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360° videos for immersive mental health interventions: a systematic review

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Abstract

Virtual reality is increasingly recognized as a powerful method for clinical interventions in the mental health field, but has yet to achieve mainstream adoption in routine mental healthcare settings. A similar, yet slightly different technology, immersive 360° videos might have the potential to cover this gap, by requiring both lower costs and less technical skills to construct and operate such virtual environments. This systematic review therefore aims to identify, evaluate and summarize mental health interventions using immersive 360° videos to support an understanding of their implementation in daily clinical practice. The quality of the 14 selected studies was evaluated using a critical appraisal tool, addressing populations with clinical levels of psychopathological symptoms, somatic conditions associated with psychological implications and other at-risk groups. Immersive 360° videos successfully increased users' feelings of presence, given their realistic features, and therefore yielded positive outcomes in clinical interventions where presence is considered as an essential precondition. Because the technical skills required to create immersive 360° video footage are fairly limited, most of the interventions using this approach have been created by mental health researchers or clinicians themselves. Immersive 360° videos are still in an early phase of implementation as a tool for clinical interventions for mental health, resulting in high heterogeneity in focus, procedures and research designs. An important next step for making use of this technology may therefore involve the creation of standardized procedures, as a means to increase the quality of research and evidence-based interventions.

Keywords: systematic review; 360° video, virtual reality; mental health; immersive technology

Introduction

Immersive technology (IT) has already demonstrated its value for mental healthcare: as a means to treat symptoms or conditions, as a source of distraction or entertainment, and as a means for skills training (Carl et al., 2019; Hoffman et al., 2019; Riva et al., 2019; Rizzo et al., 2017, 2018; Rothbaum et al. 2014; Slater et al., 2019). IT is one of the most advanced forms of human-technology interaction, in which users experience digitally simulated realities similar to their experience of the real physical world (Slater & Sanchez, 2016). Different forms of IT, such as computer-generated virtual reality (VR), augmented reality (AR) or immersive 360° videos have been used to support mental healthcare. Unlike virtual and augmented reality, where the content of an alternative world or the content superimposed to reality is generated using computer graphics, immersive 360° video content presents users with photorealistic scenes of real-life settings.

Computer-generated virtual reality (VR) has been established as a means for successfully delivering exposure therapy in the treatment of anxiety disorders (Carl et al., 2019; Opris et al, 2012) including social anxiety disorder (SAD; Bouchard et al., 2019), fear of flying (Ferrand et al., 2015), panic disorder or agoraphobia (Bottela et al., 2007; Gromer et al., 2018) and posttraumatic stress disorder (PTSD; Best, McKenna, Quinn, Duffy, & Van Daele, 2020). Relying on IT as an exposure technique consistently seems to yield better results compared to imaginal exposure (Guitard, Bouchard, Bélanger, Berthiaume, 2019). It furthermore also has important advantages over in-vivo exposure, such as context controllability or convenience (Parsons & Rizzo, 2008; Rizzo & Koenig, 2017). In addition, IT has been successfully used as a distractor or disconnector from unpleasant experiences in the context of pain management, in both chronic and acute pain (Mallari et al., 2019), in the improvement of mood in chronic diseases (Chirico et al., 2020) and for promoting motivational effects in physical rehabilitation (Howard, 2017). Finally, IT has been used as an assessment and training environment in both clinical and non-clinical populations. For example, in the assessment of ADHD, VR has been successfully used to measure attentional skills under realistic and distracting conditions (Rizzo et al., 2001; Parsons et al., 2007; Muhlberger et al., 2016). Users with high-functioning autism have shown improvements with social skills and job interview training (Yang et al., 2018; Burke et al., 2017), whereas other groups with cognitive impairments have been trained to manage the daily life requirements, using computer-generated VR programs (Standen & Brown, 2006).

One of the main advantages of IT interventions for mental health is the opportunity to act in environments that are not possible, accessible or safe in reality, such as visiting a place from one's past experience or learning a new skill without the dangers entailed by testing it in the real world (Riva, Wiederhold, Mantovani, 2019). Simulated dimensions can be designed, controlled, simplified, or amplified, in line with a specific intervention's requirements. Another important advantage of IT is the possibility to switch between subjective dimensions where one may be psychologically present, whereas their physical presence remains unchanged (Blade & Padgett, 2015). In many clinical interventions, such as exposure or meditation, this is a powerful addition to existing tools, helping to address psychological problems, to train new skills or to enlarge one's comprehension and flexibility (Freeman et al., 2017; Riva & Serino, 2020). Moreover, there is consistent evidence regarding the role of context conditioning in the emergence of anxiety (Fanselow, 2010), whereas the confrontation and processing the individualized contextual cues seems to be a key factor in PTSD recovery (Cohen, Liberzon, & Richter-Levin, 2008; Van Rooij et al., 2014; Al Abed et al., 2020). This explains why tailoring is important when techniques such as (gradual) exposure, role-playing, or meditation are employed within therapeutic interventions. The potential of IT however, sharply contrasts its actual implementation in clinical practice, which remains limited. Although hardware costs and requirements have steadily declined over the years (Bun et al., 2017), a recurring challenge is related to the costs and complexity involved in the production of highly realistic and customizable environments. VR and AR either require a high level of programming skills and effort or significant financial means to outsource these efforts, both of which most clinicians do not typically have at their disposal (van Gemert-Pijnen et al., 2011; van der Vaart et al., 2014).

A technology that might have the potential to overcome this limitation is immersive 360° video technology. Panoramic or 360° video technology consists of video recordings, made with a device able to simultaneously capture and combine scenes in a 360° degrees perspective (Rizzo, Ghahremani, Pryor, & Gardner, 2003). To fully experience the resulting virtual environments' possibilities, these recordings may be presented and experienced by means of a head-mounted display (HMD) with 3 degree of freedom (pitch, roll, and yaw) orientation tracking, similar to some forms of computer-generated VR. Experiencing these immersive 360° videos creates a subjective experience of “being there” (Bailey & Bailenson, 2017), which in turn may impact users’ attitudes and behaviours, that may transfer to their real lives (Blascovich & Bailenson, 2011; Slater et al., 2016). Initially, mental health researchers used 360° video technology to facilitate a more realistic and less expensive creation of virtual reality environments, in interventions where an accurate capture of a personal event was necessary (Rizzo et al., 2003). Unlike computer-generated, 3D graphics-based VR, 360° video technology provides a more affordable method for rapidly creating VR environments in which users can experience a sense of immersion. This approach provides opportunities for creating simulations with high applicability for clinical mental health research and the creation of assessment and intervention systems (Rizzo et al., 2003).

Given the relative novelty of 360° video technology in mental healthcare (research), there currently is no overview available concerning the psychopathological categories, the types of intervention, and the efficacy or effectiveness of these approaches. An essential aspect concerning a mental health treatment or intervention is how it is subjectively perceived by users, which may impact the degree of adherence (or the drop-up rate) seen with 360° video clinical applications. Measurements of immersiveness, enjoyability, novelty, and motion-sickness may provide significant indicators of subjective perceptionin these technology-based treatments.

The present systematic review aims to evaluate the treatment, intervention outcomes, and subjective perception of existing studies on 360° video with a focus on mental healthcare. In doing so, we aim to provide guidance to mental health professionals' decision-making concerning if, how, and for whom to use 360° video in their daily practice. Our objectives are to identify:

1. Material / technological means needed to implement immersive 360° videos in clinical interventions for mental health.

2. Population and mental health problems for whom immersive 360° videos have been proven efficacious and/or effective;

3. Types of intervention / treatment that may be improved using immersive 360° videos;

4. The efficacy of treatments / interventions using immersive 360° videos, as assessed using effect sizes;

5. Advantages and drawbacks of immersive 360° videos, compared to other / non technological means for mental health assistance.

Method

The study was pre-registered in the PROSPERO database, CRD42020215448.

Selection

A PRISMA search strategy guided the present systematic review (Moher et al. 2015). To focus the search, the reviewers used the PICO approach, which formulates clinical questions in terms of the Population/Problem, Intervention, Comparison, and Outcome. Using this strategy to search for specific strings has been found to increase the precision of looking for the empirically supported treatment outcome literature (Schardt, Adams, Owens, Keitz, & Fontelo, 2007). Them following search string was used: Population/Problem – "mental health" OR "mental well-being" OR depression OR anxiety OR PTSD OR "emotional well-being"; Intervention – "360 video" OR "360 videoing" OR "360-degree video" OR "360-degree videoing" OR "immersive 360 video"; Comparison and Outcome - treatment OR therapy OR intervention.

Scopus, Medline, Psych Info, PubMed and Web of Science databases were each searched from earliest available until 5 May 2021 to identify peer reviewed studies of experimental or treatment interventions concerning mental health conditions, using immersive 360° videos (defined as 360° viewed via HMDs).

Studies were included when focusing on a population with clinical levels of psychopathological symptoms, people with somatic conditions associated with psychological implications and people at risk (e.g., elderly people). Systematic reviews or meta-analysis, animal studies, research containing only educational use of 360° videos, or those not entirely in English were excluded from this review.

Quality Appraisal and data extraction

Joanna Briggs Institute (JBI) critical appraisal tool for systematic reviews was chosen as an appropriate quality appraisal instrument for this review, given JBI's extensive work in assessing the trustworthiness and relevance of scientific papers (Aromataris & Munn, 2020; Ma et al., 2020; Zeng et al., 2014). Based on an assessment of the research designs most frequently used in the retrieved studies (cfr. infra) the JBI tool for quasi-experimental studies was selected. For the assessment of non-randomized interventions, JBI provides a 9-item checklist, assessing aspects such as: causality, validity, reliability, and consistency of the outcomes (Tufanaru et al., 2020). Each study was assessed by two researchers, blind to each-other, who awarded 1 point for each item rated "yes", and 0 points for items rated "no", "unclear" or "not applicable".

Analysis

Descriptive and quantitative data were collected, including authors, design, participants (age, gender, relevant mental health characteristics), interventions, outcomes and objectives of study, evaluation method abd measures used, facility, timeframe, results, and limitations. Data was extracted and recorded in an Excel spreadsheet by one of the researchers and subsequently checked by another. Subsequently, a narrative synthesis of findings from the included studies was made and, when sufficiently controlled interventions studies were available, main intervention effects were summarized as effect sizes.

Results

Search results

The search strategy resulted in 170 studies meeting inclusion criteria. The selection process is summarized in Fig 1. After the removal of duplicates, and the screening of titles and abstracts, 26 articles appeared relevant, of which 14 were in the end included in the systematic review. From the 14 excluded papers, three did not contained immersive 360° videos, three were primarily focusing on computer-generated VR, five were not explicitly focusing on patients population and three did not tested mental heath interventions. Two independent reviewers conducted the papers' selection process and were blinded to each other's decisions. Any disagreements were discussed before reaching a final decision.

-- Fig 1 here -- Flow chart of the search strategy

Quality Appraisal

The scores across studies ranged from 2 to 9, with a mean of 6.07 and a standard deviation of 2.46 (Table 1). The most common shortcomings of the evaluated interventions were the lack of a control group (N = 10) and a follow-up assessment (N = 10). A reduced quality of statistical analysis was observed in 6 of the 14 studies. Papers appraised with less than 5 points were either pilot studies, case studies or only described interventions without documenting implementation or obtained effects in sufficient detail. However, despite their methodological weaknesses, these studies can nevertheless still provide important knowledge concerning possible applications and subjective experiences associated with immersive 360° video tools and the technical means necessary to create clinical interventions.

-- Table 1 here –

Methodological characteristics

Most of the 360° videos were purposefully designed for the interventions (N = 11), others used off the shelf applications, containing 360° videos (Lindner et al., 2019), selected from the available sources or from previous studies (Paul et al., 2020; Appel et al., 2020). The footage was created and/or rated by researchers (N = 7), by clinical staff (N = 4), by film agencies (N = 2) or by participants themselves (N = 1). Some interventions used actors to tailor the content of videos (N = 4). Short duration clips (1 - 6 minutes) have been used in all interventions, primarily to avoid excessive stimulation, although avoiding habituation effects was also mentioned once as a rationale (Lindner et al., 2019). Stationary footage was opted for to avoid movement sickness and specific strategies were employed to film inside an MRI scanner (Ashmore et al., 2019). To increase the feeling of presence, the camera was positioned to film from the participant's perspective (e.g., depending on intervention, a seated participant, a child, or a person speaking while standing on a podium). Different strategies were used to enhance participants' opportunities to interact with the virtual environment, such as invitations to share their own experiences or public speaking exercises. Some advanced technological features included the content manipulation using eye gaze (Veling et al., 2021).

Dedicated devices were used to record 360° videos: Samsung 360-degree cameras equipped with bright f2.0 Lens (Appel et al., 2020; Ashmore et al., 2019), VUZE 360 stereoscopic camera (Evans et al., 2020), GoPro Fusion 360° camera (Coelho et al., 2020) or SP 360° 4K VR Cameras mounted on a tripod (Reeves et al., 2021), and the created videos were post-processed using the package iMovie v10.1.2 (Apple Inc, Ashmore et al., 2019). Different equipment was employed across the interventions, to facilitate the delivery of the immersive experience for the participants: Samsung Gear VR headsets (Appel et al., 2020, Ashmore et al., 201,9 Lindner et al., 2019; Tabbaa et al., 2019; Reeves et al., 2021; Veling et al., 2021), Z4 mini-headset (BoboVR; Ashmore et al., 2019; Holmberg et al., 2020), Oculus Go headset (Evans et al., 2020), Oculus Rift VR headset with or without integrated audio system (Hussain, 2018; Coelho et al., 2020; Malihi et al., 2020), Limbix VR headset (Paul et al., 2020), Google Cardboard headset (Ashmore et al., 2019; Lindner et al., 2019), Sennheiser HD 221 headphones to render the sound and to reduce the surrounding acoustic environment (Appel et al., 2020; Veling et al., 2021), a dictaphone to interview the participants.

Intervention and participant characteristics

An overview of the main intervention characteristics can be found in Table 2. In total, 373 people participated in interventions using 360° videos, the larger category being represented by adults (60%), followed by elderly (25%) and minors (15%). Most study participants had a clinical diagnosis. Among the adults with psychopathological symptoms, 70% were diagnosed with a anxiety disorder, 17% had depressive symptoms, 5% had psychotic disorders, 8% had bipolar disorder, and one patient had a somatic condition (Evans et al., 2020). Of the participants with anxiety disorders, 10% had agoraphobia (Lundstrom & Fernaeus, 2019), and 79% were diagnosed with SAD (Holmberg et al., 2020), among which 13% had comorbid PTSD (Nason et al., 2020), and 78% had public speaking anxiety (Lindner et al., 2019, Reeves et al., 2021). Among the elderly participants, 71% were evaluated with varying levels of cognitive and/or physical impairment (Appel et al., 2020), whereas 18% were diagnosed with different levels of dementia (Tabbaa et al., 2019). 60% of the children involved in these studies had a diagnosis of autism spectrum disorder (ASD; Malihi et al., 2020), and about 40% were pediatric patients who were preparing for an MRI experience (Ashmore et al., 2019). Fig 2 illustrates the main psychopathological categories for which the interventions employed 360° videos. Each intervention focused on a particular type of psychopathology, but symptom severity varied from non-clinical to clinical levels.

-- Table 2 here --

-- Fig 2 here -- Psychopathology distribution

When we look at intervention designs, an age pattern emerges: almost all treatments for adults are based on an exposure therapy approach, gradually applied and adapted for each anxiety disorder. For example, people with SAD were exposed to social contexts/interactions and those with public speaking anxiety (PSA) had to speak in front of a difficult 360° video audience. An exception is an intervention for patients with depression, where the immersive videos were used to create an interactive witnessing experience of a recorded testimonial done by a real (depressed) person. In addition, the participants with psychiatric disorders are involved in interventions based on relaxation techniques. An exposure approach was also used with children on the autism spectrum who were also exposed to relevant sensory and social triggers. However, for both ASD children and children who were give 360 video experiences to prepare for an MRI scan, the interventions also had an educational purpose. Finally, for the interventions with older people, either with physical or cognitive impairments, or dementia, the objective was to extend the limited living environment, provide some respite, and improve participants' mood.

Most interventions using 360° videos were created by mental health professionals, with only one intervention using 360° videos created by participants, who recorded a significant event from their own lives (Evans et al., 2020). In most of the studies the 360° video application was designed as an independent, stand-alone intervention (N = 10). However, in some cases, the video recordings were used as a component of a larger intervention, such as behavioral activation for major depressive disorder (MDD, Paul et al., 2020) or cognitive behavioral treatment (CBT) for agoraphobia (Lundström & Fernaeus, 2019) and for PSA (Lindner et al., 2019). Half of the interventions took place in multiple settings: both clinical and residential (N = 5) or both clinical and laboratory (N = 2). The other half of the studies were carried out in single settings, either residential settings (N = 2), laboratory settings (N = 4) or clinical settings (N = 1).

Study characteristics

All retrieved studies were published between 2018 and 2021, despite no restrictions on the timeframe of the search. As most papers described intervention studies, the majority made use of pre-post designs (N = 12), some of which also included follow-up (N = 4). Nine of these studies used either within-measures (N = 6) or mixed designs (N = 6), two were exploratory interventions, and one was a case study. Interestingly, most studies (N = 9) also used mixed methods with standardized psychometric instruments to select participants, although sometimes patients were already diagnosed. Both standardized and non-standardized, validated and non-validated measurements were used to assess treatment efficacy. For example, fear of speaking in public was assessed with both the Public Speaking Anxiety Scale (PSAS; Bartholomay & Houlihan, 2016) or the Personal Report of Public Speaking Anxiety Scale (PRPSAS; Hook, Smith, & Valentiner, 2008), as well as continuous analog scales for anticipated and peak fear (ranging from 0 to 100). Both standardized and non-standardized observational methods were also used, as some participants could not always provide reliable self-report evaluations, i.e., for patients with dementia. Most studies evaluated the immersive experience, but the quality of the measurement tools was again heterogeneous with semi-structured interviews, questionnaires and observations. Studies that documented the instruments used to measure the immersive experience included Reeves et al. (2021), who measured spatial presence, involvement and realness with the Igroup Presence Questionnaire (IPQ; Schubert et al., 2001) and Malihi et al. (2020), who used the negative effects subscale of the Independent Television Commission–Sense of Presence Inventory (Lessiter et al., 2001) and a 39-question self-report for spatial presence, engagement, ecological validity/naturalness, and negative effects, (Newbutt et al., 2016, Wallace et al., 2017). In addition, the Simulation Sickness Questionnaire (SSQ; Kennedy et al., 1993) was used by Coelho et al. (2020), Paul et al. (2020) and Veling et al. (2021), whereas the technology acceptance model (TAM; Manis & Choi, 2019) was used to assess the intervention acceptance by Paul et al. (2020).

Almost all the studies set out to evaluate the acceptability and efficacy of immersive 360° videos. For this purpose, quantitative and qualitative data was collected to capture different subjective dimensions of the immersive experience, such as motion sickness, immersiveness and presence, enjoyment, engagement or helpfulness. Reported ratings were consistently positive, indicating good acceptability and rather limited negative effects. When queried, participants nevertheless made numerous suggestions for improvement including the need for more diverse or dynamic and less repetitive content (Appel et al., 2020), inclusion of olfactory and tactile stimuli, improved rendering and audio/visual quality, and better interaction options. Although in small percentages, several symptoms associated with motion sickness were consistently reported across studies. More specifically, a number of participants with dementia manifested a slight increase in the sickness symptoms, with two cases of eyestrain and fullness of head, one case of blurred vision and one case of burping (Coelho et al., 2020), two participants with psychiatric disorders stopped using VRelax due to nausea and dizziness (Veling et al., 2021), and the participant in the case study by Paul et al. (2020) reported symptoms of nausea, general discomfort, stomach awareness, sweating, increased salivation, vertigo, and dizziness, especially during the adrenaline activities. Some authors provided suggestions about the possible feature of the immersive

360° videos that may generate motion sickness, such as incongruent images or a mismatch between vestibular and visual cues (Evans et al., 2020; Nason et al., 2020; Paul et al., 2020), the subtle impression that the user is looking at the image through a screen, generated by a less sophisticated technology, or the illusion that the image moves, while the user remained in the same position (Paul et al., 2020). Despite the general reduced negative effects, all the studies which addressed this aspect (N = 10) reported some cybersickness symptoms among users.

Clinical outcomes

A summary of the measurements and results in each of the reviewed studies is presented in Table 3. All interventional studies reported positive clinical outcomes, including increased positive affectivity (PA), decreased negative affectivity (NA) (Evans et al., 2020, Veling et al., 2021), reduced depressive symptoms (Paul et al., 2020) and reduced anxiety in preparation for an awake MRI analysis (Ashmore et al., 2019) or for public speaking (Lindner et al., 2019; Reeves et al., 2021). The only exception was the study of Coelho et al. (2020), where no significant differences were found between the pre- and post-measurements, in terms of behavioral symptomatology and quality of life. Whereas these studies primarily used immersive 360° video as stand-alone or as a part of exposure interventions, other research brought evidence for their capacity to trigger anxiety (Holmberg et al. 2020; Malihi et al., 2020; Paul et al., 2020) in the context in exposure or behavioral activation therapy. The novelty of employing immersive 360° video technology in clinical interventions resulted in a limited number of studies, which often opted for a combination of quantitative and qualitative approaches. The quantitative data that has been retrieved allowed to infer average effect sizes and provides more insights into the impact of professional support, and the potential of 360° video to elicit anxiety, each of which will be discussed in the following paragraphs.

-- Table 3 here --

Effect sizes. Only 5 out of 14 studies provided effect sizes, which were medium to large. Four studies measured direct intervention effects on reducing anxiety (Lindner et al., 2019; Reeves et al., 2021) and NA (Evans et al., 2020, Veling et al., 2021). The other one measured the extent to which anxiety was triggered by the intervention (Malihi et al., 2020). To facilitate the comparison, all effect sizes were converted to their Cohen *d* equivalent. The original reporting can be found in Table 3. Medium and large effect sizes (ranging from d = 0.77 to d = 1.67) were found for post-intervention PSAS scores, in different conditions (Lindner et al., 2019). Reeves et al. (2021) found large effects of 360°VRET interventions for both emotion-evoking (360° videos containing real audience members) and neutral content conditions (empty room) on PSAS scores (d = 2.61 and d = 1.38, respectively), compared to control condition. Moreover, 78% of the variance in PSAS scores was explained by presence and speech duration (the recorded time of participant's speech in the exposure session). Evans and colleagues (2020) found a a 10-points increase in PA and 7-points decrese in NA for the single hospitalized patient who participated. In the study of Veling et al. (2021) VRelax application was significantly more efficient in reducing the negative affective states, compared to classical relaxation (d = 0.60). A significant and large effect size found by Malihi et al. (2020) indicated that 360° video interventions elicited increased levels of anxiety in children with ASD witnessing several scenes in a virtual school bus (d = 1.32). However, they considered it a fun experience and reported that it would reduce their nervousness about being in a real bus. In addition, Paul et al. (2020) reported a decrease from 10 to 5 points on the Patient Health Questionnaire-9, corresponding to a transition from moderate to mild depression for the participant.

Professional support and self-help. Only one study investigated the impact of therapist-delivered vs. self-help use of 360° video treatment approaches. Better outcomes were reported by Lindner et al., (2019) when a PSA intervention was conducted by a therapist, compared to a self-led variant, although both variants nevertheless managed to significantly reduce symptoms of anxiety.

Anxiety-provoking potential. Immersive 360° video and computer-generated VR both managed to elicit low and moderated anxiety levels in participants with PTSD, in the study by Nason et al. (2020). Despite some reported successes of 360° video in triggering anxiety, it did not outperform a monitordisplayed condition, when a realistic learning environment was evaluated for children with ASD (Malihi et al., 2020).

Alongside these quantitative results, there where also a number of qualitative results. Unlike quantitative data, which provide consistent evidence about the outcomes, qualitative data can help to set the ground for future advances, by indicating the potential of this technology and by raising meaningful questions that need to be answered. Qualitative research has primarily focused on how 360° video can be used to elicit various psychological responses, e.g. manipulating triggered anxiety and allowing for stimulative effects and improved mood. Another focus has been on how 360° video can improve current practices, e.g. through adding therapeutic value and by improving the acceptability of exposure treatment. These results will be discussed in more detail in the following paragraphs.

Manipulating triggered anxiety. Several content features can be manipulated to increase participants' anxiety by tailoring the degree of control one may experience within the 360 video. For example, the social context experienced by participants with SAD can be manipulated when they are immersed in a shopping queue (Holmberg et al., 2020) and have an impact on their perceived anxiety (e.g., avatars that speak directly to the participants, increased crowd density or physical features, behaviour of virtual participants; Nason et al., 2020). Other features concern the structure of the virtual dimension, such as a restricted line of sight, sounds without an identifiable source, or not being able to interact with the environment (Nason et al., 2020).

Stimulative effects and improved mood. Semi-structured interviews and observations done by a clinical researcher, using Overt Aggression Scale-Modified for Neurorehabilitation (OAS-MNR; Lawton, Van Haitsma & Klapper, 1996) and Observed Emotion Rating Scale (OERS; Alderman, Knight & Morgan, 1997) indicated significant increases in pleasure and alertness for patients with dementia (Tabbaa et al., 2019). The intervention was also observed as able to create a private, safe and isolated place, helping to reduce aggressive behaviors, increase attention span and positive mood, to stimulate cognition and patients' openness to engage in activities. Similar observations have been made by caregivers, using standardized observations and semi-structured interviews, in two immersive interventions for older people, revealing an increased mental presence, more spontaneous movements, vocalizations or conversations, increased excitement, alertness and enjoyment and more satisfactory work for caregivers, whereas the majority of participants have been temporary relieved from unpleasant feelings and thoughts (Appel et al., 2020; Lundström & Fernaeus, 2019). Another stimulative approach used individually tailored 360° videos in reminiscence therapy, in order to activate past memories in people with dementia, and found that the intervention was engaging and safe, despite no significant progress was recorded concerning the observed symptoms, such as depression, anxiety, or agitation (Coelho et al., 2020).

Adding therapeutic value. Through 360° video exposure, participants with SAD and agoraphobia managed to identify their increased vigilance for feared stimuli. They also became better aware how this increased vigilance was associated with higher anxiety (Holmberg et al., 2020; Lundström & Fernaeus, 2019). Participants with PTSD in turn, observed that the awareness of feeling anxious increased anxiety even more. In addition, the VR experience stimulated them to re-evaluate the threatening value of the triggers (Nason et al., 2020).

Improving exposure treatment acceptability. Agoraphobia patients for whom immersive 360° videos were included in CBT treatment (Lundström & Fernaeus, 2019) reported this to be a helpful technique to address their fear after long avoidance periods. Moreover, participants with SAD (Holmberg et al., 2020) felt they were able to better tolerate triggered anxiety in a simulated context compared to a real-life situation, because they had the possibility to stop the experience at will. This may suggest that the 360° video approach may have value in the first phases of the exposure, as a strategy to improve treatment acceptability.

Discussion

The purpose of this systematic review was to inform and support mental health professionals decision-making concerning if, how, and for whom to use 360° video in their daily practice. Overall, the studies reviewed here included participants across a wide age range and with a variety of clinical conditions. Medium and large effect sizes were found, mainly in interventions addressing symptoms of anxiety, but also for mood improvement, through opportunities for enjoyable, diverting, or calming experiences. The immersive interventions were well accepted by most participants as few negative effects were reported. Most 360° video applications were custom-designed by mental health professionals, suggesting that any technical barriers for the creation and implementation of this type of content were generally surmountable.

Technological and material requirements

The technology for capturing 360° video content and delivering it to users in a VR HMD is generally low-cost and not technically overwhelming. Basic consumer-grade HMD devices and cameras are sufficient to capture and run 360° videos typically at a low-cost. Interactive activities can be designed by creating appropriate content (e.g., real audience recordings for public speaking exercises, or footages with sharings of personal experiences of depression to stimulate participants' disclosure) and the use of props to enhance a more natural 1st person experience (e.g., using a real podium to step on, when the participant speaks in front of a virtual audience). The choice can nevertheless still be made for more expensive high-end systems, which for example have the added advantage to be easily supplemented with additional features, such as eye-tracking (Rubin et al., 2020) or voice recording (Hussain, 2018; Tabbaa et al., 2019).

Scope of mental health issues

Immersive 360° videos have primarily been found useful in the context of anxiety: not only for reducing anticipatory anxiety through efficiently providing information in advance of a fear inducing situation (MRI pre-exposure) but also in generating anxiety through the virtual recreation of fearful situations and stimuli in the service of its subsequent reduction. This latter approach is believed to provide a safe context where the client can begin to confront and therapeutically process the emotions that are relevant to the feared context as well as de-condition the learning cycle of the disorder via an extinction learning process. This is in line with previous research showing the efficacy of immersive technology for triggering and extinguishing anxiety in the context of exposure therapy (Opris et al, 2012, Carl et al., 2019). 360° videos have been explored in the treatment of PSA, PTSD, SAD and agoraphobia, and as a means to create realistic social environments as a part of future interventions (e.g., social skills training) for children with ASD.

However, several other mental health issues have also been the focus of immersive 360° videos, such as loneliness, isolation, and negative affectivity, generated by reduced autonomy in elderly living in long-term residential care. Also, cognitive impairments, aggressive behaviours or apathy, as seen in people with dementia from specialized institutions, such as locked psychiatric hospitals or those with invalidating chronic diseases have be targeted through immersive 360° videos.

Mental health and well-being challenges can be impacted by age-related physical deterioration, chronic diseases or anxiety-inducing physical interventions (e.g., MRI claustrophobic anxiety in children). All the mentioned clinical conditions successfully used 360° videos to alleviate the associate psychological burden. Moreover, this burden is often shared with the caretakers, either professional staff or family members, who could also benefit from these types of interventions (Appel et al., 2020; Tabbaa et al., 2019).

Advantages and disadvantages as intervention tools

Immersive 360° video can be a useful addition to conventional intervention tools and techniques by placing the user in a different environment while limiting access to the grounded reality. The user can explore the new environment according to their own interests by looking around an immersive environment which is continuously changing (Heijn et al., 2020). Therefore, using this tool has the potential to induce feelings of presence. This is critical in any mental health intervention which aims to confront individuals with specific context or stimuli, or to distract them from physical reality. Especially in the early phases of anxiety treatment, immersive instruments can be preferred to the “in vivo” exposure technique, given the greater possibilities to be controlled by both clinicians and users.

When compared with other immersive technologies, both advantages and disadvantages of 360° video tools can be found, depending on the context in which they are used. Although this systematic review does not aim to facilitate the decision making process between different immersive tools and technologies which are currently available, it can nevertheless highlight some keep points concerning 360° videos which might help to advance such a decisional process. Immersive 360° videos provide realistic content, therefore having potential to creating increased feelings of presence (Nason et al., 2020). However, no linear association was found between anxiety and presence, so that only a limited feeling of presence may be sufficient to trigger anxiety in clinical settings (Bouchard &Rizzo, 2019). Moreover, emotional and motivational aspects seem to be more important in generating the sense of presence, compared to the immersive characteristics of technology (Heijn et al., 2020). Therefore, immersive 360° videos may represent a better therapeutic option in cases where the realistic rendering is essential in eliciting intense emotions. 360° videos are furthermore easier, faster and cheaper to create compared to other immersive technologies, which often require extensive technical knowledge and programming skills. Because the threshold for creating immersive footage is quite low, both mental health researchers and clinicians have managed to successfully create efficacious interventions using such 360° videos themselves. In addition, recently created online platforms provide a large variety of freely-available panoramic videos, which may be integrated in mental health interventions (Tabbaa et al., 2019). Such a platform containing 73 immersive 360° videos has been created and evaluated for its potential to induce emotions in a study by Li et al. (2017), with the purpose to support further research in this direction. Equally important is the reduced cost of the necessary technological equipment, which may be as low as the cost of a standard smartphone and disposable cardboard HMD.

A clear disadvantage of using 360° videos, which has to be acknowledged as well, is the limited possibility for interaction with the environment (Nason et al., 2020). In mental health interventions, people with clinical levels of psychopathology can only witness other dimensions, without having the freedom to engage and act more than moving their heads in different directions. This can already capture different perspectives, but significant therapeutic effects that may be obtained through action are reduced, although some strategies can be used to facilitate participants' interaction (cfr. supra). Whereas a character in the footage can send a message or ask a question, it cannot respond to user's input, as is the case with computer-generated VR, which provide more complex interaction possibilities. Limited interaction is however possible in 360° videos and may have critical therapeutic effects. Even discrete movements in an immersive environment, such as eye-fixation or head-orientation appeared to impact users' attitudes and behaviors. Content-related eye movements, unconsciously aiming to avoid uninterested audience in PSA tasks seem to have a role in maintaining anxiety levels (Rubin et al., 2020). Another recent study (Li et al., 2017) suggested that head movement direction was related to specific emotional dimensions of arousal and valence, when participants were asked to rate immersive 360° videos from a database, aiming to induce a range of emotions. However, more research is needed to determine the precise content features that can elicit specific eye or head movements, and their association with certain emotions that may stimulate positive outcomes in clinical interventions.

Challenges and Next Steps

All the included studies were very recent, revealing a new tendency in technology-based mental health interventions, which may mirror a direction of the technological advancement and a need to capitalize the benefits of immersive technology to support mental health treatments. The current review has its limitations. Firstly, only a limited number of studies could be included in the analysis, which does not allow the drawing of extensive conclusions. However, this limitation is understandable, given the novelty of user-friendly devices allowing easy production of immersive 360° videos and the lack of procedural standards for their implementation in clinical practice for mental health. Secondly, methodological limitations, such as suboptimal study design (e.g., lacking a control group, using unreliable or insufficient measurements), biased selection of the participants (e.g., exclusion of participants prone to movement sickness) or not-transparent reporting (e.g., no data or no statistical analysis provided) may hinder a useful reflection of the method's efficacy and acceptability.

Finally, despite the generally positive findings, most studies do not offer clear conclusions for future research. They may nevertheless be considered first attempts to build a methodological base for 360° video implemented treatments, as each of their limitations can be further used for better approaches. Thus, more efficient treatments using 360° videos should aim to create more diverse, better structured and better-tailored content, according to patients' needs. The development of standardized content may increase the quality of research and evidence-based interventions. Moreover, technological advances may provide adaptable HMD (e.g., for people wearing glasses or audio correction devices) and new possibilities to interact with the environment during the immersive experience. In addition, systematic examination of psychiatric comorbidities may focus the addressability of a specific intervention.

Drawing from these first experiences, suggestions for future studies using 360° videos include testing the efficiency of more complex auditory or speech-based content for different categories of mental health disorders, comparing them with in-vivo or imaginary exposure, and assessing the interaction between psychopathology and immersive experiences.

Conclusions

This systematic review has captured an early phase of a new technology-based approach in clinical interventions for mental health. Promising results revealed possible developments for several types of psychopathological disorders, due to accessible means that can open new dimensions for people who need specific contexts, where they can psychologically process their limits and emotions, and they can act toward their fulfilment.

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Table 1. Quality appraisal using JBI checklist for quasi-experimental studies

Study	JBI evaluation
Lindner et al. (2019)	9
Malihi et al. (2020)	9
Reeves et al. (2021)	9
Veling et al. (2021)	9
Evans et al. (2020)	7
Paul et al. (2020)	7
Tabbaa et al. (2019)	7
Appel et al. (2020)	6
Coelho et al. (2020)	5
Holmberg et al. (2020)	5
Nason et al. (2020)	4
Ashmore et al. (2019)	3
Hussain et al. (2018)	3
Lundström & Fernaeus (2019)	2
Note. M = 6.07; *SD* = 2.46	

Table 2. Design features and main intervention characteristics of included studies

Authors and Publication Year	Design	Participant profile and mean age (SD)	Intervention & technology	Objectives	Settings	Timeframe
Appel et al. (2020)	Pre-post	66 older adults, with varying cognitive and/or physical impairments 80.5 (10.5)	3 to 20 min of 360° videos of nature scenes Samsung Gear VR HMD	Feasibility and potential of immersive VR 1) for enjoyment / relaxation 2) to reduce anxiety & depressive symptoms	Dedicated spaces within hospital & long-term care residences	Maximum of 20 min
Ashmore et al. (2019)	Pre-post Mixed methods	23 child patients, of which 5 initially considered to undertake MRI with anesthesia Me = 9, range 4-12	Panoramic videos of the entire MRI journey with an animated, interactive VR interface Bobo VR Z4 Google Cardboard	Reduce anxiety in children undergoing MRI scan.	Patients' homes Hospital's waiting area Scan room	Maximum of 5 min
Coelho et al. (2020)	Pilot study Pre-post Mixed methods	9 older adults with dementia (85.6 ± 7.4) 3 caregivers 1 family member	4 individual reminiscence sessions, using 360◦ video recording of a location that was relevant to participants' life story GoPro Fusion 360° camera Samsung Gear VR HDM Oculus Rift	To evaluate intervention's feasibility. To explore the effects on psychological symptoms and life quality.	Local institutions for health and social services Psychosocial Rehabilitation Lab	Maximum of 15 min
Evans et al. (2020)	Pre-post Mixed design Mixed methods	33 first year psychology students; 20.18 (3.50) 1 hospitalized patient 48	10 min of 360° video self-recorded life-event VUZE 360 stereoscopic camera Oculus Go	Acceptability and efficacy of personalized immersive interventions for healthy affect.	University setting Hospital	10 min
Holmberg et al. (2020)	Pre-post Mixed design Mixed methods	9 adults with SAD 27.4, 19-38 9 healthy controls 28.7, range 23-33	Three 360° videos from shopping situations, with increasing degree of exposure. BOBO VR headset	Developing 360° videos as an exposure therapy tool for SAD.	Laboratory / psychotherapy settings	Not mentioned

Hussain (2018)	Exploratory design	12 participants with mild and moderate levels of depression range 18 – 26	Thought-listing and say-out-loud exercise, while watching 360° videos of a personal story of depression. Oculus Rift	Improving depressive symptoms acceptability and professional help-seeking.	Laboratory settings	60 min
Lindner et al. (2019)	Pre-post Between groups design	22 participants, clinical levels of PSA 30.84 (6.63) 20 healthy controls 31.88 (7.91)	Three-hour therapist or self-led session, using 360° videos for three scenarios. Four-week module online transition program. Samsung Gear VR HMD	Evaluate and compare effectiveness of interventions for PSA.	(Therapy) room at Stockholm University Participants' homes	20–30 min
Lundström & Fernaeus (2019)	Pre-post Social care project	12 patients with agoraphobia Over 100 elderly people	1. 12 weeks of CBT treatment with exposure sessions using 360° videos. 2. Co-watching familiar, synchronized 360° videos. HMD (not specified)	1. Improve efficiency of CBT exposure therapy. 2. Increase quality of life for the elderly through shared experiences.	1. Psychology Clinic 2. Elderly care centers	12 weeks of treatment Not provided
Malihi et al. (2020)	Pre-post Mixed design	35 children with ASD 13 (5)	Virtually entering a stationary school bus, with a driver and other children on the bus. Several sensory and social triggers were included. Oculus Rift ViewSonic VP2468	To explore the safety and usability of immersive virtual reality system to deliver interventions for children with autism spectrum disorder.	Research laboratory	5 min
Nason et al. (2020)	Exploratory Comparative Qualitative design	VR: 7 veterans 32 (9.26) 360° video: 5 veterans 30 (4.06) PTSD and medium or high social anxiety	Virtual grocery store experience (in VR or 360° video). Oculus Rift	Comparing VR and 360° videos as alternatives to in vivo or imaginal exposure in CBT treatments of anxiety disorders.	VR laboratory	5 min
Paul et al. (2020)	Case report	One adult with MDD; male, 40	Modified behavioral activation protocol, using	Assessing feasibility, acceptability, and	Home / Zoom sessions	

			a VR headset to simulate activities. Limbix VR headset	tolerability of VR behavioral activation for an adult with MDD during a global pandemic.		Weekly sessions of 50 min, four weeks
Reeves et al. (2021)	Pre-post Mixt design	51 participants, high levels of self-reported PSA (>60) 26 (7.53)	Four weekly sessions of 4 to 15 min public speaking task, in emotion-evoking or neutral 360°-video content. Samsung Gear 360˚camera Samsung Gear VR HMD	Comparing 360° VRET efficacy for PSA in emotion-evoking and neutral context.	Research laboratory, Queens University Belfast	2 min preparation & 4 to 15 min
Tabbaa et al. (2019)	Observational Pre-post Mixed methods	8 people with moderate to severe dementia 69.63, range 41-88 16 caregivers	15 minutes spent in an immersive environment, with a selected content. Samsung Gear VR HMD	Assess benefits of using immersive 360° video	A locked psychiatric hospital	15 min
Veling et al. (2021)	Randomized controlled crossover trial	50 patients receiving ambulatory treatment for anxiety, psychotic, depressive, or bipolar disorder	VRelax (self-management relaxation tool) or standard relaxation Samsung Gear VR HMD; headphones	Assess the immediate effects of VR on negative and positive affective states and short-term effects on perceived stress and symptoms, compared to standard relaxation exercises.	Home setting	Minimum 10 min for 10 days

Note. ASD, autism spectrum disorder; HMD, head mounted device; MDD major depressive disorder; SAD, social anxiety disorder.

Table 3. Key measurements, main results and general comments of included studies

Study	Outcome measures	Experience measures	Results	General comments
Appel et al. (2020)	STAI MiDAS Standardized observations	Semi-structured interviews on VR experience	6/8 negative items decreased 6/8 positive emotions increased 79%: "seemed very real" 61% expressed enjoyment 82%: easy to get used to HMD No negative side-effects	Better image quality & increased narrative video content were suggested to improve the experience. VR content and equipment could be better adjusted and optimized to fit targeted population's needs. Participant selection was biased toward acceptance.
Ashmore et al. (2019)		Custom survey on patient experience Custom survey on staff experience	4 of the 5 children took MRI without GA. Patients reported feeling more positive about their MRI and would recommend the resource to other children. Staff assessed it could help prepare children for an awake MRI, by reducing anxiety. Both patients and staff rated the VR resource enjoyable, helpful and easy to use.	No control group.
Coelho et al. (2020)	Semi-structured interviews Neuropsychiatric Inventory EUROHIS-QOL-8 Guided observation	Guided observation (engagement) Simulator Sickness Questionnaire	No significant differences between pre- and post-intervention for psychological and behavioral symptomatology (M = 9.2, SD = 5.3; M = 9.7, SD = 5.3) and for quality of life (M = 28.6, SD = 5.9; M = 29.2, SD = 6.9). 83% of immersive experiences perceived as pleasant 73.5% of participants interested in exploring the virtual environment, with 57.7% communicating spontaneously. No cases of severe symptoms of motion sickness.	Small sample size without control group. Short intervention program without follow-up assessment. Low quality of measurements.
Evans et al. (2020)	PANAS	Custom survey on acceptability and satisfaction	Increase in positive affect (27 to 37) Decrease in negative affect (19 to 12) Predominantly positive feelings concerning the technology	One single patient does not allow generalizations about using 360° video interventions in hospital settings.
	SUDS	Semi-structured interviews (presence,	Patients with SAD has significantly higher SUDS scores than controls, in two of the videos.	Small sample size.

Holmberg et al. (2020)	Semi-structured interviews (anxiety)	acceptability, and cybersickness)	Presence was enhanced by sound and reduced by limited interaction. 8 out of 9 patients would want VRET as a part of their therapy. More cybersickness in controls than in SAD participants.	No data provided.
Hussain (2018)	Custom positive and negative emotions scale ATSPPHS SBISH	NA	More positive (*M* = 4.89, *SD* = .81) than negative emotions (*M* = 2.34, *SD* = .66), after watching the 360° videos. High positive attitude toward help seeking behavior (*M* = 4.34, *SD* = .96). More positive emotions marginally predicted a positive attitude for help seeking behavior (*p* = .052).	No baseline measurement or control group. The online surveys' content is not revealed.
Lindner et al. (2019)	PSAS	NA	Between-group effect size (therapist-led OST + online program versus waiting group): *d* = 1.50 Within-group effect size (before – after therapist-led OST + online program): *d* = 1.67. Within-group effect size (before – after self-led OST + online program): *d* = 1.35 Significant decrease in PSAS scores post-transition to six-month in the therapist-led arm (*SE* = 2.14, *p* = .007), but not in the self-led arm.	Relatively small sample. No systematic examination of psychiatric comorbidity.
Lundström & Fernaeus (2019)	Standard CBT measurement	NA	Significant long-term effects (6 and 12-month follow-up) More meaningful work for caregivers.	No data or statistical methods provided.
			Increased mental presence, more spontaneous movements, general excitement of the elderly. Positively evaluated 360° VR experience.	
Malihi et al. (2020)	STAI	ITC-SoPI Self-report questionnaire for spatial presence, engagement, ecological validity/ naturalness, and negative effects	Significant increase in anxiety after the HMD-VR task (Wilcoxon rank-sum: *Z* = 183.5, *p* < .001). No significant difference between conditions. Significantly greater scores on spatial presence and naturalness for 360° video condition, compared to control, (*d* = 0.3, *p* = .003 and d = 0.47, *p* = .002 respectively).	The exclusion of children with a predisposition to motion sickness and the stationary scenario may bias the negative effects evaluation.
			74% of participants preferred 360° video condition. No significant differences for negative effects between conditions	
	Semi-structured interviews	Ratings of motion sickness and immersiveness	Anxiety ratings: VR (*M* = 4.33; *SD* = 2.44); 360° video (*M* = 3.63, *SD* = 1.80)	Experience was slightly different in the compared conditions.

Nason et al. (2020)	Ratings of anxiety		Immersiveness: VR (*M* = 4.83, *SD* = 1.69); 360° video (*M* = 6.38, *SD* = 2.50) Motion Sickness: VR (*M* = 1.33; *SD* = 2.44); 360° video (*M* = 2.50, *SD* = 2.18)	Small sample size. Not enough statistical power to compare data across conditions.
Paul et al.(2020)	PHQ-9 Self-reported depressive symptoms	TAM SSQ Five-question telepresence scale	Participants' depressive symptoms decreased from a score of 10 (moderate depression) to a score of 5 (mild depression). Average presence: 9.53 out of 12 Physical tolerability: 1.8 out of 48 Emotional tolerability: 3 out of 21	Possible placebo effect. Change in medication. Single participant.
Reeves et al. (2021)	PSAS LSAS-SR FNE-B	IPQ	Significantly different PSAS scores between intervention and control groups at post-intervention (p <.001, η^2 = .52) and follow up (p < .001, η^2 = .95) Significantly different LSAS scores between intervention and control groups at post-intervention (p = .03, η^2 = .14) and follow up (p =.004, η^2 = .27) Significantly different FNE scores between intervention and control groups at post-intervention (p < .001, η^2 = .32) and follow up (p < .001, η^2 = .43) Significant difference in IPQ scores between emotion and neutral content groups (p = .01, η^2 = .27) Presence (β = .90, t = 7.13, p < .001) and speech duration (β = .30, t = 2.40, p = .03) significantly predicted changes in PSAS scores.	Not representative sample (female, white, young adults).
Tabbaa et al. (2019)	OAS OERS	Semi-structured interviews to reflect their experience. Qualitative observations	A substantial reduction of aggressive behaviors and a high level of presence was observed after 360° video experience. General alertness significantly increased from before (*Mdn* = 4.50) to after (*Mdn* = 5.00) 360° video exposure (p < .05). Significant increase in pleasure from before (*Mdn* = 1.25) to during (*Mdn* = 2, p < .05), and from before to after (*Mdn* = 1.75) 360° video exposure (p < .05).	Limited possibilities to adapt technological devices to individual needs. Relatively small sample. Single hospital setting.
Veling et al. (2021)	EMA for affective states PSS IDS-SR BAI GPTS	SSQ Time spent in VR	VRelax was significantly more efficient in reducing negative affective states, compared to relaxation exercises (16.2% versus 21.2%; t=−2.02, p = .04) Mean total score on SSQ was lower after (*M* = 43.1; *SD* = 10.9), compared to before VRelax (*M* = 48.3; *SD* = 12.7). Several participants reported cybersickness, and 2 stopped using VRelax because of nausea and dizziness.	No measure of physiological effects of VRelax.

Note. ATSPPHS, Attitude Toward Seeking Professional Psychological Help Scale; BAI, Beck Anxiety Inventory; EMA, ecological momentary assessment; EUROHIS-QOL-8, FNE-B, fear of negative evaluation scale-brief form; perceived quality of life; GA, general anesthesia; GPTS, Green et al. Paranoid Thought Scales; HMD, head mounted device; IDS-SR, Inventory of Depressive Symptomatology–Self-Report; IPQ, Igroup presence questionnaire; ITC-SoPI, Independent Television Commission – Sense of Presence Inventory; LSAS, Liebowitz Social Anxiety Scale; MiDAS, Music in Dementia Assessment Scales; OAS, Overt Aggression Scale-Modified for Neurorehabilitation; OERS, Observed Emotion Rating Scale; PANAS, Momentary/state variant of The Positive and Negative Affect Schedule; PHQ-9, Patient Health Questionnaire-9, PSAS, Public Speaking Anxiety Scale; PSS, Perceived Stress Scale; SAD, social anxiety disorder; SBISH, Scale for behavioral intention to seek help; SR, self-report; SSQ, Simulator Sickness Questionnaire; STAI, State/Trait Anxiety Inventory; SUDS, Subjective Unit of Discomfort Scale; TAM, Technology acceptance model; VR, virtual reality; VRET, Virtual Reality Exposure Therapy; VAS, visual analog scale .

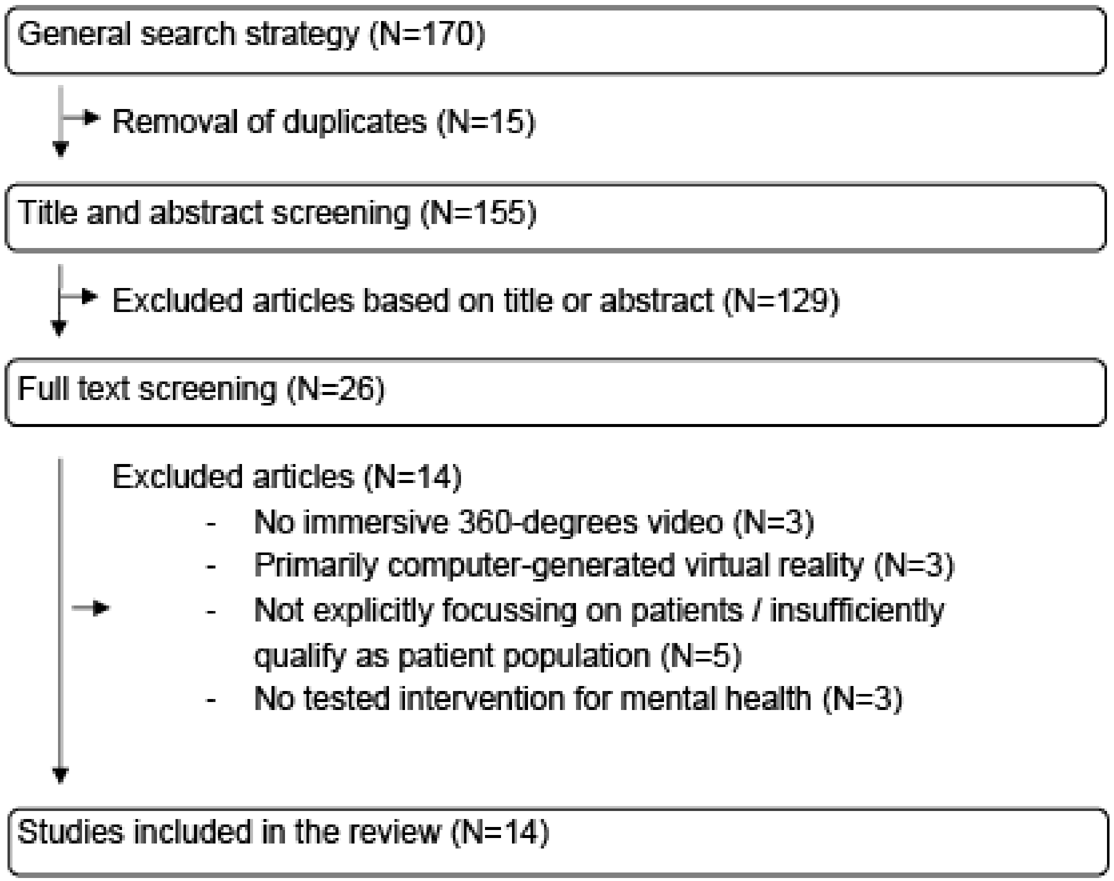
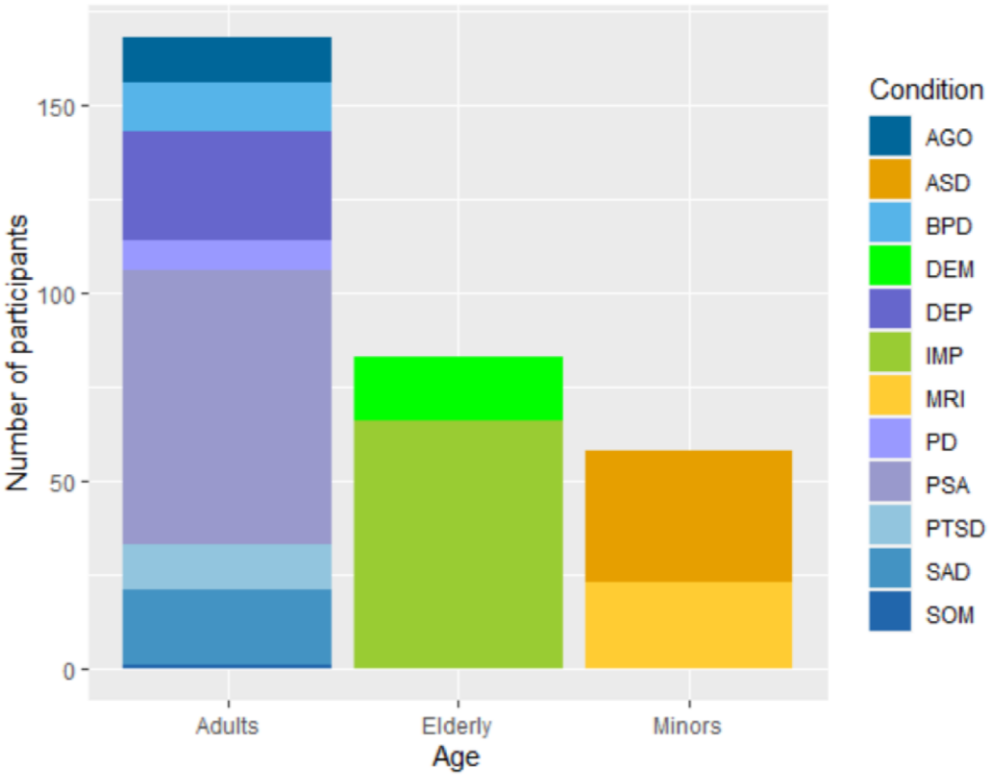


Fig. 1 Flow chart of the search strategy

Figure 2: **Psychopathology distribution**



AGO, agoraphobia; ASD, autism spectrum disorder; BPD, bipolar disorder; DEM, dementia; DEP, depression; IMP, physical or cognitive impairments; MRI, children undertaking MRI procedure; PD, psychotic disorder; PSA, public speaking anxiety; PTSD, post-traumatic stress disorder; SAD, social anxiety disorder; SOM, somatic disease.