifically provides questions and advice regarding the different criteria for recording creation, recording of audio and the interact-ability of the recordings themselves.

Figure 9

Mind map of the checklist section 'Real-life recordings/Panoramic images'

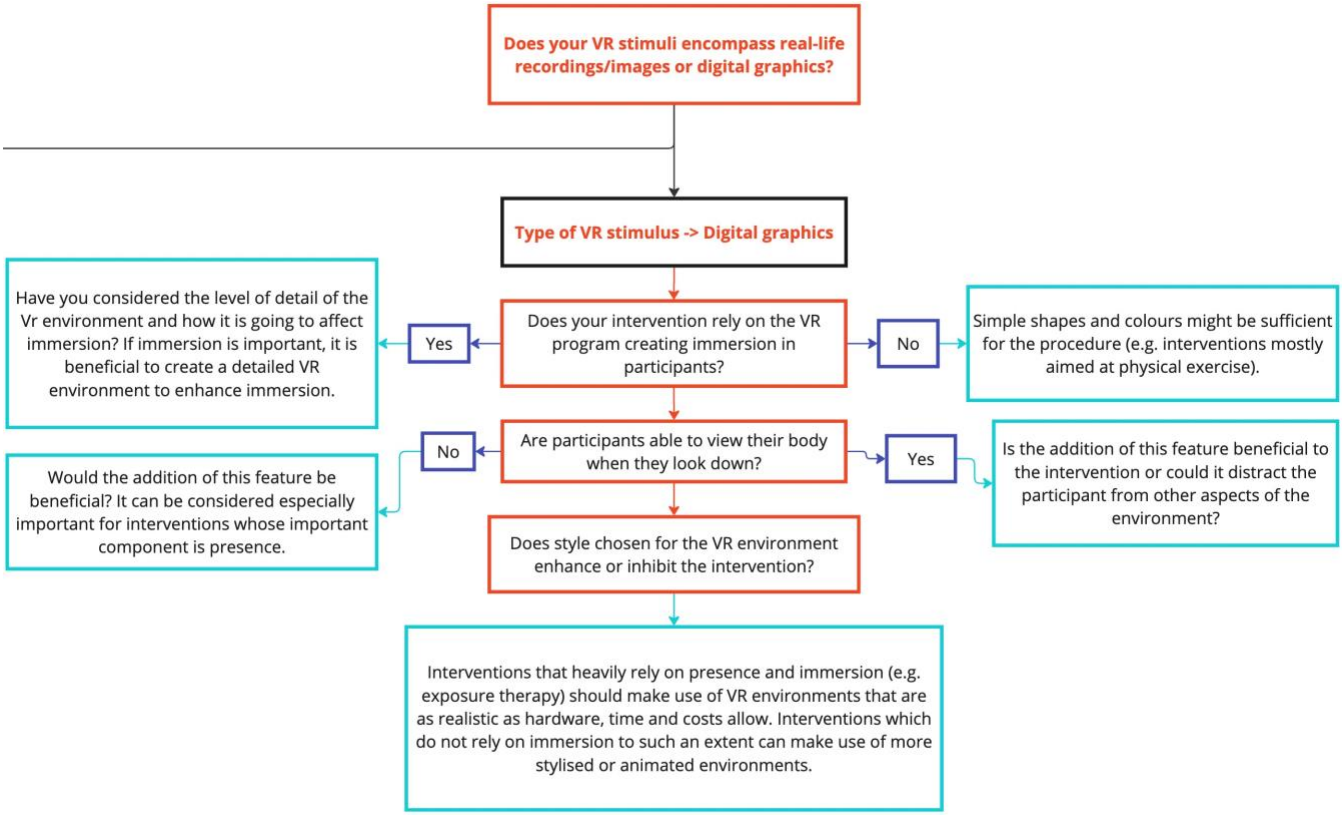


Digital Graphics Section

As mentioned in the section above, this part of the checklist begins with the researcher identifying their VR environment as either Digital graphics or real-life recordings. The *Digital Graphics* section is concerned with identifying the level of detail of used in the VR environment, the participant's ability to view oneself in VR and the style of the VR environment. The follow-up statements are aimed at identifying the levels of detail and style required for different types of interventions, at least regarding those identified within the literature review. The full mind map of the *Digital Graphics* can be found below in Figure 10.

Figure 10

Mind map of the checklist section 'Digital Graphics'

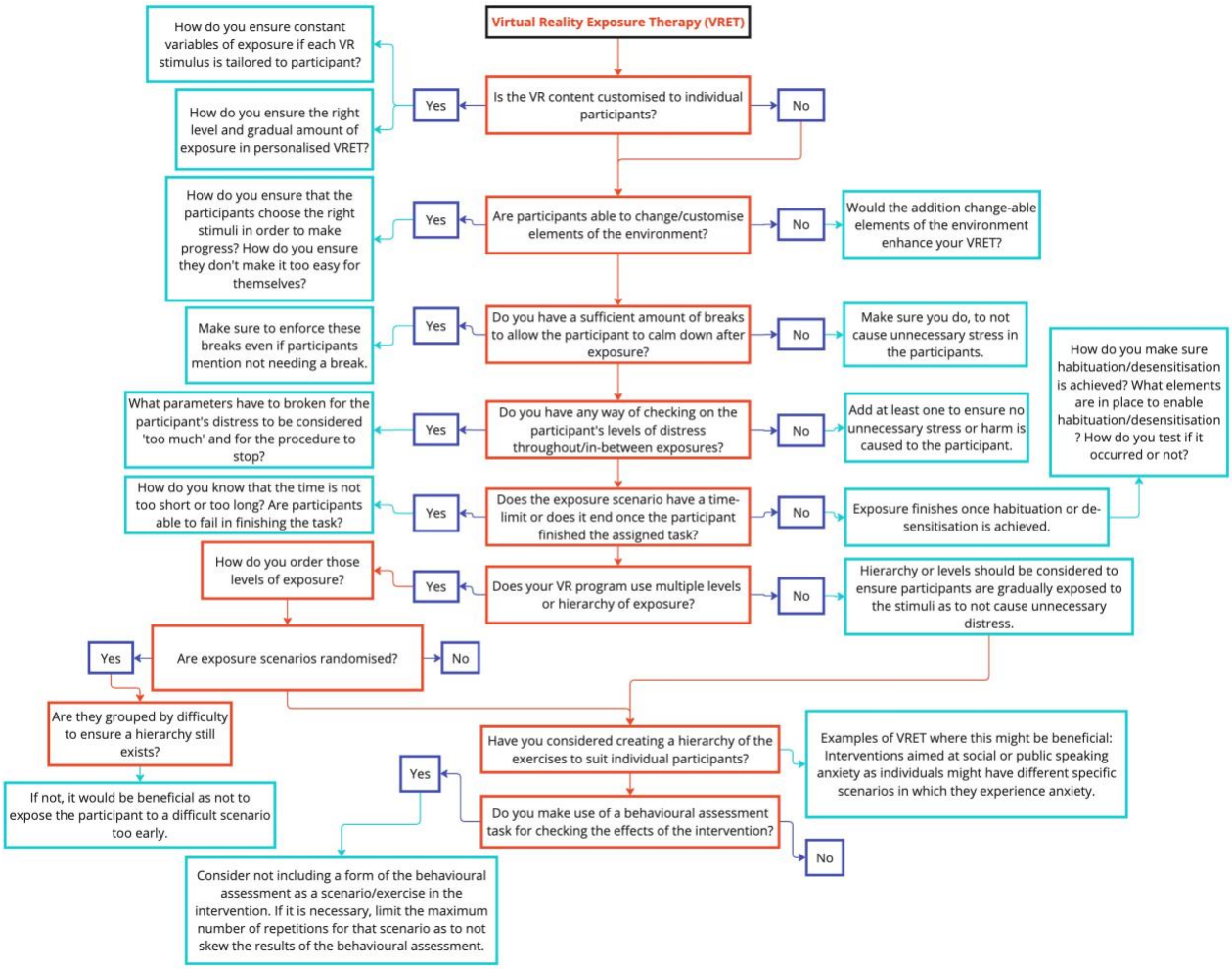


Exposure Therapy Section

Finally, the Exposure Therapy section represents the only section of the checklist which is aimed at a particular type of therapy. This is because most of the articles within the literature review utilized VR-specific interventions or a type of therapy which was only used by one article. Exposure Therapy, however, was the most common type of therapy utilized and contains certain aspects which are the same, across all types of VR Exposure Therapies (VRET). The full mind map of this section can be found below, in Figure 11.

Figure 11

Mind Map of the Checklist Section 'Exposure Therapy'



At the beginning of the checklist, the researcher can identify their intervention as one of the specific types of interventions outlined in the checklist, which is currently only Exposure Therapy. Thanks to this, the participants will be presented with this section of the questionnaire which is concerned with elements of the VR program that specifically concern exposure. The checklist poses questions for the researcher regarding the personalization of the environment to the participant, the number of breaks, use of hierarchy in exposure, behavioral assessment tasks, randomization of scenarios, and customizable elements of the environment.

Discussion

This review aimed to collect information about the key elements used for the creation of psychological immersive VR interventions, to create a checklist to enable systematic mapping of VR environments. The elements identified by this paper concerned types of VR stimuli, sensory feedback in VR, VR interaction, VR presentation, freedom of movement, presence of interactable objects and the ability to change aspects of the environment.

When it comes to types of VR stimuli used, out of 61 studies most interventions identified used the VR environment without any avatars (n = 28), while only 14 studies used direct avatar interaction, with the rest of the interventions using personalized environments or background avatars only. 12 out of the 28 interventions that used only the VR environment were categorized into *Environment Research*, meaning they focused on exposing participants to different natural environments to reduce stress and anxiety and promote relaxation. In terms of VR interaction, the most common types of VR interaction as utilising VR controllers or using no interaction, with a handful of interventions using treadmills, exercise bikes or hand gestures due to the specificity of the procedure. The trends of VR interaction and VR stimuli, indicate that the most common types of psychological interventions are ones utilising a simple environment with no avatars and no interaction. These results are quite surprising as one would assume that the relatively free level of interaction in VR, at least compared to for instance serious games, is the

driving force of VR intervention creation. However, these results seem to indicate that the main usefulness of VR intervention stems from the ability to immerse the participant into a completely different environment, rather than the activities and interactions they can have in said environment.

Other trends identified across the reports used within this literature review, contained information regarding sensory feedback and types of Vr presentation. In terms of sensory feedback, 44 interventions were found to utilize auditory feedback with very few studies utilizing any other types of senses. Specifically, one intervention aimed at sensorimotor rehabilitation was the only intervention that used proprioceptive or exteroceptive feedback, but also included auditory, olfactory, tactile, and temperature feedback (Brito et al., 2021). Only two other studies included olfactory feedback with both focusing on individuals with PTSD (Beidel et al., 2019; De Jesus Junior et. al., 2023). Due to this, it seems that the field of immersive VR interventions does not utilize varied types of sensory feedback, except for personalized interventions or interventions aimed at PTSD as the inclusion of specific sensory feedback in those cases could result in a higher sense of immersion and/or exposure. These results were surprising as the author presumed that one of the main advantageous that VR interventions can provide is the immersion of the participant to a completely new environment. Therefore, the author hypothesized that VR interventions will contain multitude of different forms of sensory feedback to create interventions with the highest immersion possible. Therefore, the checklist also contained a big section regarding different forms of sensory feedback, as currently they seem to be underutilized and the author believes that their addition across psychological VR interventions would greatly benefit their effectiveness and the participant experience.

As mentioned within the introduction, multiple literature reviews, including the current paper, identified a large problem of a lack of methodological rigor within the field of VR interventions (Turner & Casey, 2014). In the case of this paper, it did not include only reports that were excluded due to this reason, but also certain studies that were included, however lacked information regarding certain

aspects of the VR environment. For instance, the only study that made use of tactile, proprioceptive and exteroceptive feedback, simply mentioned the forms of feedback contained within the intervention but did not describe in what ways these senses were triggered (Brito et. al., 2021; Drazich et. al., 2023). This information can be considered sufficient for inclusion into this paper; however, it is still not clear enough to allow for replicability, negatively affecting the credibility of the intervention. This was a common problem found in multiple reports during the screening procedure. Due to these findings, the author opted for the inclusion of an introductory paragraph into the checklist which emphasizes the goal of the checklist as well as the importance of the reporting of all aspects of the VR environment. Both the introduction and the summary of the results presented at the end of the checklist specifically mention the reporting of the intervention design to make sure the researchers taking the checklist understand that all decisions and aspects concerning the intervention also must be included in the report, explicitly.

All the different elements found during the screening process, were utilized for the creation of a checklist, aimed at guiding future researchers in the creation of VR interventions and their reporting. The checklist is divided into multiple sections, including General questions, VR program Interaction, Sensory feedback, VR avatars, real-life recordings/panoramic images, Digital graphics and Exposure Therapy. Except General questions and Exposure Therapy, each section focuses on an element of the VR environment design and poses questions about all aspects of the given element identified in the literature review. The section on general questions focuses on elements present in all types of VR interventions and Exposure Therapy focuses on elements unique to exposure therapy, such as the presence of hierarchies of exposure.

Limitations of the evidence found in the review

This systematic literature review contains certain limitations due to the limitations of the interventions included in the review. As was already highlighted in the introduction, the main limitation of the evidence of this review is the lack of methodological rigor regarding the different elements of the

VR programs. During the final screening procedure, the biggest number of studies (n = 56) were excluded due to unclear descriptions of the VR programs and certain studies that were included did not include all information relevant to the VR program. For instance, the sensorimotor rehabilitation created by Brito and others (2021), utilized six different types of sensory feedback, however, the forms in which this feedback was given are unclear as the report only lists the different types of sensory feedback, but does not describe the form in which they took place. This intervention provides just one example of the lack of methodological rigor found in this field. With other interventions, the author had to infer the use of different sensory feedback based on the descriptions of the procedure given, indicating an insufficient description of the VR environment. The presence of this limitation within the field of VR interventions was also identified by Turner and Casey (2014), which highlighted the lack of methodological rigor as one of the key findings of their review.

Furthermore, 13 interventions used background avatars, while 14 studies utilized direct avatar interaction and only one intervention reported checking their virtual avatars for the presence of the uncanny valley effect. The uncanny valley effect is the theorized relationship between human likeness and a person's affinity towards it, which states that as human likeness increases, so does one's affinity for it (Kendall, 2024). This effect continues to a certain point at which the likeness nears complete accuracy, at which point the person's affinity flips to feelings of discomfort (Kendall, 2024). This feeling of discomfort can have drastic effects on the way the participant experiences the VR environment. This is especially true for specific types of interventions, for instance Exposure Therapy, in which the feeling of discomfort caused by the uncanny valley effect could increase the amount of distress the participant already feels being exposed to certain feared stimuli. The body image intervention, Resize Me! asked the participants to complete the uncanny valley index to identify the presence of the uncanny valley effect in the 13 models created for the body modification procedure (Döllinger et al., 2022). As the presence of the uncanny valley effect in VR interventions can have drastic effects on its effectiveness

and has the potential to cause great distress to participants, the author considers the lack of consideration of this effect when creating the interventions a limitation of the evidence found in the review.

Limitations of the review process

Once again, due to the lack of methodological rigor found in studies included within this literature review, the author believes that the checklist is missing valuable information regarding VR environments that were not described in the included studies. More specifically, there is lacking information regarding any testing for the uncanny valley effect, the amount of detail that is recommended or necessary for specific types of environments or immersion levels, and detailed information regarding the creation of personalized interventions. Personalized interventions are created specifically for each participant; however, their reports should still contain information regarding different considerations and information, including visual, that is used for their creation. Finally, as mentioned in the section above, there is a lack of specific information regarding different forms of sensory feedback used. As the created checklist is meant to enhance the creative process of intervention creation, it would greatly benefit from containing a multitude of examples for the inclusion of each type of sensory feedback. Therefore, the author recommends that further improvement and expansion of the current checklist is necessary in order for the checklist to be considered complete and fully beneficial for future VR intervention researchers. Future expansions of the current checklist should also focus on the addition of sections specific to forms of therapies, other than exposure therapy, especially for therapies which utilise a unique intervention design, compared to other, more general interventions.

Conclusion

To conclude, the objective of this research was to identify the key elements of VR environments of psychological immersive VR interventions, using a systematic literature review, to create a checklist that is meant to facilitate future VR intervention creation and reporting. The identified elements

included information regarding types of VR stimuli, sensory feedback in VR, VR interaction, VR presentation, freedom of movement, presence of interact-table objects and ability to change aspects of the environment. Utilizing the above-mentioned elements and the categories created for the analysis, a checklist was created, meant to question researchers about the different elements of their VR environment and provide suggestions and follow-up questions to enhance the effectiveness and immersion of the intervention. However, the most substantial finding of the systematic literature review was the identification of a lack of methodological rigor regarding the descriptions of VR environments and all its aspects, within the field of psychological VR interventions. Therefore, the author recommends that future research focuses on expanding the checklist and testing its usefulness to enable its widespread use, meant to enhance the interventions and the way they are being reported.

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Appendix A

Description of information found in results tables in Appendix B

The full descriptions of each study found within each category can be found in Appendix B. More specifically, the first column ‘Article name ’provides the information regarding the name of the article. The ‘experimental task ’column contains a basic overview of the experimental procedure, excluding procedures of any controls or other conditions. The conditions column refers to how many different conditions were present within the intervention and lists them. The following column, Priming/Pre-exposure Stimuli contains any information regarding any form of priming that took place before the experimental task, such as inducing a certain mood. The ‘Stimuli ’column contains any information regarding the VR stimuli and VR environment present in the intervention. It usually encompasses a description of the different elements that participants experienced. Finally, the last column ‘Sensory Factors ’lists all kinds of sensory feedback which was used in each intervention, including but not limited to auditory, olfactory and tactile feedback. Due to space limitations, the following acronyms are present within the results tables:

- Virtual Environment (VE)
- Trauma Management Therapy (TMT)
- Virtual Reality Exposure Therapy (VRET)
- Virtual Exposure and Response Prevention (VERP)
- High Intensity Interval Training (HIIT)
- Virtual Reality Therapy (VRT)
- Virtual Reality Acceptance and Commitment Therapy (VRACT)
- Point of View (POV)

Any acronyms not listed above are acronyms of names of specific interventions, such as Pegasys-VR or DiSCoVR.

Appendix B

Table B1

Descriptions of Studies in Category 'Exposure Therapy'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
Virtual Reality treatment of flying phobia	8 treatment sessions, 2 aimed at education and 6 sessions of VR exposure in 3 different VEs.	only experimental condition.	no priming.	1st VE: room in which one is packing for a trip with interact-able objects (e.g. clothes and plane ticket); 2nd VE: waiting at airport with updating flight information board; 3rd VE: flying on plane with simulation of take-off, turbulence and landing.	visual and auditory (e.g. people talking, radio, flight announcements, captain's message, sound effects of flying plane).
Trauma management therapy with virtual-reality augmented exposure therapy for combat-related PTSD: A randomized controlled trial	Both conditions experience VRET, 3 times per week for 5 weeks. TMT condition consists of 1 psychoeducation/imaginal exposure therapy scene construction session and 14 sessions of VRET.	49 participants randomised to Trauma Management Therapy and 43 randomised to Exposure Treatment only.	both conditions underwent VRET before experiencing.	Exposure is customised to individual patient's traumatic scene (e.g. delivering scents associated with traumatic scene).	visual and auditory; scent via a scent machine; tactile feedback via rumble platform.
Virtual reality in the treatment of claustrophobic fear: A controlled, multiple-baseline design	8 VR graded exposure sessions in which therapist encourages the participant to interact with the environment to decrease their anxiety. Anxiety levels assessed every 5 minutes. Participant has a lectern with buttons in VR that allow them to change aspects of the VE.	only experimental.	no priming.	2 scenarios: house and elevator; House with openable windows and a 2nd room with movable walls and no furniture; Elevator with openable doors, blocked elevator or elevator which closes to 1m squared space; all aspects of VEs adjustable by participant.	visual and auditory factors.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Gambling exposure in virtual reality and modification of urge to gamble	Participants exposed to gambling environment and asked to move around according to instructions: face bank machine (15s); face bar counter (25s); look at video lottery terminals (VLTs) and gamblers (35s); select free VLT and sit without playing it (45s). This sequence is repeated 5 times.	only experimental.	Participants primed by being asked to name 5 things that they would do if they won at gambling that day. To begin exposure, their need to gamble had to be stable or on the rise, if not priming was repeated.	Virtual bar environment with 5 VLTs and other gambling-associated stimuli (e.g. other people gambling, a billiard table, alcohol beverages; Virtual environment outside of bar was created for practicing VR controls before procedure.	visual and auditory (e.g.sounds of VLTs and ambient music).
The Effectiveness of Self-Guided Virtual-Reality Exposure Therapy for Public-Speaking Anxiety	Participants gave a 20-minute speech in a virtual classroom. Speech broken into 5 minute blocks with 1 minute breaks with the ability to change aspects of environment. Modifiable elements came in 3 grades of exposure (low, moderate, high) and included: audience size, audience reaction (approving, neutral, disapproving), speaker's distance from audience, number of speech prompts per slide and salience of self (no poster, silhouette with label speaker, or photo of participant with their full name).	only experimental.	online screening survey 60 days before first session. Screening for demographic data, public-speaking anxiety and behavioural avoidance.	Virtual classroom with virtual avatars who listen to participant's speech. A light on the wall behind avatars turns red 10 seconds before a break. On the left of the participant the speech countdown is located, as well as the salience of self poster. It is either blank, a poster with silhouette and label speaker, or participant's picture and full name. The speech prompts are given via podium display in-front of the participant.	visual only.

Continued on next page

Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Interactive Motion-Assisted Exposure Therapy for Veterans with Treatment-Resistant Posttraumatic Stress Disorder: A Randomized Controlled Trial	6 standardised weekly sessions of 70-90 min 3MDR. administered on dual-belt treadmill with synchronised virtual reality environment comprised of 180 degree projection on 3 screens. Sessions began with mental and physical warmup. Patient ran down a tunnel until meeting with one of their selected images. A literal description of the image was provided, followed by recall of traumatic memory related to the image. After recall, a ball started bouncing infront of the image, with different numbers appearing on it. Participants asked to repeat the numbers before repeating this step 6 more times. Afters they went back to neutral environment to receive positive reinforcement.	Experimental group received 3MDR treatment, Control group received non-trauma-focused treatment	selection of 10-20 images which reminded the participant of their deployment-related traumatic event. Pictures organised by theme and scored from 0-10 on subjective units of distress. Patients also chose music, deployment-related music (from that time period) and music reminding them of the present (e.g. contemporary music)	Dark tunnel environment in which participant is running towards one of their selected images. Image presentation is accompanied by deployment-related music. Neutral environment consisted of unfurnished room accompanied by present-music.	visual (virtual environment and images) and auditory (music)

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Exposure to virtual social interactions in the treatment of social anxiety disorder: A randomized controlled trial	First 2 sessions focused on creating a hierarchy of the virtual social situations according to the participant's expected anxiety levels. Sessions 3-9 contained 2 30 min. blocks of exposure exercises, organised based on previously made hierarchy. Every scene experienced at least one. The speech scenario being only available twice due to behavioural assessment task also being giving a speech.	Randomly allocated to Virtual Reality Exposure Therapy, in Vivo Exposure Therapy or waiting-list (control). Participants allocated to waiting-list were given second assessment after 5 weeks, before being randomised to one of the experimental conditions.	Pre-assessment of battery of self-report measures and a behavioural assessment task. Behavioural assessment task: Participants were given 2 minutes to prepare a 5 minute speech based on 1 out of 7 given topics. Afterwards they gave the speech infront of 2 people and a camera for 5 minutes or until indicating they want to stop.	Virtual situations covered one-to-one and group situations: giving talk infront of an audience followed by audience questions, talking to a stranger, buying and returning clothes, attending a job interview, being interviewed by journalists, dining with a friend, having a blind date. Virtual environment with avatar(s) created for each scenario. Avatars provide semi-structured dialogues controlled by therapist to allow for responses and ensure certain length and difficulty level of interaction.	visual and auditory.

Continued on next page

Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Decreased emotional dysregulation following multi-modal motion-assisted memory desensitization and reconsolidation therapy (3MDR): Identifying possible driving factors in remediation of treatment-resistant ptsd	8 sessions over an eight-week period, beginning with one to two pre-platform preparatory session(s). Participants put into VR on a treadmill. Walk in a virtual 'hallway' towards one of the selected images. The patient describes the memory of the image, the image itself and any associated feelings. Afterwards, for 30 seconds, patient watches a ball oscillating in front of the image and reading out numbers that appeared on the ball. This is repeated 7 times, after which patient listens to music associated with the present.	only experimental.	pre-platform preparatory sessions for the participant to select and order images and music. Images are meant to be symbolic representations related to patient's traumatic experiences and are rated on distress. Music is also selected to remind participant of the time period in which the trauma occurred. Preparation also included training in VR.	Virtual environment of tunnel along with patient-selected images. Exposure music selected based on reminding participant of the time period of the traumatic event. Animated ball which oscillates in-front of the image and shows random numbers which the participant is to remember.	visual and auditory (music to mimic traumatic memory and music to mimic present time).
Moving Forward from Moral Injury: A Mixed Methods Study Investigating the Use of 3MDR for Treatment-Resistant PTSD	Intervention encompassed 6 sessions of 3MDR received once a week. Control condition received evidence-based psychotherapeutic intervention(s).	A randomized controlled trial employed a waitlist crossover design.	No priming.	Same stimuli as previously mentioned 3MDR therapy	visual and auditory.

Continued on next page

Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Exposure and Response Prevention in Virtual Reality for Patients with Contamination-Related Obsessive–Compulsive Disorder: a Case Series	Sessions 4-6 included exposure therapy. Therapist first instructed the patient to induce disgust and prevent the patient from engaging in compulsive and avoidance behaviours. In VR, participant was in an empty room with gradual exposure with medium intensity which progressed to most distress-provoking stimuli.	experimental group received VERP over a period of 6 weeks which included 4 consecutive exposure sessions. Control group did not receive VERP but were given an established self-help manual for OCD.	First 2 sessions aimed at preparing patient for VERP. 3rd session included introduction to VR equipment in a neutral VR environment with no OC-triggering stimuli (unfurnished virtual room).	Exposure environment created to elicit contamination obsessions with various degrees of filthiness. Vr environment of public toilets, with differing number of stalls for men and women's bathroom. No cleaning products were visible in VR. Environment is animated, rather than recorded.	visual.

Table B2

Descriptions of Studies in Category 'Enhancing Psychological Wellbeing'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
Effect of sensorimotor rehabilitation based on an immersive virtual reality model on mental health	6 weeks of 3 25-min sessions per week. Exposed to 4 different scenarios in VR: Exploration scenario involved running on a treadmill in urban or natural environments. Participants asked to remember details about environment. In Vertigo Scenario, participants walked freely on a board placed on edge of a high-rise building in the virtual environment. In Free fall scenario, participants were suspended in prone position from a harness, while watching a first-person free fall in VR. Incarnation scenario involved participants giving positive comfort to an avatar. Afterwards the roles switched and the participants were exposed to themselves and listened to their own words of comfort.	single-blinded procedure. Experimental group participated in intervention, while Control group received no intervention.	no priming.	Exploration scenario involved incorporation of stimuli relevant to either urban or natural environment. The Vertigo scenario involved a 360 degree VR video of balancing on a board on top of a high-rise building. The Free fall scenario involved a 360 degree VR video of a first-person free fall with synchronised wind stimulus with lower and upper direction to increase immersion. The incarnation scenario, started with the participant providing comfort to an avatar of a little girl which was later changed for individuals with other characteristics.	Sensory factors depended on scenario: Exploration scenario involved auditory, visual, olfactory, proprioceptive, tactile and temperature stimuli which depended on the climate associated with natural or urban environments. Vertigo scenario included visual and auditory stimuli. The free fall scenario included visual and auditory stimuli as well as exteroceptive through the use of fans which simulated the feeling of wind during free fall. Incarnation scenario involved visual and auditory stimuli in the form of recording of the participant's voice and virtual avatars.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Brief Virtual Reality Mindfulness is More Effective than Audio Mindfulness and Colouring in Reducing Stress in University Students	VR mindfulness included a 6 minute VR body scan in which participants were to nonjudgementally focus on one's body in a virtual environment. Followed by 4 minute breathing exercises. Participants were able to customise their VR experience by picking location of the virtual environment	participants randomly assigned to 3 face-to-face stress management interventions: VR mindfulness (experimental), audio minfulness and colouring.	no priming.	The Virtual environments that could be chosen were a courtyard in Japan, a woodland campfire, a beach on a deserted island or beside a lake. All virtual environments were animated, not real-life recordings. Breathing exercises involved an animated cube that shrunk or expanded and the participant was expected to match their breathing to the animation.	Sensory factors included visual and auditory.
The use of preoperative virtual reality to reduce anxiety in women undergoing gynecological surgeries: A prospective cohort study	Participants layed in bed in a quiet preoperative room, but were able to move their body freely. They were able to select 1 scenario out of 11 virtual environments. Afterwards, they experienced 10 minutes of Relax VR which included the virtual environment, relaxing music and breathing exercises.	only experimental.	no priming.	11 immersive VR environments accompanied by background music and breathing exercises. Environments included tropical beach, rice terrace, wine glass bay beach, The twelve Apostles in Australia, Fern Bern, a forest creek, a daisy garden, the Grand canyon, northern lights, being on the moon and flying through clouds. Virtual environments presented as real-life 360 degree videos, not animated environments.	visual and auditory stimuli.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
A single-session VR intervention addressing self-compassion and self-criticism with and without perspective change: Results of a randomized controlled experiment	In the experimental task, participants were asked to provide positive encouragements and react compassionately to a virtual avatar. In the second roleplay, a perspective switch happened, meaning the participant played the role of the virtual avatar and listened to their own recordings from the first roleplay scenario.	Participants were randomised to VR interventions with (experimental) or without (control) perspective change.	60 minutes of VR instructions, informed consent and pre-assessments.	Virtual environment including avatar was controlled by the researcher (namely, avatar's movements, facial expressions and perspective change). Researcher also used microphone with voice morphing to roleplay the avatar. The virtual environment of a kitchen with living room as well as the avatars were animated, not real-life recordings.	sensory factors included visual and auditory.
A Short Bout of Exercise With and Without an Immersive Virtual Reality Game Can Reduce Stress and Anxiety in Adolescents: A Pilot Randomized Controlled Trial	Participants were put into a virtual environment of a park. In the center of the environment, a small box is present from which virtual balls will be projected directly at participant. Participants asked to keep feet on the ground and move their upper body to dodge the incoming balls. This scene lasted 2 minutes and was repeated 5 times.	participants randomly assigned to VR group (experimental) and Dodgeball group (control).	no priming.	Virtual park environment included green field to simulate grass, surrounded by black flooring, simple grey rectangles which represented buildings outside the park. Whole VR environment consists of simple blocks of colours with no textures or details.	Visual stimuli.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Development and validation of a virtual reality-based training program for promoting subjective well-being	3 VR tasks with-spoken avatars: Experience-based problem recognition task which involved selecting 1 out of 4 domains and then asked to talk about their problems regarding said-domain with a virtual expert. The Future self-based success expression task involved selecting 1 out of 5 domains after which they would be transported to virtual room with audience and microphone. Participants are asked to introduce their desired future self and give speech on what they accomplished in the selected domain. Finally, strength expression task involved participant giving an interview on their strengths in a VR radio station. A monitor was available that presented 3 categories and 3 elements of each category. Participants were to select 1 element from each category and respond to questions	only experimental.	no priming.	All virtual environments are animated. The First task occurred in a Virtual office where the participant is presented 4 books on a table in front of them. Each book represents a domain about which they are to talk about. The 2nd task, the participant was presented 5 books in the same environment. Once, one was selected, they were transported to a room with platform and microphone, with different images, associated with the selected domain, floating in the background. The virtual environment of the final task was a virtual radio station, with an avatar of the radio host. To the side of the participant was a monitor that presented the relevant categories and their elements.	visual and auditory (audio guidance during VR).

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Art making and virtual reality: A comparison study of physiological and psychological outcomes	Participants in VR condition entered Google Tilt Brush drawing app for 15 minutes and were asked to draw freely. After the drawing task, participants from all conditions were asked to sit for 5 minutes and then provide a sample of their saliva for measures.	participants randomly assigned to VR control group (sitting in Virtual office for 15 minutes), 2D drawing group or 3R drawing group (experimental task).	Before the experimental task, participants were asked to relax in a chair while the researchers set up SC and BVP sensors.	Participants given access to Google Tilt Brush drawing app which allows one to draw in 3D space.	visual only.
Virtual reality as a tool to explore multisensory processing before and after engagement in physical activity	Participants asked to Seas the Day 3 times a week for 6 weeks. Each session lasted 15-20 minutes. Participants also introduced to the OMNI rate of perceived exertion scale and were encoursged to achieve light to moderate intensity of exercise during each session.	randomly assigned to experimental (physical activity intervention) group and control (reading) group.	VR Familiarisation session occured before the procedure.	Seas the Day is a VR game which promotes physical activity through VR sessions of Tai-chi, boat rowing task and fishing. Virtual environment is an animated island with simple shapes and saturated colours. On different parts of the island, participants can engage in 1 of the 3 activities. Instructions for activities are provided via text boxes.	visual only.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Augmented experiences: Investigating the feasibility of virtual reality as part of a workplace well-being intervention	Participants were seated in an office chair with a Fitbit activity tracking device attached. They were given instructions on how to use the VR headset, before experiencing the VR program for 20 minutes.	randomly assigned to one of 3 groups: 'SoundSelf' condition, breathing condition or control condition.	briefing on how to use VR headset.	The SoundSelf program creates unique visuals based on the audio that the program receives. The visuals the program creates are meant to immerse the participant in a void of colourful lights and sounds. The breathing condition received visuals created to be comparable to those created by Soundself, accompanied by an audio guided breathing exercise. The control group viewed a real-life recording of leaves while it is raining.	visual and auditory (music or guided breathing exercise).
Virtual-reality exergaming improves performance during high-intensity interval training	Participants always started with the *blank* and *track* mode (standard mode). Participants sat on an cycle ergometer. In VR, participants cycled down a straight road, while avoiding slow moving trucks by leaning their head left or right. In *ghost* and *hard* modes, participants were asked to aim to beat the ghost avatar that appeared, that represented their *track* mode performance.	only experimental. The blank VR-HIIT mode served as control as it presented a blank blue screen.	no priming.	The VR environment consisted of an animated highway with trucks present in different lanes infront of the participant. During low-intensity phases of VR-HIIT, a sunny scene was displayed. During high-intensity phases, the scene switched to night with police cars with flashing lights appearing behind the player to evoke a sense of urgency.	visual.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
The effect of augmented reality on preoperative anxiety in children and adolescents: A randomized controlled trial	In AR, participants are presented to 2 cartoon characters which teach the participant relaxation techniques. Participants are then invited to imitate the cartoon character's movements to perform progressive muscle relaxation. In the 2nd phase, participants were able to play any animations they wanted, until the OR was ready.Final stage took place in OR, where the cartoon characters explained the sensations one might feel when put under anesthesia and reminded the participants to stay calm and brave.	participants randomly allocated to control group (standard care without AR intervention) and experimental group (standard care with AR intervention).	no priming.	Participants are introduced to 2 characters: Constellation, a living star, and Equoo, an alien species that travels to instill strength and bravery in those who meet him. In rooms and hallways, different virtual windows hung on the wall in which participants could watch the characters play on their planet. Virtual posters hang on the wall that participant can interact with to trigger animations and typical cardiac coherence exercises.	visual and auditory stimuli.
Effect of Immersive Virtual Reality Education before Chest Radiography on Anxiety and Distress among Pediatric Patients: A Randomized Clinical Trial	Participants in Waiting room experienced a 3 minute, 3D 360 degree virtual environment in which the main character of a children's show, Hello Carbot, explain the process of radiography, what one has to do and why it is being conducted.	Participants randomly assigned to control group or VR group.	no priming.	The virtual environment included all equipment and machines of a radiography room which were created via 3D rendering.	visual and auditory.

Table B3

Descriptions of Studies in Category 'Environment Research'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
Physical Versus Virtual Reality–Based Calm Rooms for Psychiatric Inpatients: Quasi-Randomized Trial	Patients were able to visit the VR or physical calm room (depending on which was available).	Patients given access to VR calm room or physical calm room, depending on which inpatient ward they were admitted to.	Before entering calm rooms, participants' measures were taken, including BP and HR.	VR animated environment of forest clearing with beach and mountains in the background. Participant is able to choose time of day and whether to freeze time (if not, time of day would slowly change). Participant is able to toggle different types of weather including rainy, cloudy, or sunny. Other parts of the environment also change to match weather, for instance with raining the environment and sound changes to a smooth drizzle and subdued colours. Participants are also able to disable animals (birds singing, rabbits in the forest, etc.).	visual and auditory stimuli

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Effects of biophilic interventions in office on stress reaction and cognitive function: A randomized crossover study in virtual reality	Participants experienced 4 types of indoor environments (3 biophilic and 1 non-biophilic) in 2 workspace types (open and enclosed). Participants started with 3-minute rest while seated before being exposed to a virtual environment which they were free to explore. Afterwards, they took a 5 min. cognitive test using a virtual computer in VR. This was repeated until all conditions were experienced.	Randomised crossover design was employed, meaning participants acted as their own control.	10 minutes to familiarise oneself with VR and instructions on how to navigate the environment.	The non-biophilic environment involved an office space with no plants or natural stimuli. The first type of biophilic environment included natural elements, mainly potted plants and living plant walls. The second biophilic environment used natural analogues, meaning furniture and wallpapers that resembled natural stimuli (e.g. shelves that look like tree branches). The final biophilic environment included a combination of natural elements and analogues.	visual stimuli. Indoor environmental conditions, including temperature, relative humidity and PM concentrations, were kept consistent thanks to a real-time sensor package. Noise disturbance kept to minimum.
Effects of Restorative Environment and Presence on Anxiety and Depression Based on Interactive Virtual Reality Scenarios	Participants experienced 1 VR scenario for 8-10 minutes once a week for a month. VR scenarios included flying a kite in lawn area, watering vegetables in gardening area, fishing in water area and feeding birds in forest area.	Interactive Vr scenarios employed a within-subjects design and order of VR scenario exposure was randomised.	no priming.	Vr program includes a Virtual park with 4 different areas for 4 different activities. All areas are independent but interconnected. All environments are animated, not using real-life recordings. Participants simulate the process of the activity they are doing using VR controllers.	visual only.

Continued on next page

Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Integrating a virtual reality relaxation clinic within acute psychiatric services: A pilot study	Participants received a single session of VR relaxation intervention in which participants viewed calming nature environments in immersive 360 degree audio-visual experience. Certain environments included interactive elements such as meditation and relaxation exercises.	only experimental condition	Briefing on the intervention and how to use VR equipment.	VR experience began on virtual beach and participants are able to navigate through various environments, including (but not limited to) meditations, relaxation exercises, coral reed, scuba diving with dolphins, watching the sea from a mountain, sunny meadow with cows and lake view with a Christian cross.	audio-visual experience.
A virtual psychiatric ward for orientating patients admitted for the first time	Participants experience a virtual guided tour with predefined rooms and locations. The guided tour presents relevant instructions, rules and regulations which show up in pop-up message boxes. When participants try to enter prohibited area, they receive a pop-up about the locked-door system and why it is necessary. Pop-ups are aimed at explaining important aspects of the ward including locked-door system, seclusion and physical restraints.	Participants randomly assigned to VR group and Non-VR group (orientation received via test-based electronic ward information).	no priming.	The VR environment is a 3D rendered model of the real-life ward with specific places that trigger appearing of pop-up with relevant information. Certain parts of the environment are interactable and give audio feedback (e.g.switching radio on/off, turning off tap of water dispenser).	visual only.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Virtual Reality to Evaluate the Impact of Colorful Interventions and Nature Elements on Spontaneous Walking, Gaze, and Emotion	Participants used step-on-the-spot controls to navigate a virtual university campus. Participants followed a path to navigate to university library. Each participant walked around the university 6 times in separate trials. In both urban and vegetation campus conditions, 3 different floor markings were used for each trial (white line, line painted in RGB colours, and colour designs embedded in RGB line).	A within-subjects design; Participants experienced conditions in semi-randomised order.	no priming.	An identical minimalistic representation of the university was created which was then edited to create Concrete urban environment with no vegetation and Vegetation urban environment including grass, tress of different shades of green. Campus environment was animated, not real-life recording.	Air conditioning was used to maintain a constant temperature in the room. Visual stimuli in VR).
The restorative effects of short-term exposure to nature in immersive virtual environments (IVEs) as evidenced by participants' brain activities	Participants asked to complete 2 rounds of Stroop tasks before and after environmental exposure. Participants sat in a chair and could swivel using their feet until they found their favorite view in the virtual environment. Participants were exposed to 4.5 minute videos of 2 forest scenes.	randomly allocation to VR urban forest environment or indoor environment (control).	Priming occurred to induce mental fatigue by participating in a cognitively intense job of finishing an abbreviated version of the Markus Peters arithmetic test.	360 degree stereoscopic videos were used for Virtual environments. The forest was chosen based on good diversity of vegetation, no buildings in vision and no dense vegetation blocking the view.	visual and auditory (environmental sounds).

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Effects of virtual reality natural experiences on factory workers' psychological and physiological stress	Participants (factory workers) spend 30 minutes of their work break immersed in 360 degree VR nature videos. Different video is presented every week and HRv measures are taken before, during and after VR exposure.	Participants randomly assigned to experimental (VR) group or control (no intervention) group.	no priming.	Real-life Nature videos were pre-recorded in 360 degree format with scenes including parks, hiking trails, forest paths and bike ways. All scenes recording on sunny afternoons.	visual only.
Different types of virtual natural environments enhance subjective vitality through restorativeness	Participants experienced different environments, presented using a VR headset and 360 degree panoramic photos. Each exposure lasted 4 minutes.	Participants randomly assigned to 1 of 4 conditions: urban environment (urban condition), national park (park condition), lacustrine environment (lake condition), and arctic environment (arctic condition).	no priming.	Panoramic photos were taken by researchers in a neighbourhood city of Rome with tall buildings and cars (urban), a national park with grass, shrubs, trees and no bodies of water (park), a lake environment of a national park dominated by water (lake), and arctic environment including solid water and large areas of permafrost. All photos were of semi-open spaces with no humans and comparable lighting.	visual only.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Daily exposure to virtual nature reduces symptoms of anxiety in college students	Participants asked to watch 1 out of 6 360 degree videos, once per day from Monday till Saturday. Each video lasted 4 minutes.	Participants randomly assigned to control group (no intervention, just measures) and intervention group.	no priming.	360 degree videos which differed between each day. Included environments like Aspen Forest, Beaches, Forests, Forests with water, Rainforest and Waters. All environments constitute a mixture of 3 components of natural landscapes - plants, water and rocks/minerals. All environments exclude cars, traffic noise, buildings and other evidence of human activity.	Visual (360 degree videos recorded on GoPro) and auditory (nature sounds).
Flourishing-Life-Of-Wish Virtual Reality Relaxation Therapy (FLOW-VRT-Relaxation) outperforms traditional relaxation therapy in palliative care: results from a randomized controlled trial	Participants are able to pick their preferred VR environment and after experiencing said-environment for 1-2 minutes, the primary investigator started relaxation coaching while participant is in VR.	Participants randomly assigned to intervention group or control group which received just relaxation coaching (10 minute coaching on diaphragmatic breathing).	no priming.	8 different environments to pick from including Beach, underwater, waterfall, snow mountain, Japan Onsen, Japan Sakura, Forest and Clouds/Sky. All VR content was selected based on being 1)a serene environment with comforting sounds and visuals, 2)filmed on stationary cameres that minimise sudden motions, 3) content with lower intensity of visual disturbances, 4) and allowed participants to focus on a fixed point.	visual and auditory (comforting nature sounds).

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Using multi-sensory virtual reality nature immersion as a therapeutic modality for improving HRV and cognitive functions in post-traumatic stress disorder: a pilot-study	pre-test, followed by three-week period free of VR immersion; followed by second pretest; followed by 12 sessions of VR. Each session lasted 15 min and was comprised of three different virtual reality environments. 1st VE was only natural environment, 2nd VE included a cardiac coherence exercises, and 3rd VE included audio-guided meditation.	only experimental condition.	Neurocognitive assessment and measures taken during pre-test, second pre-test and post-test.	3 Virtual Environments each of which were recordings of real-life natural environment; 1st VE: shore of an in-mountain lake with natural sounds and odours; 2nd VE: local beach in Canada with a sphere moving up and down and the participant is to match their breathing with it; 3rd VE: local rocky seaside surrounded by a forest with audio-guided meditation.	visual, auditory (via nature sounds and audio-guided meditation) and olfactory (via scent diffuser device attached to VR headset).

Table B4

Descriptions of Studies in Category 'Mental Disorder Treatment'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
The use of mobile-assisted virtual reality in fear of darkness therapy	Participants were exposed to 5 scenarios, ranging on difficulty. The Light mode required the participant to walk from one torch to the next, find one log and go back to the starting point. The Dark Mode required the exact same steps but with lower lighting. The rest of the levels of Dark mode (2-4), required same steps, however number of logs increased by 1 with the levels as well as the darkness of the environment.	only experimental.	no priming.	Environment created involved a forest with torches at different distances from starting point, depending on level of difficulty. All of the scenarios also included a flashlight and footsteps sounds of the participant. As levels of dark mode increased, fewer torches were present with more mileage between each of them with the final level having no torches. Levels 2-4 also included bird sounds, while levels from 3-4 included sounds of doors.	visual and auditory stimuli.
Virtual reality therapy for refractory auditory verbal hallucinations in schizophrenia: A pilot clinical trial	In 1st session, participants create a distressing avatar that is the source of the malevolent hallucinations. In Sessions 1-3, patients were asked to reproduce hallucinations and were asked to engage in conversation with the avatar. In session 4, participants reinforce self-esteem by expressing themselves and their personal qualities.	Participants were randomly allocated to wither VR-assisted therapy (VRT) or treatment-as-usual (control). The control group also received a delayed 7 weeks of VRT.	no priming.	Avatar's voice was simulated in real-time with a voice transformer and the disturbing avatar was created using the Unity 3D game engine. Using multiple programs, avatar real-time prosody and lip synchronisation was achieved.	visual and auditory.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Automated psychological therapy using immersive virtual reality for treatment of fear of heights: a single-blind, parallel-group, randomised controlled trial	In the 1st session, a virtual coach explains fear of heights, why it occurs and asks participants questions about their experience. Afterwards, participants progress through different VR exercises with the coach. Tasks are designed to be engaging and scale in difficulty. The participant is to decide whether they want to repeat an exercise or move to a more difficult one.	Participants randomised to experimental (VR) group and control group. Control group is given opportunity to receive intervention after the study.	Given Heights Interpretation Questionnaire before procedure to determine severity of fear of heights.	Virtual coach was animated using motion capture and voiced by an actor. Virtual coach takes Participant to a 10-story building, with each floor being a different exercise. Exercises were randomised but grouped based on difficulty to scale with the floors. Many tasks were made to be engaging, including rescuing cat from a tree, playing xylophone near an edge of a building, throwing balls over the edge.	visual and auditory.
Virtual reality acceptance and commitment therapy intervention for social and public speaking anxiety: A randomized controlled trial	3 face-to-face sessions with 5 environment scenarios. One session included all 5 scenarios. Audio instructions accompanied exposure, reminding participant to stay present, focus on their emotions and thoughts and how they influence them. VR exposure involved participants giving a speech for 10 minutes in different environments.	Participants randomly allocated to intervention group (VRACT) or control group (Waiting list for 3 weeks before being offered to join VRACT intervention).	no priming.	VR environment scenarios included baseline, neutral scene, one person, 3 people and lecture hall. Baseline scene involved sitting in front of empty desk. Neutral scene was sitting by a lake. One and 3 person environments involved sitting behind a table infront of 1 or 3 people. The lecture hall scene involved standing infront of a full lecture hall. All scenes were real-life recordings.	visual and auditory (audio instructions).

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Borderline Personality Traits and Emotion Regulation Strategies in Adolescents: The Role of Implicit Theories	Participants are verbally introduced to a character struggling with intense emotions. In VR, participants enter the character's brain and using controllers are meant to pacify red neurons, signalling the reduction in emotion intensity.	only experimental condition.	no priming.	Animated interactive program in which participants travel through neurons. Certain neurons glow in red and are able to be 'hit' by the participant in order to turn green. Auditory feedback is present for firing at and hitting the neurons.	visual (animation of travelling through neurons) and auditory (instructions given by inanimate voice in VR, music, auditory feedback).
The effect of feedback in virtual attention training on orienting attention in individuals with sluggish cognitive tempo	Participants watch a car driving down a road and look out for fixations appearing around or above the car. In the valid cue condition, before a correct fixation appeared a blue circle appeared on the place the fixation was to appear. In the in-valid cue condition, the blue circle appeared on the opposite side of where the fixation was to appear. Participants in feedback condition received visual feedback on whether the reaction time was faster or slower than baseline.	Participants randomised to VR feedback or no-feedback (control) groups. The VR feedback condition consists of the following sub-conditions: cue (valid, invalid) and four fixation positions (0°, 90°, 180°, and 270°).	Participants experienced the Vr program without feedback in order to record baseline measures.	Environment included animated car with a drawn background of a mountainous road. Different shapes appear above or around the car as well as blue circles that appear before fixations. Feedback on reaction time given both visually (tinting of screen) and auditory (when faster alarm sounded, when slower a warning sound rang).	visual only (feedback given via the entire screening tinting to either green (faster) or red (slower)).

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Psychedelic replications in virtual reality and their potential as a therapeutic instrument: An open-label feasibility study	Participants are put into a VR experience, where they first appear in the 'real-world' which slowly starts to acquire psychedelic phenomenology and continues to progress through 19 different levels which combine different psychedelic effects. Duration of one level is 30 seconds to 2 minutes.	Only experimental group.	Instructed on how to use VR and experienced a 10 minute demonstrative exercise of guided meditation.	Visuals mostly contain geometric patterns and abstract shapes that allow participants to project their own meaning. Specific soundtrack was created with varying intensity to match the visuals of each level.	visual and auditory.
A clinical trial of a patient-customized virtual reality intervention for tinnitus	Participants move around the VR environment while trying to locate the avatar based on the noise it emits. Avatar becomes visible after participant approaches close enough, after which participants had to place the avatar on the nosiest part of the scene to create a cognitive illusion of absorbing tinnitus sounds into louder environmental sounds.	only experimental condition.	Participants received a tinnitus avatar that recreated the subjective tinnitus of the patient via frequency and loudness, as well as acoustic modelisation of perceived tinnitus.	4 sessions of VR occurred in 4 different VR environments: living room, bedroom, a restaurant and city street. Tinnitus avatar represented as a large sparkling orb surrounded by sparkling particles.	visual and auditory. Tinnitus sounds included 5 types (whistling, hissing, roaring, humming and ringing sounds). Noisy parts of environment included stimuli naturally found in environment (e.g. noises from TV in the living room).

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Virtual reality cognitive training among individuals with alcohol use disorder undergoing residential treatment: Pilot randomized controlled trial	Participants underwent 10 sessions, 30-40 minutes each. Sessions guided by therapist and increasing in difficulty. Participants were put into a virtual city in which they are free to walk around and are given tasks to pick up certain objcts in order to achieve a number of preset goals (e.g. buy ingredients from list in a grocery store).	Participants randomly assigned to VR-based cognitive training combined with treatment as usual or to control group which received treatment as usual without VR-based cognitive training.	no priming.	Virtual environment of a city containing several built-in areas such as mini market, a pharmacy, an art gallery, an interactive home. City also contains multitude of non-player characters walking around.	visual and auditory (program provides audio-visual feedback on tasks).

Table B5

Descriptions of Studies in Category 'Enhancing Social Functioning'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
Design and development of a virtual dolphinarium for children w/ autism	After priming, participants watch a video of a real-life dolphin with its trainer. Afterwards, participants are shown each gesture possible in VR one at a time with a tutorial. Afterwards, they are led to the VR room to practice the learned hand gestures. Each participant given 20 minutes to play with virtual dolphins.	only experimental condition	Before procedure, participants fill out the test of nonverbal intelligence and conduct 6 tasks in Vr to screen for functional development learning and behavioural suitability for VR program.	Virtual environment is presented via 3 projectors covering 3 out of the 4 walls in the room. VR environment includes a virtual dolphinarium, with the ability to see under water. Dolphins are pink and animated to react to participant's hand gestures.	visual and auditory feedback (on correct hand gestures, dolphins do the correct trick and make noises).
Dynamic Interactive Social Cognition Training in Virtual Reality (DiSCoVR) versus Virtual Reality Relaxation (VRelax) for People with a Psychotic Disorder: A Single-Blind Multicenter Randomized Controlled Trial	DiSCoVR contains 3 modules: In 1st module (sessions 1-5) participants formulate social goals and in VR explore a shopping street where they identify facial expression of stationary avatars. In 2nd module (session 6-9) the participant views interactions between avatars and answers open-ended questions about their behaviour, thoughts and emotions. In final module (session 10-16) participants roleplayed personally relevant social scenarios, with therapist controlling and speaking for an avatar.	Participants randomly assigned to DiSCoVR (experimental) group and VRelax (control) group. In VRelax, participants explores nature scenes with relaxation exercises.	no priming	Environments in DiSCoVR include city street, caffe, supermarket. All environments are virtually animated, not real-life recordings. VR scenes include non-player characters and an avatar controlled and spoken for by the therapist with a voice changer.	visual and auditory

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Treating Childhood Social Anxiety Disorder With Virtual Environments and Serious Games: A Randomized Trial	Pegasys VR has identical structure to SET-C with virtual environments replacing peer generlisation. Program consists of 24 sessions, 12 of which are in vivo exposure. For peer generalisation in the VR program, participants practiced newly learning skills in virtual environment. The homework included serious games aimed at practicing skills (e.g. identifying open-ended questions) and free play in the Pegasys VR environment. In vivo exposure involved VR exposure that addressed each participant unique fear (e.g. reading aloud, giving speech).	Participants are randomised to Pegasys-VR (experimental) or Social Effectiveness Therapy for Chilren (control)	no priming	Pegasys-VR environment includes a virtual environment of a school with non-player characters that the participant is able to interact with.	visual only

Table B6

Descriptions of Studies in Category 'Behavior Change'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
A randomized trial testing the effectiveness of virtual reality as a tool for pro-environmental dietary change	In VR, Participants enter a living room and are asked to pick out food they typically eat. After they are finished, the environment changes to either Swedish or Us mountains (distant/proximal) 30 years into the future to see the effect of their food choices on the environment. Afterwards, participants re-do task 1 but are asked to choose foods with lower carbon impact. Afterwards, again transported to mountains in the future, if everyone would employ the same low-carbon food strategy as in previous task.	Participants randomly assigned to VR condition or control (no intervention). The VR condition used a 2 x 2 design of geographical location (proximal or distant) and feedback on the mountain (generic or normative).	no priming	Participants appear in living room with a virtual tablet on one of the tables. The tablet displays different types of food that participants are to pick from. 2nd environment included mountainous area covered in brown smog with dying trees and no grass/animals. Normative feedback was presented by presenting number of KG of CO2 as well as comparison of the participant's results with the average female/male Scandinavian. Generic feedback only gave numebr of KG of CO2. Both conditions shown a pyramid diagram of environmental impact of different foods. The 2nd mountainous environment was identical but with no smog, a lake, growing trees and grasses.	visual and auditory

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
The Impact of Vivid Messages on Reducing Energy Consumption Related to Hot Water Use	Participants in all conditions took a virtual shower with a window through which they could see stimuli depending on their condition. The avatar-coal condition showed 2 tables, 1 containing a pile of coal with 1 piece of coal moving to the empty table every 15s. Afterwards, the avatar standing by the table would eat the coal. The coal-only condition was identical to the one described above but contained no avatar. The personal sign condition showed only a sign stating "You have used 1 piece of coal." with the number increasing every 15s. The impersonal sign condition was the same as the personal one but the sign stated "1 piece of coal has been used."	Participants were randomly assigned 1 out of 4 energy feedback conditions: the avatar-coal (vivid x personal), the coal-only (vivid x not personal), the personal sign (not vivid x personal) or impersonal sign (not vivid x not personal).	no priming.	The environment included a shower head under which a small square window was placed which showed different stimuli. 2 digital photographs of the participant were used for the creation of the avatar for 1 condition. In both coal conditions, when the coal moved or was eaten, the floor slightly vibrated along with crunching sounds and haptic feedback. All stimuli were animated, not real-life recordings.	visual and auditory, haptic feedback.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
The enemy's gaze: Immersive virtual environments enhance peace promoting attitudes and emotions in violent intergroup conflicts	After priming, participants in immersive perspective-taking and control were told to pay attention and listening carefully while watching the VR scene. Participants in imagined perspective-taking instructed to adopt perspective of Palestinian couple.	Participants randomly assigned to watch 1-minute 360 degree VR scene depicting an interaction they previously read about in one of 3 conditions: Palestinian/outgroup POV (immersive perspective-taking), Israeli/ingroup POV + imagined outgroup perspective-taking instructions, and Isreali/ingroup POV with no extra instructions (control).	Participants read a brief description of a confrontation between Israeli soldiers and a Palestinian couple at a military checkpoint.	The real-life recording showed a Palestinian couple approach a military roadblock where they are stopped by soldiers who begin inspecting them and an altercation starts. The scene ends with the Palestinian man reaching into his jacket and the soldier pointing his rifle at the couple.	visual and auditory.
Evaluation of a virtual reality enhanced bullying prevention curriculum pilot trial	After priming, 3 sessions each began with discussion, afterwards participants experienced 3 original bullying-relevant scenarios in VR. Participants are directed to take different perspective of characters in the scenarios. In the last 2 sessions, participants were grouped together to develop a script, record and present a 30-60s anti-bullying video.	A class at 1 middle school was randomly selected to receive virtual reality enhanced bullying prevention program and a class at a different middle school in same county served as 'business-as-usual' control comparison group.	Priming involved 1 session of VR training.	The 1st VR scenario involved a student being bullied and after his best friend started being bullied, he joined the bullying to regain social standing. 2nd scenario involved ineffective responses of adults to bullying. The final scenario transported participants in the future where bullying doesn't exist and the avatars explain how that was achieved.	visual and auditory stimuli.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Can't simply roll it out: Evaluating a real-world virtual reality intervention to reduce driving under the influence	Participants subjected to 15 minutes in VR and driving simulator console, in which they entered a night-club environment. In this environment, participants picked their substance of choice (alcohol, marijuana, mushrooms or Ecstasy). After consuming chosen substance in VR, they are asked to drive home and experience the effects of the substance on their driving. Each driving scenario encompassed several parts of different roads including motorway and rural. If participants crashed, they were put back at the beginning to try again.	Separate recruitment conducted for gathering of experimental group and control group.	Driving simulator was adjusted for participants comfort. Participants also drove around on a straight road in order to adjust to driving in VR.	VR driving environment changed according to the substance picked by participant. The environment included an animated road along with the car and trees by the road. In the alcohol condition, the vision area was reduced and there was a delay between vehicle's response and its command. With Ecstasy, everything moved at an increased pace with sharpened sensors and intervals of colourful, flashy and blurry colours. The cannabis condition slowed everything down, with calmer colours with reduced vision. Finally, in magic mushroom condition the world became unreal with imaginary scenes and characters. The car behaved in opposite way of the inputs received.	visual and auditory

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Encouraging bystander helping behaviour in a violent incident: a virtual reality study using reinforcement learning	After priming, participants are put into a virtual bar environment after which a virtual character enters wearing an Arsenal football shirt. Once the participant noticed them, the avatar starts a conversation with the participant about football. During the conversation, another avatar appears and starts to yell at the other avatar, with his behaviour becoming more and more aggressive until he physically pushes the other avatar towards a wall, after which the scenario ended.	only experimental condition.	2 minutes of getting accustomed to VR and the virtual environment before procedure begins.	The bar environment including the avatars were animated, not real-life recordings. The bar was made to be as immersive as possible with a bar table, wall of alcohol bottles and different tables set around. 3 bystander avatars were present, one which stood up and got closer once the altercation started.	visual and auditory.
Teaching children to cross streets safely: A randomized, controlled trial	Participants are put into a simulated environment of a crosswalk near a local school. The crosswalk is midblock and crosses a two-lane bidirectional road. The participants view the VR on 3 monitors infront of them. They view the traffic on the monitor and step down from a wooden block once it's safe to cross. Afterwards, environment switched to 3rd person and shows a race- and gender-matched avatar crossing the street to see if it is safe or not.	Participants randomly allocated to VR group, street-side group, video group or control group.	no priming.	The virtual environment also contains ambient and traffic noises to increase immersion. Virtual environment includes an animated street with houses, trees and different cars driving by. Monitors on which environment are presented are angled in a way that they show the straight road across the cross-walk and incoming cars from left and right.	visual and auditory stimuli.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Using immersive virtual reality to improve the beliefs and intentions of influenza vaccine avoidant 18-to-49-year-olds: Considerations, effects, and lessons learned	Participants experience 5 minute VR story. Participants are in a restaurant lobby while being infected with influenza and transmitting the virus to others via coughing. Afterwards, participant shrinks and enters the body of an older citizen where they are to use video game controllers to send immune cells after the influenza virus. Afterwards, participants were shown the elderly citizen in hospital. Participants were then moved to doctor's office where they received influenza vaccine and again shrinking inside the body to send immune cells after a small number of viruses. Final scene was back in restaurant lobby, this time with no coughing. All participants given VIS after procedure which included neutral and balanced benefit-risk information in a non-persuasive format on vaccinations.	Study employed a one-way between-subjects design with random assignment into 3 experimental groups: VR + VIS, video + VIS, e-pamphlet + VIS) and 1 control group (VIS only). Participants in other experimental groups received same video either via monitor or pamphlet with pictures.	no priming.	Transmission of the virus in the first environment was simulated via coughing noises and animation of particles travelling through the environment. All environments were virtually animated, not real-life recordings.	visual and auditory.

Table B7

Descriptions of Studies in Category 'Body Image'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
Resize Me! Exploring the user experience of embodied realistic modulatable avatars for body image intervention in virtual reality	After priming, participants are transported to exposition environment. In this environment, they performed 5 movement tasks in front of virtual mirror. Afterwards, participants estimated modified body weights of avatar 9 times. This was followed by conducted active body weight estimation 9 times by using the controllers to adjust the body weight of the avatar to match a presented number.	only experimental.	Researchers create an avatar based on the scans and measurements of each participants.	2 virtual environments were created. The first environment replicates the room in which participants conduct the procedure. This environment is used during avatar creation. The procedure uses the exposition environment which simulates a typical therapeutic office with indoor plants and a mirror. Before and in-between exposure to modified body types via the mirror the screen black-out briefly to cover up avatar changes.	visual and auditory (instructions given via audio and text boxes).
Using immersive virtual reality to modify body image	The procedure took 4 days, at the beginning of each a baseline measure was taken to establish categorical boundary for the participant. In VR, participants were exposed to 3 presentations of each of the 15 models in a randomised order. The participants were to identify the models as either fat or thin. After each model, participants given written feedback on their correct/incorrect identification.	Participants randomly assigned to 1st experimental group (time-limited labeling of models) 2nd experimental (unlimited labeling of models) and the control.	no priming.	The VR stimuli included 15 model avatars whose BMIs from 15.45 to 33.70 by increments of 1.30. All avatar models were female and of the same height. The virtual environment was of an office with planters and small bookshelves in the background.	visual only.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Developing a novel measure of body satisfaction using virtual reality	All participants experienced all conditions. In high social presence conditions, 3 groups of 3 avatars, each with varying body sizes. In these conditions, participants viewed all 3 groups and were asked to approach each group in order of their preference. In environment with no avatars, participants stood in areas of interest in the environment for the same amount of time.	Participants screened and separated into weight-concerned group and control group. A 2x2 design was used (high vs. low) to vary the degree of body salience (visibility of naked body) and social presence (presence/absence of avatars).	no priming.	2 environments were created to vary the degree of body salience. For low body salience an indoor scene of a university building was created with avatars in long-sleeved shirts and long pants. For high body salience, a virtual beach was created with avatars wearing swimsuits. An environment mirroring the physical room in which study took place was created for checking of equipment and training with VR.	visual only.

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
A virtual reality full body illusion improves body image disturbance in anorexia nervosa	In VR environment, participants were asked to look down and watch the body of the avatar. The experimenter stroked the participant's stomach with a soft brush. The brush contained a movement sensor in order to simulate the movement of the brush in VR. Depending on the condition, the stroking on the actual abdomen and VR abdomen took place simultaneously (experimental group) or was delayed in VR (control group). After exposure, participants again asked to estimate their body size.	Participants experienced both experimental condition and control condition. The experimental group had Full Body Illusion induced by synchronous visuo-tactile stimulation and for the control it was induced via asynchronous visuo-tactile stimulation.	Participants asked to estimate width and circumference of several parts of their body. Width of shoulders, abdomen and hips was estimated by putting tape on the wall indicating the left and right side of the body. Circumference was estimated using a string placed on the floor.	The environment created in Vr was an empty room with a virtual avatar that the participant viewed from 1st person. They viewed their naked abdomen as a virtual brush moved up and down slowly on their abdomen, simulating the real-life sensation accompanying VR.	visual and tactile.

Table B8

Descriptions of Studies in Category 'Miscellaneous'

Article name	Experimental Task	Conditions	Priming/Pre-exposure Stimuli	Stimuli	Sensory Factors
Effect of Immersive Virtual Reality Reminiscence versus Traditional Reminiscence Therapy on Cognitive Function and Psychological Well-being among Older Adults in Assisted Living Facilities: A randomized controlled trial	Immersive reminiscence was implemented using VR photos and videos. Using VR Wander, a tour of the participant's hometown was also conducted. They were able to walk around and visit familiar locations. Participants given controllers to look through digital images while listening to a voice describing their past significant situations and events about these images. Controllers could be used to turn music on or off.	Participants randomly assigned to 1 out of 3 groups: VR reminiscence group, the traditional Reminiscence therapy group, and the control group which received routine care.	Pre-VR preparation included preparation of VR equipment and preparation of Vr content. An interview was conducted with each participant to gather information regarding their recent memories, musical memories, memories from early childhood and other parts of their life. Based on gathered information, computer graphics VR images and videos were created. Family members also provided materials of personal or past significance.	VR reminiscence included exposure to old songs, old friends and childhood memories. VR exposure was mostly a slideshow of old photos along with audio description of important memories gathered during priming. VR Wander app helps build a 3D virtual environment based on real places, allowing participants to visit their hometown.	visual and auditory

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
A virtual reality intervention to improve the understanding and empathy for people with dementia in informal caregivers: results of a pilot study	Into D'mentia uses a shipping container furnished as a living kitchen with sensors and projections used to help simulate what it's like to have dementia. Participants watched a 13-minute 1st-person simulation movie which showed several situations that reflected a regular day of a person with dementia. Movie was accompanied by an inner voice that reflected the thoughts of person with dementia.	only experimental	Movie exposure was preceded by short demo which introduced the characters and let the participant get used to VR headset and its functions	Scenes in movie included: Person with dementia is alone and has to clear groceries, but they cannot find the fridge. They realise they bought the same groceries twice. The 2nd level of interaction involved a person with dementia in interaction with their daughter (informal caregiver). Your daughter confronts you that the TV remote is in the kitchen cupboard and talks about the situation with someone on the phone. The final level of interaction involved person with dementia and a group of people. In this scenario, you feel confused about why everyone is eating cake even though it is your birthday. You have a strong feeling that you want to go home but you are already home.	visual and auditory

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Article name	Experimental Task	Conditions	priming/pre-exposure stimuli	Stimuli	Sensory Factors
Investigating the value of immersive virtual reality tools for organizational training: An applied international study in the biotech industry	Participants are given organisational training via a virtual lab with scientists who guide the participant through different steps of enzyme discovery and development. Player progresses through training tasks, engaging with NPCs, interacting or reading different objects.	Participants were randomly assigned to experiemntal condition (VR) or control condition (prerecorded presentations)	no priming	VR environment of animated laboratory. Conceptual information is presented via exercises in which they were required to use body movements to perform different lab experiments. Factual information was presented through static posters in the environment. Spatial knowledge involved the same exercises as conceptual knowledge however more emphasis was put on spatial visual representations as key conveyor of knowledge (e.g. assembling molecule in 3D space).	visual and auditory

Appendix C

Introductory paragraph of the Checklist

The following checklist is meant to provide guidance to any researcher working on creating a VR psychological immersive intervention. You will be presented with multiple-choice questions, regarding different elements of the VR program, that you are meant to fill out based on the current plan of your intervention. Based on your given answers, you will be presented with follow-up questions and recommendation statements which you may consider in context of your intervention. The follow-up questions and statements will be presented to you in summary at the end of the checklist to ensure you are able to take your time considering the addition or changing of certain VR elements. Please make sure that all the elements added into your intervention are described in detail in your written report to increase the methodological rigor of the VR intervention field.