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Review Article

Virtual Reality-Based Mindfulness for Chronic Pain Management: A Scoping Review

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ABSTRACT

Objectives: To identify and synthesize the scientific literature on virtual reality (VR)-based mindfulness applications for the management of chronic pain in adults.
Design: A scoping review methodology was followed and conducted according to Preferred Reporting Items for Systematic Review and Meta-Analyses extension for Scoping Reviews guideline.
Data sources: Combinations of key words related to "virtual reality", "mindfulness", and "chronic pain" were searched for in PubMed, CINAHL, EMBASE, Scopus, and the Cochrane library databases. Title, abstracts, and full-text articles were screened against inclusion criteria.
Review/Analysis methods: Braun and Clarke's thematic analysis approach was used.
Results: Seven studies were included in the review and their findings synthesized into three overarching themes: (1) physical and mental health benefits; (2) treatment engagement and satisfaction; and (3) intervention usability. The last theme had four subthemes which were cybersickness, physical limitations, technical support, and personalized design.
Conclusions: While studies suggested VR could improve chronic pain management by enhancing the practice of mindfulness, weak study designs and small sample sizes limited the utility of the review results. Future research should rigorously co-design and test VR-based mindfulness applications with people with chronic pain to assess if they improve health and other outcomes.

Chronic pain affects approximately 60 million people worldwide including those with low back pain, arthritis, fibromyalgia, and cancer among others (Mills et al., 2019). It is described as "pain which persists beyond normal tissue healing time", generally taken as more than three months, and can cause numerous problems including anxiety and depression, an inability to work and perform normal everyday activities, and a dependence on opioids (Dahlhamer et al., 2018). In addition, the health and social care costs associated with chronic pain are significant, with approximately £5 billion spent in the United Kingdom (British Pain Society, 2021), and between $560 and $635 billion spent in the United States on pain management each year (Gaskin, 2012). These costs are likely to rise given aging populations across the world. Hence, the management of chronic pain is of urgent importance. While pharmacologic interventions are commonly prescribed, alternative psychosocial therapies such mindfulness (Majeed et al., 2018) are also used by people to self-manage chronic pain.

Mindfulness is a practice which brings attentional focus to the present moment, for example through awareness of breathing or acknowledging one's thoughts or emotions as they occur (Kabat-zinn, 2003; Liu et al., 2018). Formalized mindfulness interventions such as mindfulness-based stress reduction (MBSR) and mindfulness-based cognitive therapy (MBCT) are increasingly used in healthcare, particularly to support emotional regulation such as stress reduction or behavior change (Schell et al., 2019). It is also considered a successful psychosocial therapy to improve the management of physical health, including those that live with chronic pain, as mindfulness can enhance one's awareness of the body, increase relaxation, and facilitate stress management (Chiesa, 2011). However, traditional face-to-face mindfulness programs can be limited by cost, poor accessibility, and lack of availability (Goldberg et al., 2018; Hoffmann, 2017). Those delivered online or through mobile applications (apps)

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may better address users' needs in providing convenience and privacy (Flett et al., 2019; Plaza et al., 2013), and can also be inexpensive to access, particularly for hard-to-reach populations (Schultchen et al., 2020). However, some digital mindfulness apps use poor visualizations and provide limited feedback. This may lead to low adherence to and drop out from these types of digital health interventions designed to facilitate self-management of conditions like chronic pain (Mani et al., 2015). Furthermore, an individual's digital literacy skills, their preferences towards using technology to manage health, and access to affordable digital tools among other factors may also contribute to a lack of engagement with digital health interventions (O'Connor et al., 2016).

Virtual reality (VR) is a synthetic world in which a user is entirely immersed in computer-generated representations of an environment, with display technologies that capture the gaze direction of the user (Slater & Sanchez-Vives, 2016). The immersive experiences offered by VR are used in a variety of healthcare settings (O'Connor, 2019), deployed for relaxation to mitigate against distress when experiencing acute pain (Hoffman et al., 2019), and to help reduce pain and anxiety for cancer patients (Ahmad et al., 2020), among others. In contrast, Augmented Reality (AR) superimposes virtual information over a real word view, blending the digital and physical environments. In both of these technologies, the sensory illusion of 'being there' in a specific space has a connection to mindfulness practices (Flett et al., 2019).

A recent scoping review by Austin (2022) on virtual reality for people with chronic pain, identified 44 studies across a range of application areas such as exercise, gaming, relaxation, and mindfulness (three studies). However, only two bibliographic databases, MEDLINE and Embase, were searched, only studies using validated outcomes measures were included, and single case studies were excluded, meaning some pertinent literature may have been missed. Another recent narrative review of VR-based mindfulness interventions found that the immersive and multisensory environment created by VR had potential features that could support mindfulness practice (Arpaia et al., 2021). Nonetheless, the review looked broadly at a range of clinical applications including pain, stress, depression, anxiety, and borderline personality disorder. Whilst VR apps designed to enhance mindfulness practices are increasingly used to help mitigate psychosocial issues and support subjective wellbeing, there are relatively few studies which explore the potential for the management of chronic pain through mindfulness practice using virtual environments (Chandrasiri et al., 2020). Furthermore, a review of the scientific literature in this niche area has not yet been undertaken and a review focused on VR mindfulness applications for chronic pain specifically could benefit both patients and practitioners. Hence, this scoping review aimed to identify and synthesize the current scientific evidence on VR-based mindfulness practice to manage chronic pain.

Methods

Review Design

Scoping reviews are a type of knowledge synthesis that tend to be more exploratory in nature, aiming to address broader topics where different study designs are utilized, and focused research questions are typically not asked or answered (Arksey & O'Malley, 2005). They are particularly useful when an area of research is emerging and complex, and has not been comprehensively reviewed, as the process can rapidly map key concepts and the types of available evidence (Tricco et al., 2016). Therefore, a scoping review was deemed an appropriate approach to reviewing the literature on VR-based mindfulness practice for managing chronic pain. The Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) checklist for reporting scoping reviews was followed when conducting this review (Tricco et al., 2018) (Appendix 1).

Sources and Search Strategy

A rigorous search of five bibliographic databases: CINAHL, the Cochrane Library, Embase, PubMed, and Scopus, were searched in November 2021 using key search terms relevant to the review, i.e., "chronic pain", "virtual reality", and "mindfulness". A detailed search strategy for CINAHL can be found in Appendix 2, which was adapted for the other databases. Searches were limited to published empiric primary research using any study design, published in the English language, with a date range from 2010 to 2021, acknowledging the swift technological changes in VR technologies. The reference lists of included articles were also hand searched for any potentially relevant studies.

Screening and Eligibility

In line with the central tenant of scoping reviews, broad inclusion criteria were applied to identify relevant articles. The Population, Intervention, Context, Outcome (PICO) framework was used to guide the inclusion criteria for the review (Methley et al., 2014). The population were those of any adult socio-demographic profile experiencing chronic pain, the intervention was a VR application used to support mindfulness practice, and the outcome related to any physical, mental, or social health outcome. In this context, studies did not necessarily involve comparators, as they were largely small-scale pilot or feasibility studies instead of randomized controlled trials. The initial search yielded 2,606 studies which were exported to Rayyan (https://www.rayyan.ai/) for screening. Duplicates were removed and then titles and abstracts were reviewed for eligibility. Studies whose participants were drawn from pediatric populations, those which focused on specific acute conditions that caused pain, mindfulness mixed with other meditative, relaxation or other therapies, where specific gamified environments such as Second Life^{TM}, or outcomes that related to the delivery of digital health services were excluded. Next, full-texts were retrieved and screened, and those not meeting the criteria were excluded (see Fig. 1). Screening was undertaken by a single reviewer and any ambiguity during the process was discussed with the research team.

Data Extraction and Synthesis

A data extraction sheet was prepared on Microsoft Excel and piloted and refined using a handful of studies. Then, the key characteristics of all included studies were extracted (Table 1). Thematic analysis was utilized to code and categorize data into higher order themes, which were mapped within and across studies to identify emerging themes and subthemes related to VR-based mindfulness for chronic pain management (Fig. 2) (Braun & Clarke, 2006). Coding clinics and peer debriefing sessions were held with members of the research team, to cross check samples of analyses to improve qualitative rigor and reduce researcher bias. A critical appraisal of the included studies was not undertaken, as scoping reviews focus more broadly on the heterogenous body of knowledge on a topic instead of determining the quality of the evidence base.

Results

Study Characteristics

Seven articles were included in the final scoping review, published between 2013 and 2021 (Table 1). Five were set in

Table 1
Characteristics of Included Studies.

Authors, year, country, publication	Research aim(s)	Study design	Participants and setting	Intervention	Results
Botella et al. (2013), Spain, *Cyberpsychology, Behavior, and Social Networking*	To examine the effectiveness of a VR intervention in the treatment of fibromyalgia as an adjunct to Cognitive Behavioral Therapy (CBT)	Design: Pre-test, post-test, 10 × 2-hour group CBT sessions in a VR environment and education on pain and healthy habits; facilitated by therapists over 7 weeks, 6-month follow-up	Participants: Adult patients with Fibromyalgia (FM), Female = 6; Male = 0; Age: 47-65 years Setting: rheumatology service within a public hospital	VR hardware: 2 personal computers, a large projection screen, 2 projectors onto a 4 × 1.5 screen with surround audio (no headset) VR software: engaging Media for Mental Health Applications world	Measures: FM Impact Questionnaire, Chronic Pain Coping Inventory, Beck Depression Inventory II, Positive and Negative Affect Schedule, VR Satisfaction Scale Findings: Participants improved over a six month follow up period; some reduction in levels of depression; increase in positive affect; no increase in negative affect; no change in use of illness-focused coping strategies; high increase in wellness-coping strategies; experience of VR rated consistently highly
Darnall et al. (2020), USA, *JMIR Formative Research*	To evaluate the feasibility and preliminary efficacy of a self-administered VR program for chronic pain	Design: a parallel-group, randomized controlled trial (RCT), 21-day (3-week) intervention, 1 of 2 unblinded treatments (VR or audio narration), 4-8 treatment sessions (1-5 minutes)	Participants: a web-based convenience sample of adults (n = 46 audio, n = 42 VR) aged 18-75 years with self-reported chronic low back pain or fibromyalgia Setting: community-based	VR hardware: Oculus Go VR headset preloaded with software VR software: software with 3 components, 1) skills rooted in pain CBT, 2) relaxation training and 3) mindfulness	Measures: Defense and Veterans Pain Rating Scale, Average Pain Intensity, Pain Interference on Activity, Mood, Sleep, and Stress, Pain Catastrophizing Scale, Pain Self-Efficacy Questionnaire, Patient Global Impression of Change, Satisfaction with treatment, Motion Sickness and Nausea Findings: Symptom improvement was found for each pain variable (all $p < .001$). Most VR participants reported no nausea or motion sickness (n = 19/25, 76%). Significant time × group effects were found in favor of the VR group for average pain intensity ($p = .04$), pain-related inference with activity ($p = .005$), sleep ($p < .001$), mood ($p < .001$), and stress ($p = .003$).
Garcia et al. (2021), USA, *Journal of Medical Internet Research*	To assess if VR would evidence superior outcomes for all baseline to post-treatment comparisons in people with chronic low back pain compared to those assigned to a Sham VR	Design: double-blind, parallel-arm, single-cohort, remote, randomized placebo-controlled trial, one of two 56-day (1 session daily) treatment programs: 1) therapeutic VR or 2) Sham VR	Participants: community-based adult individuals with chronic low back pain for 6 months or more (n = 179), female: 76.5%, 137/179; Caucasian: 90.5%, 162/179, mean age: 51.5 years Setting: community-based	VR hardware: Pico G2 4K all-in-one head-mounted VR device (exhalation is measured by the microphone embedded in the hardware) VR software: EaseVRx - principles of CBT, mindfulness, and pain neuroscience education, and Sham VR an active control that utilizes non-immersive, 2D content)	Measures: Defense and Veterans Pain Rating Scale, Pain Interference With Activity, Mood, Sleep, and Stress, Patient's Global Impression of Change, NIH Physical Function and Sleep Disturbance, Pain Catastrophizing Scale, Pain Self-Efficacy Questionnaire, Chronic Pain Acceptance Questionnaire, Satisfaction with treatment, VR use, System Usability Scale, Motion Sickness and Nausea, Over-the-Counter Analgesic Medication Use, Opioid use Findings: For EaseVRx, large pre–post effect sizes ranged from 1.17 to 1.3 and met moderate to substantial clinical importance for reduced pain intensity and pain-related interference with activity, mood, and stress. Pain catastrophizing, pain self-efficacy, pain acceptance, prescription opioid use did not reach statistical significance for either group.

(*continued on next page*)

Table 1 (*continued*)

Authors, year, country, publication	Research aim(s)	Study design	Participants and setting	Intervention	Results
Garrett et al. (2020), Canada, *Heliyon*	To explore the experiences of individuals with cancer related chronic pain in using a daily VR-based self-administered home therapy	Design: qualitative inductive (constant-comparative) approach using two focus groups (approx. 60 minutes each)	Participants: patients with cancer (aged >16) with chronic involved in an ongoing RCT of a VR intervention (n = 12), 30 min of activity per day for six days Setting: at home	VR hardware: HTC Vive stereoscopic headset VR software: two interventions based on cognitive engagement and two based on mindfulness meditation	Measures: none – qualitative study Findings: Five major thematic categories emerged: (1) activities; (2) usability; (3) effects; (4) mode of action; and (5) technical aspects. Mixed results in the use of adjunctive VR therapy to manage chronic cancer pain. Future designs of VR interventions engage pain patients in the design process to ensure maximum efficacy of experiences to with individuals' preferences
Gromala et al. (2015), Canada, *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*	To examine the effectiveness of a VR based Mindfulness Based Stress Reduction (MBSR) program to manage long-term pain	Design: focus groups and participatory design sessions, followed by a single 12-minute experimental VR session with control group (audio only)	Participants: Patients with chronic pain Female = 7; Male = 6; Age: 35-55 Setting: university hospital pain clinic	VR hardware: Deepstream VR viewer and galvanic skin response (GSR) sensors VR software: Virtual Meditative Walk (forest environment)	Measures: Numerical Rating Scale Findings: As slow movement of camera mimics act of walking, GSR sensors respond to arousal levels with changing weather immersive visuals and stereoscopic sounds. Responses suggest observing biofeedback data helps participants monitor management of perceived pain. VR appears effective in teaching MBSR to manage attention as therapeutic pain control intervention and more effective than MBSR
Igna et al. (2014)), Romania, *Journal of Evidence-Based Psychotherapies*	To evaluate the effectiveness of a VR enhanced CBT intervention with MCBT usual care in reducing pain intensity and associated emotional and cognitive problems, improving quality of life	Design: clinical trial, 6 session intervention program, with 2 individual meetings per week, all participants received physiotherapy and pharmacotherapy	Participants: 68 adult patients with chronic pain (CBT = 18, MBCT = 25, control = 25), mean age of 47, most were female n = 36, Setting: unclear	VR hardware: HTC Vive stereoscopic headset VR software: five minutes of exposure to the "SnowWorld" and afterwards debriefing about how shifting attention from pain decreases intensity of pain	Measures: Visual Analogue Scale, McGill Pain Questionnaire, State-Trait Anxiety Inventory, Beck Depression Inventory, Profile of Mood States Short Version, Functional Assessment of Cancer Therapy Scale – General Version, General Attitudes and Beliefs Scale – short version, Pain Anxiety Symptoms Scale, Pain Catastrophizing Scale, Automatic Thoughts Questionnaire, Mindful Attention Awareness Scale, Chronic Pain Acceptance Questionnaire Findings: There were no significant differences between intervention groups and control group at post-treatment, except for the pain intensity scores but there were significant differences between pre-treatment and post treatment, for all three conditions, in mindfulness ($t(62) = -3.365$, $p = .001$) and pain catastrophizing ($t(49) = 4.147$, $p = .000$).
Gromala et al. (2015), Canada, *International Conference on Virtual, Augmented and Mixed Reality*	To examine effectiveness of Virtual Meditative Walk VR system (based on MBSR) in managing chronic pain	Design: Single 12-minute VR test sessions; control group continued usual clinic MBSR exercise	Participants: Patients with chronic pain, Female = 4, Male = 3 (in VR group); Female = 3, Male = 3 (control group); Age: 35-55 Setting: established pain clinic	VR hardware: stereoscopic display mounted on movable arm (gazing into device held at shoulder height) and GSR sensors VR software: prototype of Virtual Meditative Walk (foggy forest)	Measures: Numerical Rating Scale Findings: VR and MBSR training with biofeedback appears significantly more effective than MBSR alone in reducing reported pain levels. Specific benefits of combination of VR and MBSR mediation identified as immersive sonic and visual signals about real time feedback to reinforce training.

Abbreviations: CBT = cognitive-behavior therapy; FM - Fibromyalgia; MCBT = mindfulness-based cognitive-behavior therapy; MBSR = mindfulness based stress reduction; RCT = randomized controlled trial; VR = virtual reality

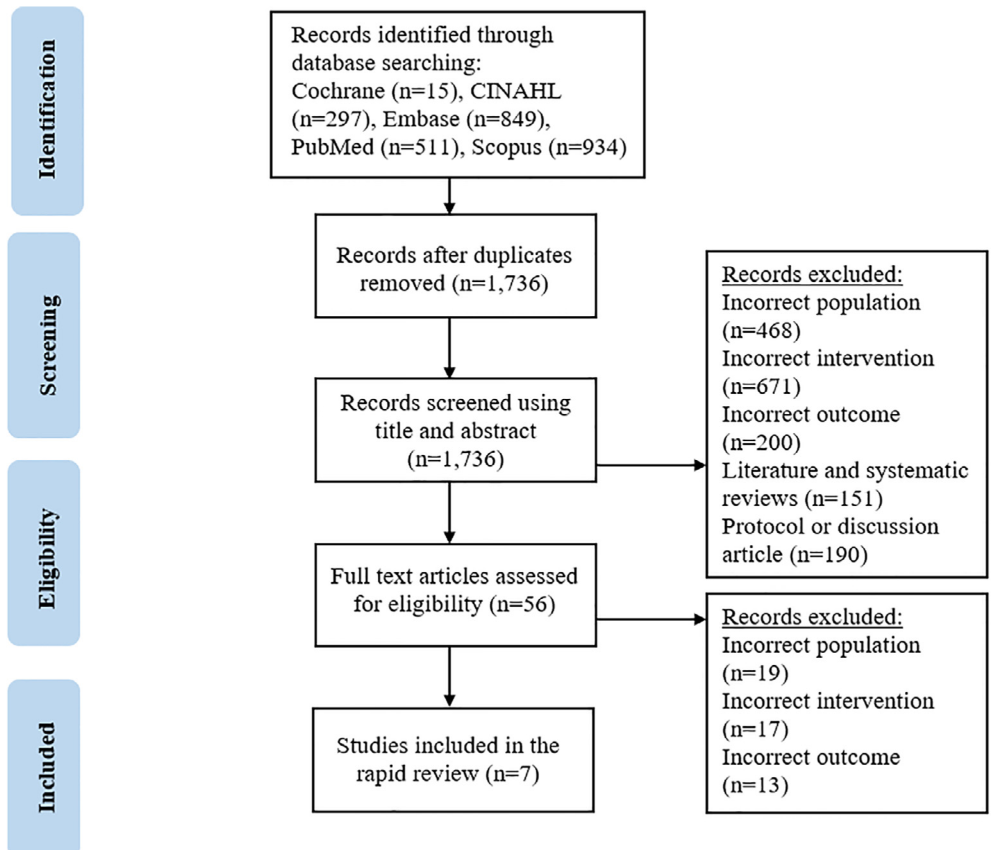

Figure 1. PRISMA flow diagram.

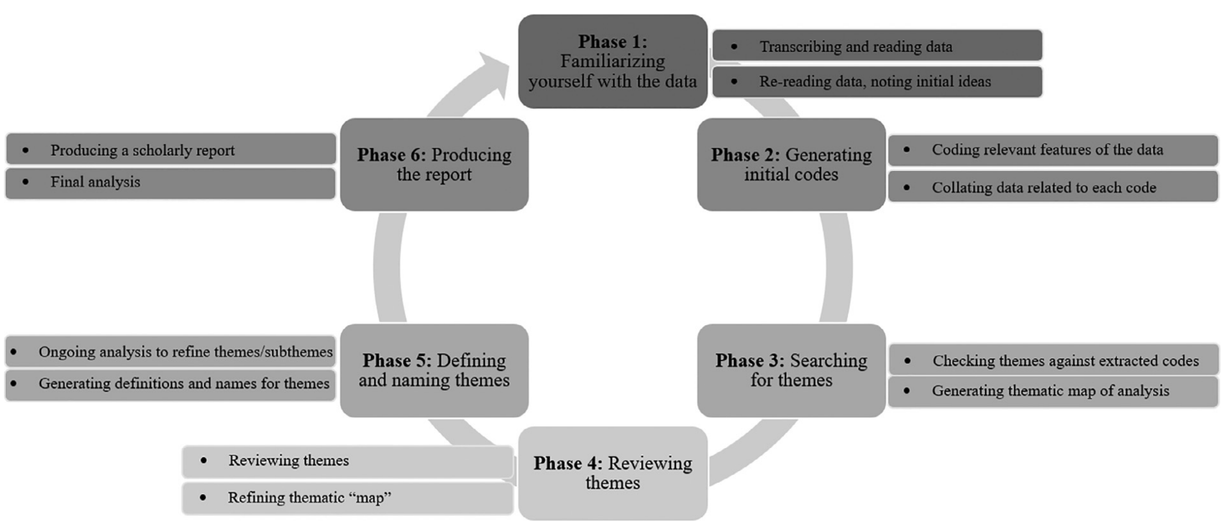

Figure 2. Thematic analysis process.

North America: two in the United States (Darnall et al., 2020; Garcia et al., 2021) and three in Canada (Garrett et al., 2020; Gromala et al., 2015; Tong et al., 2015). A further two studies were based in Europe: one in Spain (Botella et al., 2013) and one in Romania (Igna et al., 2014). Two were published in medical informatics (Darnall et al., 2020; Garcia et al., 2021) and psychology journals (Botella et al., 2013; Igna et al., 2014), one in an all-science journal (Garrett et al., 2020), and two were conference proceedings in the computer science and virtual reality domains (Tong et al., 2015; Gromala et al., 2015). The study authors held a variety of professional backgrounds including business, computer science, medicine, nursing, psychology, and science, along with clinical and industry co-authors. The populations recruited to the included studies were a mixture of men and women with chronic pain, chronic low back pain, chronic cancer pain, or fibromyalgia. However, women comprised the majority of participants where these data were available. Other sociodemographic data such as ethnicity and educational level were often not reported, except in Garcia et al. (2021) who noted that 90.5% of participants were White. Typically, the sample size was small, ranging from a minimum of 6 (Botella et al., 2013) up to 179 participants (Garcia et al., 2021).

In terms of the VR interventions, the interpretation of mindfulness varied across studies with some mixing mindfulness with relaxation, CBT, and other techniques (Botella et al., 2013), whereas others were based specifically on MBCT (Igna et al., 2014), or MBSR (Gromala et al., 2015; Tong et al., 2015). The VR sessions lasted from as little as 1-5 minutes (Igna et al., 2014; Darnall et al., 2020) to a maximum of 120 minutes (Botella et al., 2013), with some taking place only once (Gromala et al., 2015; Tong et al., 2015), while other VR mindfulness sessions were run over several weeks (Botella et al., 2013; Darnall et al., 2020; Garcia et al., 2021; Igna et al., 2014). Only a single study incorporated a 6-month follow-up (Botella et al., 2013). A range of VR hardware was used across the included studies such as Oculus (Go, Quest, or Rift), HTC, and Samsung headsets, with only two studies incorporating physiologic monitoring devices (Gromala et al., 2015; Tong et al., 2015). Participants were immersed in a variety of virtual environments, namely natural landscapes such as forests.

The outcomes included a range of measures for chronic pain such as the Chronic Pain Coping Inventory, Chronic Pain Acceptance Questionnaire, and Fibromyalgia Impact Questionnaire, as well as general pain measures such as the Pain Interference on Activity, Pain Catastrophizing Scale, and Pain Self-Efficacy Questionnaire among others. Other aspects impacted by chronic pain such as depression, and quality of life were also assessed. One study measured mindfulness using the Mindful Attention Awareness Scale (Igna et al., 2014), while others evaluated aspects of the VR experience such as VR usability (Botella et al., 2013; Garcia et al., 2021). The study designs varied from randomized controlled trials (Darnall et al., 2020; Garcia et al., 2021; Igna et al., 2014), to quasi-experimental studies (Botella et al., 2013; Tong et al., 2015), with one taking a qualitative approach (Garrett et al., 2020), and another utilizing a mixture of methods (Gromala et al., 2015). The settings ranged from hospital outpatient clinics (Botella et al., 2013; Gromala et al., 2015; Tong et al., 2015), to those based in the community (Darnall et al., 2020; Garcia et al., 2021), or in participants' homes (Garrett et al., 2020). Overall, the small-scale nature of the studies and the diversity of their designs, participants, interventions, and outcome measures meant the effectiveness of VR mindfulness applications for managing chronic pain could not be determined, as a meta-analysis was not feasible to undertake.

Key Themes

Three main themes were identified around VR mindfulness practice for managing chronic pain: (1) physical and mental health benefits; (2) treatment engagement and satisfaction; and (3) intervention usability, which had a number of subthemes.

Physical and Mental Health Benefits

All seven studies reported some physical or mental health benefit from those who practiced VR-based mindfulness to manage chronic pain (Botella et al., 2013; Darnall et al., 2020; Garcia et al., 2021; Garrett et al., 2020; Gromala et al., 2015; Tong et al., 2015; Igna et al., 2014). For instance, Botella et al. (2013), reported that the post-treatment scores of the Fibromyalgia Impact Questionnaire and Beck Depression Index showed a reduction in impairment and depression levels for participating patients. Likewise, Darnall et al. (2020) found that a number of pain related measures (i.e., pain intensity, pain-related activity, mood, sleep, and stress interference) were lowered by 30%-50% in the VR group using the digital mindfulness intervention during the three-week RCT, demonstrating a clinically important change, particularly after Day 15. However, the measures for pain self-efficacy and pain catastrophizing improved for both the treatment and control groups, who received an audio-only version. Furthermore, Garcia et al. (2021) showed that physical function and sleep disturbance improved during their RCT of a VR mindfulness intervention, as the treatment group had higher physical function (p = .022) and lower sleep disturbance (p = .013) compared with the control after eight weeks.

A qualitative exploration by Garrett et al. (2020) supports the physical health benefits of VR mindfulness applications, as many participants reported less pain, due to the relaxing, immersive, or distracting nature of the virtual experience, although for some this only lasted a short time (approximately 30 minutes). A handful of participants also reported improvements in sleep and mobility due to being more relaxed and feeling less pain (Table 2). Another physical health benefit reported in one study was a substantial decrease in over-the-counter analgesic medication use by the VR mindfulness intervention group (p = .01), although prescribed opioid use remained unchanged (Garcia et al., 2021).

Treatment Engagement and Satisfaction

Two studies mentioned that participant engagement with the VR mindfulness application was excellent, with Darnall et al. (2020) reporting users completed 34 sessions over 21 days and Garcia et al. (2021) reporting participants used the VR device on average 43 times. Satisfaction with VR mindfulness as a treatment intervention to help manage chronic pain was also indicated in three studies (Botella et al., 2013; Darnall et al., 2020; Garcia et al., 2021). In Botella et al. (2013) satisfaction levels of six women with fibromyalgia ranged from 7 to 10, where zero was "not at all" and ten was "very much". Darnell et al. (2020) also highlighted the majority of participants in the VR group, with selvvf-reported chronic low back pain or fibromyalgia, were either extremely satisfied or very satisfied (n = 21/25, 84%) with the treatment. In Garcia et al. (2021), the VR group reported greater satisfaction with the treatment, were also more likely to recommend VR to another person, and were more likely to continue using the VR headset, than the control (p < .001). However, the authors noted their clinical trial took place during the coronavirus pandemic and so engagement and satisfaction may have been higher than normal as people were social distancing and working in more remote, isolated environments.

Intervention Usability

Garcia et al. (2021) was the only study that explicitly measured VR usability, via the System Usability Scale, with both treatment groups (VR and Sham VR) who had chronic low back pain reporting high levels of VR usability, 84.33% and 81.16% respectively. Four usability sub-themes emerged from the review findings: (1) cybersickness; (2) physical limitations; (3) technical support; and (4) personalized design. Supporting quotations from included studies can be found in Table 2.

Cybersickness

Three studies commented that participants experienced some type of motion sickness or nausea while using a VR mindfulness application (Darnall et al., 2020; Garcia et al., 2021; Garrett et al., 2020). Most individuals in Darnell et al. (2020) reported never experiencing cybersickness (n = 19/25, 76%), with five out of the six individuals who did only experiencing it 'sometimes' and the other participant 'often'. This did not seem to affect engagement with the digital intervention, except for the single participant reporting it 'often' as they used the VR application a third less times compared with the rest of VR group. Similarly, a small number of participants in Garcia et al. (2021) experienced nausea and motion

Table 2
Quotes from Included Studies.

Theme / subtheme	Supporting quote from included study
Theme 1: Physical and mental health benefits	"I also looked forward to my sessions every day. Because I actually would get to the point where I was in the game and I realized I had no pain. And it was like, wow! I'm not only enjoying myself, but I actually have no pain!" (Garrett et al., 2020, p. 6) "The meditation was great, the scenery was beautiful, and the scenery in the other one with the ocean scenes and that, that was relaxing, beautiful. Those were good" (Garrett et al., 2020, p. 6) "One of the things that I found too, before I had bone cancer I was very active. I was hiking, I was always into rock climbing, sports, things like that. So, for me to be able to like virtually go to, like… I would just go and check and explore something and watch the water. I really enjoyed that part, it took me to places that I just relate to from my climbing days" (Garrett et al., 2020, p. 7) "It was about 30 min…that I felt sort of calmer and more relaxed, and just… you'd felt like you'd had a break from the pain" (Garrett et al., 2020, p. 6) "With the slight analgesic effect yes, mobility was increased somewhat…When I'm in pain I'm less mobile, whereas with the VR headset, when I was done the VR, I was thinking about my pain less" (Garrett et al., 2020, p. 6)
Theme 3, Subtheme 3.1: Cybersickness	"The butterfly [Wildflowers], that made me nauseous. I couldn't do it, I couldn't control the butterfly flying around, and it was making me sick" (Garrett et al., 2020, p. 6)
Theme 3, Subtheme 3.2: Physical limitations	"I just thought it was important to have a comfortable chair to make sure that - because I have leg issues, so you have to start off with a comfortable chair, because after a half an hour, if you're sitting on a stool, the pain can be worse. So, I made sure I had a pillow and my heat blanket" (Garrett et al., 2020, p. 5) "I found that the headset was really quite heavy, which actually affected my neck" (Garrett et al., 2020, p. 5) "For me, half an hour is long enough. In actual fact, I did have eye strain after about 20 min and I needed to remove the glasses from my head and take a break. So, it did bother me, with the eyes" (Garrett et al., 2020, p. 6)
Theme 3, Subtheme 3.3: Technical support	"I just want it to work and I don't know how to fix things like that. So, it's something that I would absolutely educate myself on and want somebody that I could reach out to if I was having problems" (Garrett et al., 2020, p. 7)
Theme 3, Subtheme 3.4: Personalized design	"Most of us here I would assume spend a lot of our effort and time in the day trying to escape from pain, and in a variety of ways, so this is a tool that we could use. Especially in the future, you could have thousands of different situations that you could immerse yourself in, for as much time as you want in the day" (Garrett et al., 2020, p. 5) "I found that - I'm not sure which one, one of the talking ones – where they got you to focus on your pain [VMW]. I found that that made my pain much worse, and I think part way through I actually stopped doing it and went to a different one to do my 30 min a day, because the pain was just so aggravated by concentrating on it." (Garrett et al., 2020, p. 6)

sickness during the VR treatment (n = 7/72, 9.7% and n = 5/75, 6.7%). Some individuals interviewed during focus group sessions in Garrett et al. (2020) also mentioned negative physical effects of motion sickness from being immersed in a virtual world.

Physical limitations

Most of the cancer patients with chronic pain in Garrett et al. (2020) found physical limitations with the VR equipment or software. This ranged from being uncomfortable when sitting or standing during the VR mindfulness intervention, discomfort when wearing the VR headset or eyeglasses inside the headset to improve vision, or eye strain from immersion in a three-dimensional, digitized environment.

Technical support

Garrett et al. (2020) was the only study to highlight that technical support might be needed for those using a VR mindfulness application, as several participants mentioned this during the focus group sessions, particularly if using the digital intervention at home. The author hypothesized that this could reflect the early stage of VR development and how complex it could be to use some of the headsets and virtual software applications:

Personalized design

The need for more personalized design was highlighted in Garrett et al. (2020), as some participants would have preferred more open environments that they could explore rather than following a guided virtual experience. More choice over the type of virtual environment and stimulus when practicing mindfulness for pain management was noted by a couple of participants, who valued the ability to curate their own virtual world that was tailored to their needs. One individual felt the design of the virtual space he inhabited made the pain worse and changed to a different VR experience, indicating a need for a variety of virtual environments within which to practice mindfulness.

Discussion

This scoping review found that there was limited scientific evidence to support using VR mindfulness applications to manage chronic pain, as this is an emerging research area with evolving technologies and more robust, large-scale studies are needed to determine the effect of VR based mindfulness interventions on those who experience chronic pain. However, preliminary evidence suggests that VR may help enhance aspects of mindfulness practice, such as feeling relaxed, centered, or distracted, which could lessen pain and improve sleep and mobility for some people. Although sample sizes were generally small, those who used VR mindfulness applications tended to engage with them on a regular basis and were satisfied with this type of digital treatment modality. The usability of the technology, both the hardware and software, seemed to be an issue as some participants experienced cybersickness, discomfort from wearing a VR headset, or eye strain from being fully immersed in a virtual environment. In these cases, potential benefits in the self-management of chronic pain could have been outweighed by short-term discomfort and nociceptive pain from the VR equipment. Others recommended technical support when using VR technology at home and more personalized designs of virtual worlds to support tailored mindfulness practice.

The findings of this review have been mirrored in other literature. Rice et al. (2019) found that a non-patient population, U.S. military veterans, had less pain (24.4%) and stress (17%) after eight weeks of a mindfulness meditation training program delivered virtually using customized avatars in Second Life. Although few studies have examined VR-based mindfulness in relation to pain, Flores et al. (2018) found similar results when examining a VR mindfulness intervention to deliver dialectical behaviour therapy (DBT) among patients with a spinal cord injury, as they felt less depressed, anxious, and emotionally upset afterwards. Equally, Gomez et al. (2017) tested a VR DBT mindfulness skills training program with a patient with severe burns and found it decreased negative emotions.

The level of satisfaction with VR as a mental health treatment modality found in this review has been noted elsewhere, as Navarro-Haro et al. (2017) tried a VR DBT mindfulness skills training technique with meditation experts and reported high levels of acceptance towards using VR to practice mindfulness. Navarro-Haro et al. (2016) also tried the same approach with a patient with borderline personality disorder and found the intervention was well accepted by the participant. The high level of engagement with VR mindfulness interventions reported in this review has been echoed elsewhere, as Sol Roo et al. (2017) reported meditation practitioners who used a VR Zen garden enjoyed the immersion and sense of control it offered and found the design of the virtual experience engaging. Likewise, Navarro-Haro et al. (2019) highlighted those with general anxiety disorders were more adherent to VR DBT mindfulness skills training than those receiving standard mindfulness-based interventions.

The factors affecting the usability of VR identified in this review have also been highlighted by others. The negative physical side effects of being immersed and interacting with virtual environments such as nausea and motion sickness, along with discomfort when wearing VR headsets have been widely reported in the literature (Austin, 2022; Brown & Powell, 2021). Although technical support is not often mentioned in the VR literature, it emerged as a facilitating factor in this review and warrants further exploration in light of the ever-changing technologies in this area. For example, some headsets such as the Oculus Go are no longer available on the market and newer technologies such as immersive AR glasses like Magic Leap (2021) are available for mindfulness practice that could help people better manage chronic pain. The importance of personalized design of VR mindfulness applications also came to the forefront in the review. Similarly, Prpa et al. (2018) highlighted how virtual environments closely attuned to users' preferences when practicing mindfulness are more likely to be effective. Co-creating VR and AR mindfulness environments with those experiencing chronic pain is also being explored to improve future designs based on these technologies (Mayne et al., 2020), as more complex realizations using AR, bringing together mindfulness practitioners' awareness of both 'being there' and 'being elsewhere' by combining the affordances of the augmented as well as the familiar may be helpful in managing chronic pain.

Strengths and Limitations

This scoping review was strengthened by employing a systematic approach to identify relevant literature and following best practice guidelines such as PRISMA Extension for Scoping Review (PRISMA-ScR) to improve reporting. A robust thematic analysis was undertaken to reflect emerging themes in this novel area of research. However, a number limitations are present as only a handful of relevant studies, hailing from North America and Europe, were identified. This lack of geographic diversity means some cultural and socioeconomic aspects of VR-based mindfulness practice for managing chronic pain may be missing. The seven studies were also heterogeneous in nature in terms of their definitions of mindfulness, populations, digital interventions, and outcome measures, making meaningful comparisons challenging, particularly given their small scale and weaknesses in some of the study designs employed. This raises some questions about the generalizability of the review findings and hence they should be interpreted with caution.

Clinical and Research Implications

This review indicates that VR-based mindfulness interventions have the potential to alleviate chronic pain and some of its side effects such as depression and anxiety. Therefore, nurses and other healthcare professionals should consider alternative technology-based therapies for patients experiencing long-term pain. More studies related to different types of VR applications for managing acute pain exist (Haisley et al., 2020; Malloy & Milling, 2010), but those who experience chronic pain may require lengthier and more in-depth digital interventions due to the lasting nature of their pain and its impact on quality of life. Future researchers should examine the effect of VR mindfulness applications over months and years, to ensure people with chronic pain adhere to this type of digital intervention and the longitudinal impact of this technology on managing pain long-term can be established (Scherer et al., 2017).

While the levels of engagement with VR as a treatment option is encouraging, Liaw et al. (2020) warns that a novelty factor may be influencing how often people utilize VR technologies. Hence, the uptake and retention of these types of digital health interventions needs to be examined in more depth to determine if people with chronic pain will remain using them long-term. Clinicians could re-assess how often a patient engages with VR applications during clinic or outpatient visits and researchers could employ the Digital Health Engagement Model to help assess if people will adopt VR mindfulness applications for chronic pain management or not (O'Connor et al., 2016). Nurses are also well placed to advise patients to limit the time spent in a virtual simulation to reduce the risk of cybersickness or physical discomfort from wearing a VR headset. The timing, frequency, and duration of VR mindfulness practice for managing chronic pain also needs further exploration, so that recommendations for an optimal digital intervention can be made. The Template for Intervention Description and Replication (Hoffmann et al., 2014) is a 12-item checklist that could be used to clearly describe future VR interventions to aid their design and development, and enhance the quality, transparency and replicability of research studies.

Finally, the cost-effectiveness of VR mindfulness applications did not emerge in the review findings which could be a barrier for some people. Therefore, understanding the costs associated with virtual, online, mobile, and in-person mindfulness program for managing chronic pain would help patients and practitioners make more informed decisions about which type of intervention to pursue. Future research should examine this to determine which is most affordable and effective, as there could be a trade-off between the two.

Conclusion

The review findings suggest VR could improve self-management of chronic pain by enhancing mindfulness practice through the use of immersive virtual environments and employing design that considers the diversity of users' needs. Further research examining the efficacy of VR-based mindfulness applications in more rigorous ways is needed to demonstrate positive health outcomes, alongside in-depth co-design of virtual environments with people who experience chronic pain so that personalized mindfulness practice can be facilitated and some of the usability issues associated with these digital health interventions can be addressed.

Declaration of Competing Interest

None.

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Appendix 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	3
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3 - 5
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	5
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	NA
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	6
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	6
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	6 and appendix 2
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	6
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	7
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	NA
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	7
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	8
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	9-14
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	NA
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	9-14
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	15-19
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	19-23
Limitations	20	Discuss the limitations of the scoping review process.	22
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	24
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	NA

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

Appendix 2. Search strategy for CINAHL (EBSCO)

No.	Search terms
S1	(MH "Chronic Pain")
S2	(MH "Chronic Pain (NANDA)")
S3	(MH "Chronic Pain Control (Saba CCC)")
S4	(MH "Chronic Pain (Saba CCC)")
S5	TI (pain* OR painful OR "chronic pain" OR fibromyalgia OR “back pain” OR ache OR sciatica OR "knee pain" OR “joint pain” OR “idiopathic pain” OR “musculoskeletal pain” OR “limb pain” OR “neuropathic pain”) or AB (pain* OR painful OR "chronic pain" OR fibromyalgia OR “back pain” OR ache OR sciatica OR "knee pain" OR “joint pain” OR “idiopathic pain” OR “musculoskeletal pain” OR “limb pain” OR “neuropathic pain”)
S6	S1 OR S2 OR S3 OR S4 OR S5
S7	(MH "Virtual Reality")
S8	(MH "Virtual Reality Exposure Therapy")
S9	TI (virtual OR "virtual reality" OR VR OR "virtual simulation" OR “virtual realism” OR “virtual environment” OR “virtual setting” OR “virtual therapy” OR “virtual rehabilitation” OR “virtual system” OR “virtual world” OR “virtual object” OR “haptic device” OR haptics) or AB virtual OR "virtual reality" OR VR OR "virtual simulation" OR “virtual realism” OR “virtual environment” OR “virtual setting” OR “virtual therapy” OR “virtual rehabilitation” OR “virtual system” OR “virtual world” OR “virtual object” OR “haptic device” OR haptics)
S10	S7 OR S8 OR S9
S11	(MH "Mindfulness")
S12	(MH "Mind Body Techniques")
S13	TI (mindfulness OR " Mindfulness-Based Stress Reduction" OR MBSR OR " Mindfulness-Based Cognitive Therapy" OR MBCT OR body-mind OR mind-body OR “Mindfulness-Oriented Recovery Enhancement” OR "Mindfulness-Based Relapse Prevention" OR MBRP OR "mindfulness meditation") OR AB (mindfulness OR " Mindfulness-Based Stress Reduction" OR MBSR OR " Mindfulness-Based Cognitive Therapy" OR MBCT OR body-mind OR mind-body OR “Mindfulness-Oriented Recovery Enhancement” OR "Mindfulness-Based Relapse Prevention" OR MBRP OR "mindfulness meditation")
S14	S11 OR S12 OR S13
S15	S6 AND S10 AND S14

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