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Virtual Reality Combined with Mind-Body Therapies for the Management of Pain: A Scoping Review

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ABSTRACT

When used separately, virtual reality (VR) and mind-body therapies (MBTs) have the potential to reduce pain across various acute and chronic conditions. While their combination is increasingly used, no study offers a consolidated presentation of VR and MBTs. This study aims to propose an overview of the effectiveness of VR combined with MBTs (i.e., meditation, mindfulness, relaxation, and hypnosis) to decrease the pain experienced by healthy volunteers or patients. We conducted a scoping review of the literature using PubMed, Science Direct and Google Scholar and included 43 studies. Findings across studies support that VR combined with MBTs is a feasible, well-tolerated, and potentially useful to reduce pain. Their combination also had a positive effect on anxiety, mood, and relaxation. However, insufficient research on this VR/MBTs combination and the lack of multidimensional studies impede a comprehensive understanding of their full potential. More randomized controlled studies are thus needed, with usability evaluation protocols to better understand the effects of VR/MBTs on patients wellbeing and to incorporate them into routine clinical practice.

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Introduction

Today, relieving patients' pain still represents a major challenge to the medical community. Analgesic medications are conventionally used for this purpose with treatments including non-steroidal anti-inflammatory drugs, antidepressant, antiepileptic, paracetamol, weak and strong opioids, and variable adjuvants, which have questionable efficacy, carry risks

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of adverse events, misuse and dependency (Vanhaudenhuyse et al., 2020). Despite being effective in some cases, especially for acute pain, their capacity to provide consistent relief often encounters limitations when it comes to chronic pain. This was demonstrated by a comprehensive European study that revealed a 40% dissatisfaction rate among individuals with chronic pain regarding their prescribed treatment (Breivik et al., 2006). To mitigate some of those risks, complementary approaches are currently being investigated for the management of acute and chronic pain. Mind-body therapies (MBTs) and virtual reality (VR) are emerging as effective techniques for alleviating both acute pain (i.e., during various medical procedures) and chronic pain (Austin, 2022; Gasteratos et al., 2022). Applied separately, these techniques have demonstrated beneficial effects, both in healthy participants and in patients suffering from pain in a range of medical conditions (e.g., cancer, phantom limb pain, headaches/migraines, postoperative pain) (e.g., Bicego, Delmal, et al., 2022; Grégoire et al., 2022; Honzel et al., 2019; Maindet et al., 2019; Rousseaux, Dardenne, et al., 2022; Vekhter et al., 2020; Zhang et al., 2021). While MBTs' effects seem to be observed in the long term (Majeed et al., 2018; Skelly et al., 2020), the positive effects of VR seem limited to the duration of the VR session. This is particularly notable in the context of chronic pain, raising questions about its long-term efficacy (Mallari et al., 2019). In addition, VR's ability to increase pain tolerance appears to be limited, which may explain its finite utility in managing chronic pain (Huang et al., 2022).

Consequently, combining VR with other complementary interventions, such as MBTs, could yield greater efficacy in pain reduction compared to their separate application. The purpose of this scoping review is to summarize the existing scientific knowledge regarding the combination of VR with MBTs (i.e., meditation, mindfulness, relaxation, and hypnosis) for the management of both acute and chronic pain in healthy and clinical populations. More precisely, this study aim to make a comprehensive review of the efficacy and feasibility of integrating VR and MBTs for the management pain in clinical (i.e., acute and chronic pain) and healthy (i.e., experimental pain) populations. The introduction will define acute and chronic pain, followed by an explanation of VR and MBTs, and their potential combination and synergy explored the benefits of integrating VR and MBTs for the management of pain in healthy and clinical populations.

Pain

Pain is defined as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" (Raja et al., 2020). Acute pain is typically brought on by trauma, acute medical conditions or treatments, during a surgical procedure or in the context of an experimental investigation (i.e., induced through mechanical, thermal, chemical, or electrical stimulation in an experimental setting) (Michaelides & Zis, 2019; Sunil Kumar Reddy et al., 2012). Acute pain can be considered as "an adaptive response to dangerous stimuli in order to prevent further injury or damage to the organism" (Julius & Basbaum, 2001). On the other hand, chronic pain is characterized by persistent, prolonged pain that lasts for at least three months (Merskey, 1994). Chronic pain is a complex phenomenon usually described by a biopsychosocial model, which postulates that it is the result of interactions between biological, psychological, and socio-professional factors that impairs patients' everyday life (Gatchel et al., 2007). An estimated 20% of the global population experiences chronic pain, significantly diminishing their overall well-being (2015). Indeed, patients with chronic pain frequently exhibit altered beliefs and attitudes in addition to painful perceptions, which contribute to maladaptive cognition exacerbating pain (e.g., pain catastrophizing, anxiety, negative pain beliefs) (Bicego, Rousseaux, et al., 2022). It is becoming more and more evident that trying to manage chronic pain through biological pathways alone (i.e., through analgesic medications) is an impasse given its characterization as a disease involving complex and dynamic interactions (Gatchel et al., 2007). As a result, non-pharmacological complementary approaches based on the biopsychosocial model, such as MBTs are becoming popular among patients and clinicians. Some of these approaches, like meditation, mindfulness, relaxation, and hypnosis, have shown promising signs of reducing pain perception, anxiety and depression; reshaping coping mechanisms; and thus enhancing patients' quality of life (e.g., Bicego, Rousseaux, et al., 2022; Vanhaudenhuyse et al., 2018, 2020; Zeidan & Vago, 2016).

Virtual Reality

VR corresponds to the simulation of a three-dimensional (3D) environment produced by computer technology. The current generation of VR systems includes head-mounted devices (HMDs) with 3D glasses and head-tracking systems, sensory input devices, headphones with sound/music and sometimes noise canceling, and occasionally additional equipment such as joysticks and data gloves (Austin, 2022). Thanks to this innovative setup, the user lives a unique multisensory (i.e., visual, auditory, tactile) experience, and feels completely immersed in the virtual environment (Li et al., 2011; Weech et al., 2019). Two concepts are commonly used to describe a VR experience: the feeling of presence (i.e., the observer's sensation of mentally leaving their location and being transported to a virtual environment) and immersion (i.e., the amount of sensory stimuli the VR system creates) (Gupta et al., 2018; Weech et al., 2019). Although distinct, a rise in immersion commonly corresponds to an elevation in the sense of presence experienced by the user (Hoffman et al., 2006).

VR simulations can be defined as non-immersive (i.e., through a computer screen, offering users complete control over their physical surroundings), semi-immersive (i.e., users are connected to their physical environment while perceiving a different reality when they focus on a digital image) or fully immersive (i.e., involves HMDs with realistic stimulations, completed with sight and sound, where movements are projected in the virtual reality) (Camargo-Vargas et al., 2021). Mixed reality is also currently developed, merging real environment specifics and computer-generated elements. Furthermore, VR can be categorized as either contemplative (e.g., engaging in the exploration or observation of a designated environment without the capacity to modify it, except by altering one's perspective through head movements) or participatory (such as actively interacting within a personalized environment using specialized joysticks, sensors, or focal points through the eyes) (Buche et al., 2021; Perez-Marcos, 2018).

Initially, VR technology was acknowledged for its entertainment value and games, but in the past 20 years, its application has been enlarged to a wide range of medical fields (e.g., pain management, physical rehabilitation, treatment for psychiatric disorders) (Li et al., 2011). More specifically, the use of VR for pain management has been increasing recently, with a growing number of applications in both acute pain (i.e., wound care, pre- and postsurgical procedures, and labor pain) (Indovina et al., 2018; Madden et al., 2016) and chronic pain (i.e., cancer-related pain, physical trauma, fibromyalgia, and phantom limb pain) (Ioannou et al., 2020; Pourmand et al., 2018; Wiechman et al., 2022). VR is thought to have an impact on pain thanks to a mechanism known as distraction analgesia (Ahmadpour et al., 2019). It aims to distract a patient from painful stimuli while they are immersed in a virtual setting. Distraction therapy is based on the idea that inputs like cognition, sensation, and affect – as well as elements influencing these inputs, like attention – can alter pain output (Melzack, 2001). This suggests that an individual's interpretation of pain may depend on a variety of factors, including how much attention is paid to it, the emotion it evokes, and previous experiences with it (Melzack, 2001). In addition to this theory of pain, it is also believed that human beings have a limited capacity for attention, and that a painful stimulus must be brought to an individual's attention for it to be felt as painful (McCaul & Malott, 1984). Thus, it is hypothesized that the incorporation of various sensory modalities, made possible using VR, will leave fewer resources for pain processing (Ahmadpour et al., 2019). It is also believed that VR technology may have analgesic effects through other mechanisms, such as affect (i.e., the attentional shift from unpleasant circumstances to appealing or pleasant stimuli), focus shifting (i.e., by involving patients in particular cognitive tasks), or skill development (i.e., through pain educational programs delivered through the device) (Ahmadpour et al., 2019).

Mind-Body-Based Therapies

Mind-body based therapies (MBTs) are commonly characterized by their emphasis on the interplay between the mind and the body. These therapies explore how emotional, mental, social, spiritual, experiential, and behavioral elements can directly impact one's health (Garland et al., 2020). MBTs include hypnosis, meditation, mindfulness, relaxation (e.g., guided imagery, biofeedback and progressive muscle relaxation), and "moving meditations" (e.g., yoga, tai chi and qi gong) (Bauer et al., 2016). Through the process of modulating individuals' responses to stressors that originate from within themselves or from their external environment, MBTs place a strong focus on engaging both mental and physical aspects in order to alleviate stress and enhance overall well-being (Lee et al., 2014). MBTs are an especially appealing option for modulating pain because they are relatively cheap, can be used in conjunction with pharmaceutical strategies, have few unfavorable side effects, and can be used independently by patients with the appropriate training (Kwekkeboom et al., 2010). MBTs can be used to decrease and/or prevent a wide range of conditions, including both widespread and localized pain disorders, even though they are more frequently used for chronic rather than acute pain (Lee et al., 2014).

Hypnosis is a "state of consciousness involving focused attention and reduced peripheral awareness, characterized by an enhanced capacity for response to suggestions" (Elkins et al., 2015). This definition states that the hypnotic process is characterized by a peculiar state of consciousness during which is observed a modified attention directed toward oneself (internal consciousness) and a reduction in environmental awareness (external consciousness) as a result of induction and verbal suggestions (Rousseaux et al., 2020). Hypnosis can be seen as a state of focused attention described by four main characteristics: absorption (i.e., the tendency to become completely immersed in a perceptive or imaginary experience), dissociation (i.e., corresponds to a separation of mental processes and bodily awareness and perception), suggestibility (i.e., a tendency to follow suggestions and to suspend one's critical judgment) and automaticity (i.e., an altered state of agency which is lived as a non-voluntary response to a suggestion) (Spiegel, 1991, Weitzenhoffer, 2002). When compared to normal wakefulness and control conditions, individuals in a hypnotic process typically report experiencing a higher level of absorption and dissociation, increased internal awareness and reduced external awareness and a modified perception of time (Demertzi et al., 2011). Presently, hypnosis is widely acknowledged for its effectiveness in acute pain management (Kendrick et al., 2016), and an increasing body of research indicates benefits for patients dealing with chronic pain or cancer-related pain through hypnosis-based treatments (Bicego, Rousseaux, et al., 2022, Franch et al., 2023, Langlois et al., 2022).

Relaxation refers to a comprehensive term encompassing a collection of interconnected physiological processes and adaptations that arise when an individual participates in repetitive mental or physical actions while disregarding intrusive thoughts (Salamon et al., 2006). This technique is also known to alter pain perception in acute and chronic pain populations, decrease oxygen consumption, heart rate, arterial pressure and respiratory rate (Salamon et al., 2006).

The term "meditation" currently includes a range of techniques, such as contemplation, concentration, dissociation with external awareness, body feeling and absorption to specific thoughts (i.e., feeling of inner peace), utilization of natural sounds, guided meditation, and meditative movement practices such as yoga, tai chi, qi gong, breathing exercises, and mantra (Sharma, 2015). Meditation encompasses training focused on attention and emotional regulation, offering the prospect of sustained analgesic effects and the improvement of pain intensity and psychological dimensions associated with chronic pain, such as depression and overall quality of life (Hilton et al., 2017; Lutz et al., 2008).

Mindfulness is the practice defined as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment" (Kabat-Zinn, 2003). Mindfulness techniques have demonstrated the capacity to diminish pain intensity and associated psychological effects, while also enhancing functional well-being and overall quality of life in patients with chronic pain (Khusid & Vythilingam, 2016; Morone et al., 2008).

Integrating Virtual Reality with Mind-Body Interventions

By combining MBTs with VR, practitioners can potentially leverage the strengths of both modalities to create more engaging, effective, and accessible interventions for pain management. This integration allows individuals to engage with MBTs in novel and captivating ways, potentially increasing motivation and adherence to the intervention.

Performing MBTs with VR can work harmoniously for several reasons: VR devices offer opportunities to show feedback which aid in self-regulation, allow to isolate outside distractions and be transported in various environments according to one's preferences. Visual cues in VR environments can further enable focus guidance compared to audio instructions alone or small-screen visual guides for a great number of people (Döllinger et al., 2021). VR can also standardize how images, instructions, and environmental noise are presented during mind-body interventions (Keefe et al., 2012).

Combining VR with MBTs in the context of pain management can further facilitate deep relaxation, consequently reducing anxiety and depression, which are comorbid conditions known to be associated with increased perception of pain severity (Michaelides & Zis, 2019). Moreover, this combined approach can be highly individualized according to everyone's specific needs and preferences. Notably, it can be conveniently used at home, especially with the decreasing costs of VR equipment (Keefe et al., 2012). This accessibility makes home-based training an attractive option for those seeking ongoing therapy. Home-based trainings can also probably lead to an improved adherence to the therapy, as it can be more appealing and enjoyable for patients in the comfort of their homes (Garcia et al., 2022; Keefe et al., 2012). Ultimately, these straightforward interventions hold the potential to enhance pain management for individuals dealing with such conditions. The hope is that by combining VR and MBTs, there could be a reduced reliance on medication to manage pain for these patients.

Methods

This scoping review was conducted in accordance with the PRISMA-ScR statement for scoping reviews (Tricco et al., 2018). A comprehensive literature review was conducted by one person (M.L.) until August 2023 in PubMed, Science Direct, and Google Scholar. This study focused on specific MBTs that are currently used in combination with VR. The search strategy consisted of the keywords "Hypnosis," "Mindfulness," "Meditation," OR "Relaxation" used in combination with "Pain" AND "Virtual Reality."

Inclusion criteria for the review consisted of adult/pediatric population; pain-related; randomized controlled trials (RCT) or quasi-experimental design; group study, case reports or case series; hypnosis in live settings or by audiotape; mindfulness, relaxation, meditation; no time limit since publication; articles written in English. Exclusion criteria consisted of books; non-English language; and articles on virtual reality alone, or not related to pain management.

The screening process, conducted by one of the authors (M.L), involved selecting studies exploring the integration of VR with any of the described MBTs, such as hypnosis, mindfulness, meditation, and relaxation, with a primary focus on pain relief outcomes. Subsequently, data extraction, including author names, title, study design, participant characteristics, VR type, therapy specifics, outcomes, key findings, effect sizes and limitations, was undertaken by one person (M.L) for each study. Finally, a common agreement between three authors (M.L., A.B., A.V.) was made after the extraction process regarding the inclusion of each of the studies. The presentation of results is organized according to the respective MBT categories.

It should be noted that the defined categories of relaxation, mindfulness and meditation are not mutually exclusive. Indeed, some techniques integrated in the VR device proposed by the studies can overlap the different categories. Thus, the terminology used by the authors was used to categorize the study in one or another classification.

Results

Out of the three databases, 51.464 articles were screened. Based on abstracts, titles, and duplicates, 112 original papers that could be included in the review were identified. After further reading, book chapters, reviews, a letter to editor, protocols only, and papers not assessing pain were removed. Finally, 43 articles were included, amounting to a total of 1975

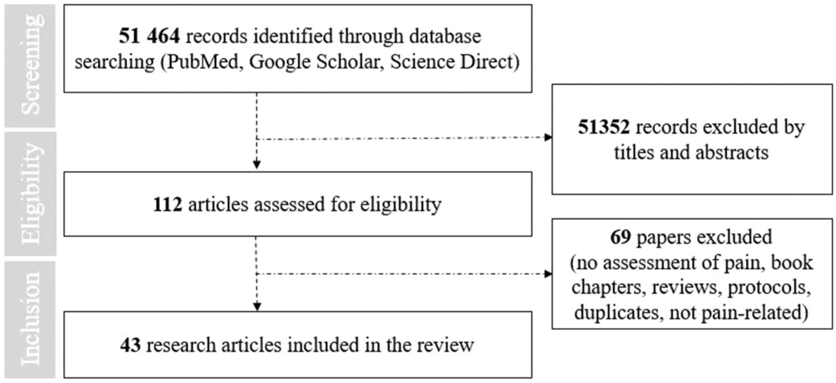

Figure 1. Flow Chart Diagram

patients and 511 healthy participants. The 43 studies tested a combination of hypnosis (*n* = 15; 532 patients and 401 healthy volunteers), relaxation (*n* = 11; 490 patients and 49 healthy volunteers), meditation (*n* = 9; 280 patients) or mindfulness (*n* = 8; 673 patients) or with VR for the management of pain (Figure 1). A total of 38 clinical studies and 5 experimental studies were included. The designs of studies included were: RCT (*n* = 19), single-arm trials (*n* = 10), case studies (*n* = 5), case series (*n* = 2), 2:1 case-control (*n* = 1), crossover (*n* = 4), non-randomized controlled trial (*n* = 1), and 2 × 2 parallel group (*n* = 1).

Among these protocols, 20 focused on acute pain in clinical settings (usually during or after surgery or medical procedure), 15 focused on chronic pain conditions, 5 studies investigated the impact of experimental pain in healthy volunteers and 3 studies explored MBTs/VR combination in patients with cancer-related pain.

Among the 20 studies centered on acute pain, VR was employed prior to intervention in 6 cases, during in 4, and post-intervention in 2, while 2 studies utilized VR both before and after the procedure. The remaining 6 studies incorporated VR during patients' hospitalization without specifying specific timings. In terms of sessions number, the average was 5.33 sessions (range: 1–56). Notably, 27 studies conducted only one single VR session.

Regarding the evaluation of pain, the studies employed a variety of scales: Numeric Rating Scale (*n* = 16) (Hartrick et al., 2003), Visual Analog Scale (*n* = 13) or Graphic Rating Scale (*n* = 8) (Haefeli & Elfering, 2006), with a few including alternative questionnaires including the Brief Pain Inventory (*n* = 1) (Cleeland & Ryan, 1994), Revised Faces Pain Scale (FPS-R) for pediatric patients (*n* = 1) (McGrath et al., 1996), Analgesia Nociception Index (*n* = 1) (Ledowski et al., 2013), Chronic Pain Coping Inventory (*n* = 1) (Jensen et al., 1995), Defense & Veterans Pain Rating Scale (*n* = 1) (Buckenmaier et al., 2013) or open questions (*n* = 1).

VR in Combination with Hypnosis

The review included fifteen studies that employed VR-hypnosis (VRH) (Coulibaly et al., 2022; Enea et al., 2014; Gullo et al., 2023; Oneal et al., 2008; Patterson et al., 2004, 2006, 2010, 2021; Rousseaux, Dardenne, et al., 2022; Rousseaux, Panda, et al., 2022; Soltani et al., 2011; Teeley et al., 2012; Terzulli et al., 2022; van den Berg et al., 2023; Wiechman et al., 2022) (Table 1). Out of these, eight studies employed VRH for managing clinical acute pain

Table 1. Articles Combining VR and Hypnosis

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Authors Limitations
Enea et al. (2014)	– 120 university students – women – Age (not mentioned)	Groups: 1) VRH 2) HYP 3) VR 4) Control further divided by low and high hypnotizability	Stages: 1) Baseline, 2) Preparation stage 3) Intervention: mechanical pain stimulus	*VR(H)*: SnowWorld © with or without hypnotic suggestions *HYP*: audio *Control*: No treatment	– Hypnotic susceptibility - Pain intensity (NRS) – Pain unpleasantness – Presence	↘ Pain intensity regardless of the subject's hypnotizability in VRH, ↘ in pain unpleasantness in HYP only in high hypnotizables	– Experimental pain
Patterson et al. (2021)	– 205 university students – 119 women – Age range:18-20 ys.	2 × 2 parallel groups design: 1) VRH 2) HYP 3) VR 4) Control	1) Baseline = identification of a painful but tolerable T° 2) Test phase based on the group (15 min with one 30 sec pain stimulation)	*VR(H)*: SnowWorld © with or without hypnotic suggestions *HYP*: audio *Control*: No treatment	-Worst pain intensity (GRS) – Pain unpleasantness – Pain catastrophizing	↘ Worst pain intensity in VR, HYP and VRH	– Pain stimulation in hypnosis – VR design not optimal
Rousseaux, Panda, et al. (2022)	– 18 healthy subjects – 10 women – Mean age: 27.22 ± 4.03 y.	Randomized two-arm crossover design VRH condition or control	One VRH session or a control condition with eyes open 16-min	Underwater environment + hypnotic suggestions (calm, relaxation, safety)	– Pain intensity (VAS) – Anxiety – Absorption – Dissociation – Time perception	↘ Pain and higher dissociation in VRH Other variables: no difference	– No blinding – Homogenous sample (in age) – Self-reports – Only one session
Terzulli et al. (2022)	– 58 healthy participants – 31 women – Mean age: 30 ± 9.4 y.	Comparative cross-over study each subject had thermal painful stimulation in both VRH and control condition, randomly	One VRH session with thermal stimuli on the dorsal surface of the non-dominant hand during and after the session 20 min	*VRH*: Natural environment + hypnosis (relaxing and analgesic suggestions) *Control*: Nothing	– Pain threshold (ANI) – Physiological changes (heart rate, respiratory rate)	VRH: ↗ Mean T° thresholds ↘ Respiratory rate	– Not the clinical reality – Electrical artifacts
Coulibaly et al. (2022)	– 25 patients (electrophysiology pacing procedure)/61 controls – 20 women – Mean age: 66 ± 16 y.	2:1 case-control comparison	For all, one VR session ± 50 min.	*Intervention*: Natural environment + hypnosis (relaxing suggestions) *Control*: Usual care	- Pain (VAS) – Comfort	No significant results	– Retrospective – Monocentric – Non-RCT – Underpowered

(*Continued*)

Table 1. (Continued).

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Authors Limitations
Gullo et al. (2023)	– 100 patients – Peripheral endovascular interventions – 50 women – Age: 47.4 ± 16.8 y.	– RCT – groups: VRH or usual care	During procedure One session (mean duration: 40 min)	Underwater environment + hypnotic suggestions (calm, relaxation, safety)	- Pain (VAS) – Anxiety	– No significant results for pain intensity – ↘ Mean anxiety within groups and between groups	– Heterogeneous procedures – No quantitative measures *Other limitations*: –No hypnotizability assessment
Oneal et al. (2008)	– One woman – C4 tetraplegia and upper extremity neuropathic pain – 36 yo.	Case study	33 VRH sessions (±30 min each) within 6 months	SnowWorld ©	- Pain intensity (NRS) – Pain unpleasantness – Treatment effect in time	No significant results	–No control for factors influencing pain perception - Self-reports
Patterson et al. (2004)	– One man – Severe burns – 37 yo.	Case study	Day 1: 16 min hypnotic audiotape with VR, before wound care. Day 2: 16 min audiotape hypnosis, before wound care.	SnowWorld ©	– Worst & average pain (GRS) – Time spent thinking about pain – Anxiety	No significant results	– No follow-up – Preference of the patient for VRH
Patterson et al. (2006)	– 13 patients – Burn injuries – 1 woman – Mean age: 38 y.	Case series	16 min VRH before wound care on day 2 & 3	SnowWorld ©	– Pain (GRS) – Anxiety	Non significant results	– No RCT – Selection bias – High dropout
Patterson et al. (2010)	– 21 patients – Chronic physical trauma – 4 women – Mean age: 31.8 ± 15.2 y.	– RCT – Groups: 1) VRH 2) VRD (no hypnotic suggestion) 3) Control	One session – VRH : 40 min in the morning – VRD: as much time as wanted (10-20 min) in the morning	*VRH*: SnowWorld © *Control*: only standard analgesic care	- Pain intensity (GRS) – Pain unpleasantness	↘ Pain with VRH	– Small sample size – No hypnotizability assessment – One session only
Rousseaux, Dardenne, et al. (2022)	– 100 patients – cardiac surgery – 24 women – mean age: 66 ± 11.5 y.	– Prospective RCT – groups 1) VRH 2) VR 3) HYP	Each patient had 2 20-min sessions, one on the pre-operative day, and a second on postoperative day	– *VRH*: hypnosis + VR session – *VR*: mountain cabin near a lake at sunrise followed	– Pain (VAS) – Anxiety – Fatigue – Relaxation – Physiological	No significant difference between groups ↘ relaxation in all groups in the pre-operative and postoperative period	–No blinding

(*Continued*)

Table 1. (Continued).

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Authors Limitations
		4) Control		by a relaxing moment in the clouds (no voice) – *HYP*: suggestions for positive body sensations and landscape observing in a white cloud chair – *Control*: usual care	parameters – Opioid use		
Soltani et al. (2011)	– One patient – Gluteal hidradenitis 55 yo.	Case study	During 2 days, 30minVRH	SnowWorld ©	- Pain (GRS) – Anxiety	Non significant results	– Case report – No follow-up
Teeley et al. (2012)	– 3 patients – Orthopedic injuries – 3 men – Age: 23y., 29y. and 55 y.	Case series	Day 1: GRS, VRH session (time not mentioned), GRS 1 hour later. Day 2: same. Day 3: GRS for the previous 24 h without VRH	SnowWorld ©	– Pain (GRS) – Anxiety	Non significant results	– Case series – No controls – No hypnotizability assessement – Only 2 VRH sessions
van den Berg et al. (2023)	– 114 children – Needle-related procedure – 62 women – Age range: 6-18 y.	– RCT – groups: 1) VRH 2) Hypnosis	Durations 5 to 30 minutes during procedure.	– *VRH*: VR + interactive modalities + hypnosis and music – Medical hypnosis	– Pain (NRS) – Fear – Blood pressure – Heart rate – Treatment satisfaction – Adverse effects	No significant difference	–No blinding – Dropout (not able to participate after surgery)
Wiechman et al. (2022)	– 153 patients – Hospitalized – Physical trauma – 44 women – Mean age: 34 ± 13.5 y.	– RCT – groups: 1) VRH 2) VRD 3) Control	40 min of VRH or as many as wanted for VRD 1×/day during max. 10 days	*VRH*: SnowWorld© *VRD* *Control*: Usual care	- Pain (GRS) – Anxiety – Opioid use – Length of stay at hospital	No difference	– VRH intervention not sufficient – Patient selection – Nature of trauma care

Note: ANI = analgesia nociception index, HYP = hypnosis, GRS = graphic rating scale, NRS = numeric rating scale, VAS = visual analog scale, VRD = virtual reality distraction, VRH = virtual reality hypnosis, T° = temperature, RCT: randomized-controlled study.

(Coulibaly et al., 2022; Gullo et al., 2023; Patterson et al., 2004, 2006; Rousseaux, Dardenne, et al., 2022; Teeley et al., 2012; van den Berg et al., 2023; Wiechman et al., 2022), while only three studies were focused on chronic pain management (Oneal et al., 2008; Patterson et al., 2010; Soltani et al., 2011). The remaining four studies investigated the effects of experimental pain in healthy participants (Enea et al., 2014; Patterson et al., 2021; Rousseaux, Panda, et al., 2022; Terzulli et al., 2022). Nine of these studies used SnowWorld© or a derived version for delivering VRH (Enea et al., 2014; Oneal et al., 2008; Patterson et al., 2004, 2006, 2010, 2021; Soltani et al., 2011; Teeley et al., 2012; Wiechman et al., 2022).

Regarding sample sizes, three clinical studies were case reports (Oneal et al., 2008; Patterson et al., 2004; Soltani et al., 2011), and two were case series with 3 and 13 patients (Patterson et al., 2006; Teeley et al., 2012). The remaining clinical studies had samples sizes ranging from 25 to 153, while the experimental studies on healthy volunteers involved 18 to 205 participants.

The results indicated that VRH significantly reduced experimental pain in healthy volunteers (Enea et al., 2014; Patterson et al., 2021; Rousseaux, Panda, et al., 2022; Terzulli et al., 2022). However, the clinical studies conducted with patients yielded more mixed results, with only one study showing a significant reduction in pain for chronic pain patients (Patterson et al., 2010) and four acute pain studies showing no significant difference after VRH (Coulibaly et al., 2022; Rousseaux, Dardenne, et al., 2022; van den Berg et al., 2023; Wiechman et al., 2022).

Out of these studies, only two conducted with healthy volunteers calculated effect sizes. One suggested that VRH may significantly reduce pain intensity with a large effect size (Rousseaux, Panda, et al., 2022), while the second study indicated that pain was only slightly affected by VRH (Terzulli et al., 2022).

VR in Combination with Relaxation

Eleven papers focused on the utilization of VR to induce a relaxation state (Bernaerts et al., 2021; Brown et al., 2020; Colloca et al., 2020; Esumi et al., 2020; Kelleher et al., 2022; Konstantatos et al., 2009; McCune et al., 2023; Menekli et al., 2022; Merliot-Gailhoustet et al., 2022; Olbrecht et al., 2020; Scates et al., 2020) (Table 2). Among these studies, eight reported the use of VR-relaxation for acute pain relief (Bernaerts et al., 2021; Brown et al., 2020; Esumi et al., 2020; Konstantatos et al., 2009; McCune et al., 2023; Menekli et al., 2022; Merliot-Gailhoustet et al., 2022; Olbrecht et al., 2020), two for cancer-related pain (Kelleher et al., 2022; Scates et al., 2020) and one study investigated its impact on experimental pain in healthy volunteers (Colloca et al., 2020).

Nine studies employed VR to deliver relaxation by immersing participants in peaceful natural environments (such as underwater, on a beach, mountains, or the countryside) accompanied with calming music (Brown et al., 2020; Colloca et al., 2020; Esumi et al., 2020; Kelleher et al., 2022; Konstantatos et al., 2009; McCune et al., 2023; Menekli et al., 2022; Merliot-Gailhoustet et al., 2022; Scates et al., 2020). Two studies examined the efficacy of VR-relaxation in a pediatric/adolescent patient population with acute pain (i.e., postoperative pain and during various medical procedures) (Bernaerts et al., 2021; Olbrecht et al., 2020).

Among the eight studies that indicated a trend toward decreased pain ratings after VR relaxation, only four (Brown et al., 2020; Menekli et al., 2022; Merliot-Gailhoustet et al.,

Table 2. Articles Combining VR and Relaxation

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Authors Limitations
Bernaerts et al. (2021)	51 – Pediatric patients – Diverse medical procedures (NA) – 30 girls – Mean age: 10.88 ± 3.17 y.	– One-arm – 3 relaxation modules before the procedure, for all	– Module 1 & 2- 6-7 min. – Module 3 used as long as needed	1) Breathing exercises, 2) Meditation exercises, 3) Interactive scenes with objects/ animals	– Pain (FPS-R) – Anxiety – Tension – Happiness – Acceptability – Feasibility – Tolerability	No significant results	– Unblinded – No controls – Possible subjectivity (self-reports) – Lack of generalizability
Brown et al. (2020)	– 45 patients – Chronic low back pain – 27 women – Mean age: 61.9 ± 17.7 y.	– RCT – groups: 1) Audiovisual computer (2D) 2) VR (3D) 3) Control group (no intervention)	Prior to a spinal injection procedure – 5 min nature relaxation	*2D, 3D*: Video of a relaxing nature *Control* : no intervention	– Pain (NRS) – Anxiety	No significant results	– Not blinded – Numeric pain rating scale – Missing data – Interference with clinic procedures
Colloca et al. (2020)	– 49 healthy volunteers – 25 women – Mean age: 27.4 ± 6.47 y.	– Within-subject randomized design – conditions: 1) VR ocean 2) VR Opera 3) Control Ocean (2D) 4) Control Opera (2D) 5) Attention/ distraction condition	Each condition lasted ±6 min	1)Virtual scenery of the ocean with relaxing music 2) On a stage with opera performers 3) & 4) show the same scenery in 2D 5) 2-back task	- Pain tolerance threshold (GRS) – Mood – Anxiety – Pain – Unpleasantness – Enjoyment	– ↗ Pain threshold and duration tolerated with immersive VR Ocean compared to VR Opera - ↘ Pain unpleasantness with VR Ocean	– Not translational – Lack of sham condition (i.e., non-immersive, non-interactive headset)
Esumi et al. (2020)	– 1 man – Acute compartment syndrome – 40 y.	Case study	– 3 30 min-VR sessions – 2 days – 30 min.	beach beside a calm sea on a sunny day	- Pain (NRS) – Anxiety	No significant results	None mentioned
Kelleher et al. (2022)	– 20 patients – Stage 4 colorectal cancer – 6 women	– Pilot study – One-arm	For all patients – 1 VR session underwater/sea environments – 30-min	3 environments: 1) a coral reef with aquatic wildlife	– Pain severity & interference (BPI) -Catastrophizing –	- ↘ Pain (59%) – ↗ Relaxation (38%) – VR is highly accepted, safe, and feasible	–Small sample size – Patient heterogeneity – No formal

(*Continued*)

Table 2. (Continued).

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Authors Limitations
	– Mean age: 56.66 ± 10.73 y.			2) a shipwreck with a whale 3) the deep sea	Self-efficacy – Anxiety – Feasibility – Acceptability – Safety		statistical analyses
Konstantatos et al. (2009)	– 43 patients – Burned, wound changes – mean age: 38.6 ± 15.95 y.	– RCT – groups: VR + intravenous morphine or morphine alone (same dosage)	Prior the wound care: – One session – 18 min.	*VR*: Calming visual scenery with gentle suggestions and a vision of a moving spiral	– Pain intensity (VAS) – Anxiety	↗ Pain intensities in the VR group	None
McCune et al. (2023)	30 women laparoscopy hysterectomy mean age: 41.3 ± 11.9 y.	RCT groups: VR program or routine care	After the procedure: – one session VR lasting as long as desired (average of 27.4 ± 16.6 min)	*VR*: meditations in natural environments + music. *Control*: usual care	– Pain (VAS) – Narcotic consumption – Adverse events	No difference	– Various VR duration – Small sample size
Menekli et al. (2022)	– 139 patients – Cancer – Port catheter implantation – 87 women – Age range: 20-63 y.	– RCT – groups: VR or controls	VR: before the implantation and until the end of the implantation + after if needed. Each video lasted 3-10 minutes	*VR*: natural environment with thematic music *Control*: No intervention	– Pain (VAS) – Anxiety – Systolic & diastolic blood pressure – Heart rate – Respiratory rate	↘ Pain, ↘ anxiety, ↘ heart rate, ↘ systolic and diastolic blood pressure with VR	– Single-center study – Number of patients limited – No blinding
Merliot-Gailhoustet et al. (2022)	– 60 patients – ICU (i.e., liver transplant, postoperative, ARDS, hemorrhagic shock, others) – 20 women – Mean age: 62 y.	– Crossover – Randomized study	4 15-min relaxation sessions consecutively in a randomized order	1) Relaxation of choice 2) Psycho-musical intervention 3) Natural environment of choice 4) Filmed sequence of choice	- Discomfort (NRS) – Pain – Anxiety – Dyspnea – Thirst – Fatigue	↘ Pain, ↘ Anxiety and overall discomfort reported in the intervention n°3	– Selection bias – Moderate symptoms' intensities
Olbrecht et al. (2020)	– 51 pediatric patients – Postoperative pain – Age range: 7-21 y.	– Pilot study – One-arm	All patients – one 10 min VR session	Exercise of slow breathing in a relaxing environment	– Pain (NRS) – Pain unpleasantness – Anxiety	↘ Pain unpleasantness ↘ Anxiety	– Only one session – Self-reports – Menu navigation hard to some patients – No controls

(*Continued*)

Table 2. (Continued).

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Authors Limitations
Scates et al. (2020)	– 50 patients – Cancer (not specified) – 35 women – Age not mentioned	– Repeated-measure – Experimental study – Each patient underwent IV intervention with and without VR	During IV: – VR simulation (as many times as needed) – 7 min.	Natural environments and sounds in Florida	– Pain (NRS) – Stress	– No difference in pain – VR ↗ relaxation, distraction frustration	– Health complications – Lack of health care providers

Note: ARDS = acute respiratory distress syndrome, BPI = brief pain inventory, FPS-R = revised faces pain scale, GRS = graphic rating scale, ICU = intensive care unit, IV = intravenous, NRS = numeric rating scale, VAS = visual analog scale.

2022; Olbrecht et al., 2020) reported statistically significant results in terms of pain reduction. Two clinical studies found no significant difference in pain levels (McCune et al., 2023; Scates et al., 2020). Interestingly, one study found that VR-relaxation increased pain levels in patients with burns (Konstantatos et al., 2009).

Concerning sample sizes, one study constituted a case report (Esumi et al., 2020), another was an experimental study involving a total of 49 healthy volunteers (Colloca et al., 2020) and the remaining studies were clinical with sizes ranging from 20 to 139 patients.

Only two studies examined the effect sizes of VR-relaxation interventions. One study reported a moderate effect size for pain intensity (Bernaerts et al., 2021), while the second study demonstrated a negative effect size, indicating no significant impact of the intervention (Scates et al., 2020).

VR in Combination with Meditation

Nine of the 43 studies included in this review explored the combination of meditation and VR (Faraj et al., 2021; Garrett et al., 2020; Groninger et al., 2021; Haisley et al., 2020; Hargett et al., 2022; Liu et al., 2023; Payne et al., 2022; Sarkar et al., 2022; Venuturupalli et al., 2019) (Table 3). Among these, four studies applied VR-meditation to patients experiencing acute pain (i.e., during surgical procedures, heart failure hospitalization, orthopedic injuries) (Groninger et al., 2021; Haisley et al., 2020; Hargett et al., 2022; Payne et al., 2022), four focused on patients with chronic pain (Faraj et al., 2021; Liu et al., 2023; Sarkar et al., 2022; Venuturupalli et al., 2019) and one in patients with cancer (Garrett et al., 2020). All of these studies reported a reduction in pain perception, with seven of them demonstrating statistically significant results (Faraj et al., 2021; Groninger et al., 2021; Hargett et al., 2022; Liu et al., 2023; Payne et al., 2022; Sarkar et al., 2022; Venuturupalli et al., 2019).

Sample sizes ranged from 11 to 88 patients. Meditation exercises were delivered using different VR-compatible methods. Four studies were based solely on guided breathing exercises through VR (i.e., showing an oscillatory pacer or body movements) (Faraj et al., 2021; Haisley et al., 2020; Sarkar et al., 2022; Venuturupalli et al., 2019), two combined breathing exercises with a virtual natural environment (such as a white sand beach, a quiet field under the stars, a forest, or a waterfall) (Hargett et al., 2022; Liu et al., 2023), and the remaining three studies displayed nature environments along with calming background music (Garrett et al., 2020; Groninger et al., 2021; Payne et al., 2022). Only three studies used arm and body movements (Faraj et al., 2021; Garrett et al., 2020; Sarkar et al., 2022), with the majority corresponding to contemplative meditation (Groninger et al., 2021; Haisley et al., 2020; Hargett et al., 2022; Liu et al., 2023; Payne et al., 2022; Venuturupalli et al., 2019).

VR in Combination with Mindfulness

Eight of the 43 studies examined mindfulness-based therapies using VR to manage chronic pain (Aivaliotis et al., 2020; Botella et al., 2013; Darnall et al., 2020; L. Garcia et al., 2021; Groenveld et al., 2023; Louw et al., 2019; Rice et al., 2019; Wren et al., 2021) (Table 4). The findings indicated that seven of these studies observed a significant reduction in pain intensity. Only one study, which presented a case report of a woman with chronic neck

Table 3. Articles Combining Virtual Reality (VR) with Meditation

Authors	Participants	Design	Method	Content	Outcomes	Results	Authors Limitations
Faraj et al. (2021)	– 15 patients – Opioid use disorders – 9 women – Age range: 19-50+ y.	– Non-blinded – One-arm	12-week 30-min VR-based meditation 2×/ week	Martial arts-based movements with meditation (breathing exercises)	– Pain (VAS) – Opioid cravings – Anxiety – Depression – Anger – Cortisol – CRP	↘ Pain ↘ opioid cravings ↘ anxiety ↘ depression	– Unblinded – Small sample size – No control group – Mostly females
Garrett et al. (2020)	– 12 patients – Past/current cancer – 4 women – Median age: 58.5 y.)	– RCT – groups: 3D VR vs. laptop in 2D – Blinded for participants only	4 randomized interventions during 1 month, 30 min/day for 6 days: – 2 on a contemplative mindfulness environment – 2 on cognitive engagement	In the 2 groups: 1) Walking through a forest with music, 2) Flying in a virtual environment 3) Completing puzzles 4) Exploring a sci-fi adventure game + completing puzzles	- Daily pain (open questions) – Weekly pain and health quality – Sleep quality	No effect	– Small sample size – Heterogeneous cancer – Heterogeneous pain levels – Heterogeneous timing of VR intervention – Only cognitive engagement in a static position
Groninger et al. (2021)	– 88 patients – advanced heart failure – 35 women – Mean age: 56 ± 13.2 y.	– RCT – groups: 3D VR vs. tablet in 2D	One single 10-min session	*3D VR*: guiding through a forest & waterfall (with audio) *Tablet 2D*: meditation with guided-imagery session on a tablet (background music)	– Pain (NRS) – Quality of life – Stress – Side effects – Satisfaction	– ↘ Pain – No side effects reported	– Same condition – Early termination due to Covid-19 – Only an active control group, a group with no distraction is lacking
Haisley et al. (2020)	– 52 patients – Foregut surgery – 38 women – Median age: 64.5 y.	RCT – groups: VR + meditation vs. meditation alone	– Day 1-surgery: One session of 3 exercises ±13 min – Postoperative day: 3 exercises ±15 min	*VR+meditation*: 6 guided exercises teaching meditation & mindfulness *Meditation* : standard care	– Pain (NRS) – Anxiety – Satisfaction – Narcotic consumption	No difference	– Small sample size – Heterogenous medical procedures – Mostly elderly women (digital naive)
Hargett et al. (2022)	– 11 patients – Acute orthopedic injuries – 6 women – mean age: 53.5 y.	– Pilot study – One-arm	One 10 min VR guided meditation	Guided meditation of choice between 10 different meditations, nature landscape	– Pain (NRS) – Side effects	↘ Pain, no side effects reported	– Small sample size – Not randomized – No controls
Liu et al. (2023)	– 31 veterans – Chronic pain – women – Mean age: 55.2 ± 14.8 y.	– Pilot study – One-arm	One 10-minute VR-guided meditation	Guided meditation of choice between 6 different meditations, nature landscape	– Pain (NRS) – Heart rate – Stress – Blood pressure – Satisfaction	↘ Pain, ↘ Stress, ↘ Heart rate, ↘ Blood pressure & high satisfaction	– Small sample size – No controls

(*Continued*)

Table 3. (Continued).

Authors	Participants	Design	Method	Content	Outcomes	Results	Authors Limitations
Payne et al. (2022)	– 35 women – Laparoscopy – Mean age: 40.47 ± 11.56 y.	– RCT – 2 groups – Crossover	one session: – Active VR distraction, 10 min. – Washout, 10 min. – VR meditation, 10 min. – or the opposite post-operation	1) Active VR distraction: quiet field looking at lanterns 2) VR meditation with relaxing music	– Pain (NRS) – Feasibility – Acceptability – Opioid use – Adverse event	↘ Pain in the 2 groups	*Authors limitations*: No controls
Sarkar et al. (2022)	– 19 patients – Chronic knee pain – 13 women – Mean age: 67.9 ± 4.6 y.	– Pilot study – One-arm	One 10-min VR-guided meditation	Breathing exercises with arm movements with different choices	– Pain (NRS + BPI-SF) – VR presence – Cyber sickness	↘ Overall pain and knee pain (even >48 h post-intervention)	*Authors limitations*: – Small sample size – No controls
Venuturupalli et al. (2019)	– 17 patients – Autoimmune disorders – 15 women – Mean age: 52.65 ± 16.1 y.	– RCT – 2 groups – Differed in order of VR modules	One 30-minute session *Group 1*: VR GM then respiration BFD *Group 2*: respiratory BFD first, then GM	1) *BFD*: breathing with an oscillatory pacer (6 breaths/minute) 2) *GM*: maintaining awareness of the body and breath	– Pain (VAS) – Anxiety – Order of intervention	↘ Pain in both groups ↘ Anxiety in the BFD group	*Authors limitations*: – Small sample size – No controls

Note: BFD = biofeedback, BPI-SF = brief pain inventory – short form, CRP = C-reactive protein, GM = guided meditation, NS = non-significant, NRS = numeric rating scale, RCT = randomized controlled trial, y=year, VAS = visual analog scale.

Table 4. Articles Combining VR with Mindfulness

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Limitations
Aivaliotis et al. (2020)	– 62 patients – Chronic abdominal pain – 51 women – Median age: 41 y.	– RCT – groups: VRM vs. VRD	10 min session in each group	*VRM*: guided meditation, nature landscape & breathing *VRD*: underwater environment (no audio)	- Pain (VAS) – Anxiety	Both groups: ↘ Pain ↘ Anxiety	*Authors limitations*: none mentioned
Botella et al. (2013)	– 6 women – FM – Mean age: 55 ± 7.6 y.	– Pilot study – One-arm	– CBT program – 10 group sessions – 2 hours – 7 weeks	Group CBT, pain education VR, breathing exercises, mindfulness	– Functional status related to pain – Depression – Positive and negative affect – Coping skills	↘ Pain ↘ Depression ↗ Positive affect	*Authors limitations*: Pilot study
Darnall et al. (2020)	– 74 patients – Chronic pain – 22 women- Age range: 25-74 y.	– RCT – groups: VR vs. audio only – Home-based	For both groups: – 21-day program 1 session/day – Ranging from 1-15 min. 1) CBT 2) Relaxation training 3) Mindfulness – Sessions:	1) Pain and emotions education 2) Breathing exercises 3) Mindfulness: awareness of the mind and body	– Pain intensity (NRS) – Pain interference on activity, mood, sleep and stress – Satisfaction – Motion sickness	Both groups: ↘ Pain & good satisfaction	*Authors limitations*: – Not blinded – No medication assessment – Heterogeneous pain duration
L. Garcia et al. (2021)	– 179 patients – Chronic low back pain – 137 women – G1: 51.45 ± 13.2 y.	– RCT – groups: 3D VR vs. sham VR	For both groups: – 56-day program, – 1 session/day, – between 2-16 min	*3D VR*: PNE, CBT and mindfulness exercises *Control*: non-immersive 2D.	– Pain intensity – Pain interference – Satisfaction	VR : ↘ Pain intensity + effect on pain interference with activity, mood, sleep and stress	*Authors limitations*: – Sample mostly composed of white educated females – Same pain condition
Groenveld et al. (2023)	– 40 patients – chronic low back pain – 33 women – Mean age: 51.5 y	– RCT – groups: VR and control	– 4-week – 1 session/day (max. 3×/day), – Between 10-30 min	*VR*: Patient “travels” through the NS with explanation of pain mechanisms+ educational element, alternated over the days *Control*: No treatment	– Daily pain scores (VAS) – Quality of life – Analgesic use	↘ Pain	*Authors limitations*: – Nocebo effect because of waiting lists
Louw et al. (2019)	– 1 woman – Chronic neck/upper back pain – 18 y.	Case study	– 3 sessions –±20 min – One week apart delivering PNE, mindfulness and breathing exercises	PNE delivered through VR	– Pain (NRS) – Disability – Pain catastrophizing – Pressure pain thresholds	No significant result	*Authors limitations*: none mentioned

(*Continued*)

Table 4. (Continued).

Reference	Participants	Design	Methodology	Content	Outcomes	Results	Limitations
Rice et al. (2019)	– 250 US veterans – 91 women – Mean age: 48.5 ± 11.9 y.	– Non RCT – groups: 1) In person mindfulness training 2) Virtual training 3) Controls	1) One 2.5-hour session/week during 8 weeks + one all-day silent retreat 2) Eight 1.5-hour training and one 3.5 hour silent class 3) No training	1) Mindfulness-based stress reduction with a practitioner + at home practices using guided meditation CD. 2) Online exercises with VR headset (i.e., walking meditations and yoga) + home practices 3) No training	– Pain (VAS) – Stress – Energy levels	Mindfulness and VR groups: ↘ Pain, ↘ anxiety, ↘ stress	*Authors limitations*: – Not randomized - Non-standardized questionnaires
Wren et al. (2021)	– 61 patients IBD – 26 women mean age: 15.6 ± 3.29 y.	– Pilot study – One-arm	For all participants – One mindfulness-based VR – 6 min	Focus on breath in a peaceful environment, mindfulness.	– Pain (VAS) – Anxiety – Feasibility	↘ Pain ↘ Anxiety	*Authors limitations*: – No control group – Not randomized – No objective biomarkers

Notes: CBT = cognitive behavioral therapy, CPCI = chronic pain coping inventory, IBD = inflammatory bowel disease, FM = fibromyalgia, NS = nervous system, NRS = numeric rating scale, PNE = pain neuroscience education, RCT = Randomized controlled trial, US = United States, VAS = visual analog scale,VRM = Virtual reality mindfulness, VRD = Virtual reality distraction.

and upper back pain, indicated a trend toward pain reduction that did not reach statistical significance (Louw et al., 2019).

The techniques used to deliver mindfulness-based therapies through VR typically involved a combination of approaches. Five studies incorporated a combination of mindfulness training, breathing exercises, and pain education or cognitive behavioral therapy to help patients develop these skills and healthy coping strategies for managing daily pain (Botella et al., 2013; Darnall et al., 2020; L. Garcia et al., 2021; Groenveld et al., 2023; Louw et al., 2019). Two studies immersed patients in virtual landscapes (a waterfall scene or northern lights) and guided them to focus on their breathing (Aivaliotis et al., 2020; Wren et al., 2021). The remaining study (Rice et al., 2019) did not provide specific details about the type of mindfulness delivered via the VR device.

Concerning sample sizes, one study was a case report with one woman (Louw et al., 2019), one study was a pilot with 6 patients included (Botella et al., 2013) while the remaining studies reported sample sizes ranging from 40 to 250 patients.

Three studies documented effect sizes: one reported large effect sizes for pain interference with daily activities, mood, stress, sleep, as well as a medium-to-large effect size for pain (Darnall et al., 2020); another found large effect sizes for pain intensity and positive affect (Botella et al., 2013); and a third demonstrated moderate effect sizes for pain intensity and its interference with daily activities, mood, and sleep (Garcia et al., 2021).

VR/MBTs: Much More Than Only Pain Management

While not the primary focus of this study, 21 studies within the four categories of MBTs also included assessments of anxiety levels. It is worth mentioning that the combination of VR with MBTs show a significant reduction in anxiety in most of these studies ($n = 13$) (Aivaliotis et al., 2020; Botella et al., 2013; Colloca et al., 2020; Faraj et al., 2021; Gullo et al., 2023; Merliot-Gailhoustet et al., 2022; Olbrecht et al., 2020; Patterson et al., 2004, 2006; Rice et al., 2019; Rousseaux, Dardenne, et al., 2022; Venuturupalli et al., 2019; Wren et al., 2021). Additionally, there is a noticeable trend toward anxiety reduction in six studies, although statistical significance was not reached (Bernaerts et al., 2021; Brown et al., 2020; Haisley et al., 2020; Kelleher et al., 2022; Soltani et al., 2011; Teeley et al., 2012). Only two studies showed no significant differences between the intervention and control groups (Rousseaux, Dardenne, et al., 2022; Wiechman et al., 2022).

Interestingly, 11 studies also explored the acceptability (i.e., how suitable and appropriate the technique is perceived), feasibility (i.e., the number of patients recruited compared to the potential number of eligible patients), tolerability, and safety of utilizing VR in combination with other MBTs (Bernaerts et al., 2021; Botella et al., 2013; Brown et al., 2020; Darnall et al., 2020; L. Garcia et al., 2021; Haisley et al., 2020; Kelleher et al., 2022; Merliot-Gailhoustet et al., 2022; Payne et al., 2022; van den Berg et al., 2023; Venuturupalli et al., 2019). They consistently reported high levels of patient satisfaction, along with excellent tolerability and acceptability. Some individuals with chronic pain expressed their interest in using VR/MBTs again and found the prospect of integrating it into their daily lives intriguing (Garrett et al., 2020; Haisley et al., 2020).

Lastly, four clinical studies (Darnall et al., 2020; Hargett et al., 2022; Patterson et al., 2006; Sarkar et al., 2022) investigated whether VR induced motion sickness or discomfort during meditation, mindfulness, and hypnosis sessions. The majority of patients reported minimal to no discomfort with VR when combined with these MBTs (Hargett et al., 2022; Patterson et al., 2006; Sarkar et al., 2022). Only one study found that six of them experienced nausea or motion sickness, with five reporting it occurring occasionally and one participant reporting it happening frequently (Darnall et al., 2020).

Discussion

To date, no comprehensive review has explored the benefits of integrating VR and MBTs for the management of pain in healthy and clinical populations. Thus, the objective of this scoping review is to provide an overview of existing scientific research on the utilization of VR in conjunction with MBTs to aid in pain reduction. In summary, the collective evidence suggests that their combined use as a complementary approach to pain management generally indicates a trend toward pain reduction, although statistical significance is not consistently achieved in a substantial portion of the included studies and the quality of the employed methodologies is relatively poor.

This scoping review encompassed a total of 43 studies that explored the integration of VR with meditation, mindfulness, relaxation, or hypnosis. Our findings indicate that using VR in conjunction with MBTs is generally thought to be feasible, highly accepted, and well tolerated. Most of these studies ($n = 37$) revealed that this combination effectively contributes to pain reduction, although not all of these achieved statistical significance (23 studies reported significant results, while 14 did not). However, it is important to note that non-significant findings also stemmed from study designs like case reports ($n = 4$) or case series ($n = 2$). Only five clinical studies (Coulibaly et al., 2022; Rousseaux, Dardenne, et al., 2022; Scates et al., 2020; van den Berg et al., 2023; Wiechman et al., 2022) found that, when compared to control interventions (such as usual care), the use of VR combined with MBTs had no impact on pain. Additionally, one study involving patients with severe burn injury during dressing changes reported an increase in reported pain levels after receiving VR-based relaxation (Konstantatos et al., 2009). The researchers argued that this outcome is likely a result of the statistical analysis, with values hovering just below or above the significance threshold. Figure 2 illustrates the main findings.

More precisely, VRH appears to demonstrate moderate utility in both acute and chronic pain conditions directly after the session and seems interesting to study experimental pain in healthy participants. A recent systematic review conducted in patients with musculoskeletal and neuropathic chronic pain revealed that, when compared to usual treatments or controls, hypnosis, even used alone, can result in a moderate decrease in pain intensity and pain interference (Langlois et al., 2022). Similar findings were observed in chronic pain populations, such as cancer patients (Sine et al., 2022) and in acute procedural pain (e.g., bone marrow aspirations, angioplasty, burn debridement) (Kendrick et al., 2016). However, for chronic pain conditions, it is recommended that a minimum of eight hypnosis sessions be administered to achieve a moderate to large effect size (Langlois et al., 2022). Given the established effectiveness of hypnosis in alleviating pain across various conditions (Bicego, Rousseaux, et al., 2022; Kendrick et al., 2016), one could argue that the incorporation of VR to hypnosis is particularly appealing due to its numerous advantages, such as not requiring a specifically trained professional, eliminating the need for constant in-person presence, and minimizing variability in patient responses (Rousseaux, Panda, et al., 2022). However, in our review, VRH demonstrated statistically significant effects only in studies involving

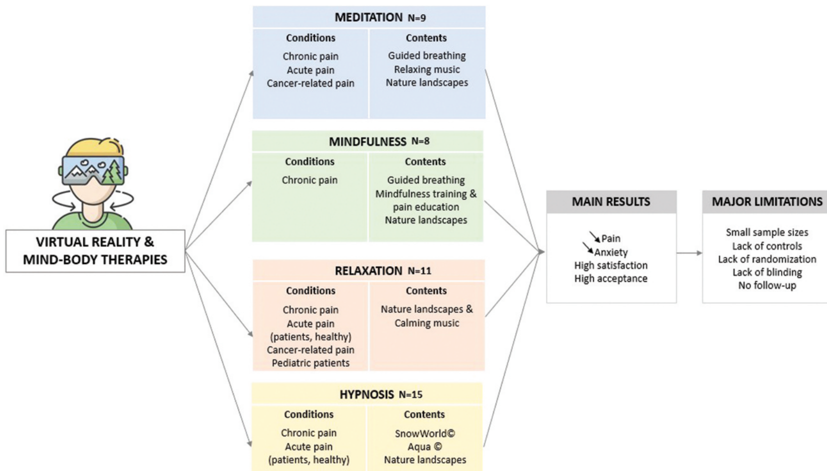

Figure 2. Illustration of Main Medical Conditions, Contents, Results and Limitations for VR-Mediation, VR-Mindfulness, VR-Relaxation, and VR-Hypnosis
Notes: VR = Virtual reality; VRH = Virtual reality hypnosis. *N*= number of articles included in each category.

healthy subjects, and there was a noticeable reduction in pain in case reports and case series. Studies with larger participant samples never consistently demonstrated statistically significant differences between VRH and control conditions, and in some cases, no distinctions were observed. Consequently, based on these results, it appears that VRH may yield varying outcomes in patients, and its effects cannot be generalized to a broader patient population. This variance could be attributed to the substantial differences in hypnotizability observed among individuals, potentially leading to variations in absorption and dissociation levels and, consequently, differences in the sense of presence, distraction, and pain relief experienced by patients and participants. Therefore, the first study proposed potential mechanisms of action of VRH and then determined if hypnotizability would provide valuable insights into the proportion of individuals who may benefit from VRH. Another factor may be the absence of a therapeutic connection when using virtual reality, in contrast to human interaction.

Then, for the combination of VR with relaxation, our findings indicate that it appears to be appropriate for both clinical acute and chronic pain conditions, and even in acute pain settings involving healthy participants. Previous literature has examined the use of relaxation alone in various conditions, especially in the context of labor for acute pain and cancer for chronic pain. During labor, the most recent review demonstrated that relaxation could lessen the pain intensity experienced by women (Smith et al., 2018). However, the authors also mention that results are of very low-quality evidence and may thus not be generalized. Similarly, a recent study explored the effect of VR for pain relief during labor (Wong et al., 2022). A total of 20 women were included, describing that VR helped them to better connect with their breathing, feeling more relaxed, and being disengaged from pain. A total of 70% of women reported a decrease in pain with VR, 60% a decrease in anxiety, and 100% would recommend it for labor. Thus, combining VR and relaxation could be an interesting way for improving the pain experienced in this specific context. In patients with cancer, a specific type of relaxation has also been studied, known as progressive muscle relaxation training. It involves the systematic tightening and relaxing of the body muscle groups along with breathing exercises (Tan et al., 2022). Tan et colleagues (2002) recently showed that this is a promising complementary intervention that may improve the health-related outcomes of patients with cancer and their quality of life by relieving symptoms of anxiety and pain. Still in patients with cancer, Kwekkeboom et al. (2010) categorized as relaxation any technique which is designed to elicit a state of relative freedom from mental and/or physical tension, and included progressive muscle relaxation as well, jaw relaxation, focused breathing, or abdominal breathing. Their results show that significantly greater pain relief can be obtained using these techniques compared to treatment-as-usual or no treatment in these patients (Kwekkeboom et al., 2010). Aside from that, the research on treating patients with chronic pain by only relying on relaxation techniques is still very limited. One of the studies also focused on VR-relaxation in patients with colorectal cancer (Kelleher et al., 2022). Their results show that directly after a single 30-min VR/relaxation session, participants felt that their pain decreased by 59%, relaxation improved by 38% and stress decreased by 68%, and that they had a high satisfaction rate. VR/relaxation may represent a cutting-edge tool, which seems to be successful in reducing both acute and chronic pain. The results of our review corroborate this, with most of them showing a trend for a decrease in pain (and anxiety/stress), even if statistical significance is not reached in half of the studies (Bernaerts et al., 2021; Brown et al., 2020; Esumi et al., 2020; McCune et al., 2023; Scates et al., 2020).

Furthermore, the combination of VR with meditation was commonly used for both chronic pain and perioperative acute pain management. In the literature, meditation alone is primarily seen to treat conditions involving chronic pain. However, even though meditation-based therapies are being increasingly studied for releasing chronic pain, most studies only indicate a small-to-moderate pain intensity reduction (Hilton et al., 2017; Majeed et al., 2018). This low quality of evidence might be explained by the large heterogeneity seen in study designs (e.g., variation in the total length of the interventions, the type of meditation-based therapy used, the questionnaires used, the presence/absence of medication) (Hilton et al., 2017). While there may be little effect on pain from meditation, comorbid conditions that highly impact the quality of life of these patients, particularly stress-related outcomes, could benefit more from this intervention. Indeed, a systematic review demonstrated that 8-week meditation programs had moderate evidence of improved anxiety, depression and also pain of patients with chronic pain, which are particularly promising results (Goyal et al., 2014). Our findings revealed that when meditation is combined with VR, there is consistently an observed tendency toward pain reduction. In fact, seven out of the nine included studies yielded statistically significant results in this regard. In addition, three studies also reported a significant decrease in anxiety levels (Faraj et al., 2021; Liu et al., 2023; Venuturupalli et al., 2019). Consequently, although this study acknowledged various reported limitations, like prior research, the simultaneous use of VR and meditation appears to hold greater promise compared to using either of them in isolation.

Regarding the combination of VR with mindfulness, all the studies considered in this review focused on the treatment of chronic pain conditions. Similar to the findings for meditation, reviews including patients with chronic pain suggest that mindfulness-based techniques, when used in isolation, are more likely to have a positive impact on the psychological aspects of pain, such as reducing depression and anxiety, rather than directly alleviating pain intensity itself (Ball et al., 2017; Creswell, 2017; Pei et al., 2021). However, it is essential to acknowledge that methodological limitations, such as small sample sizes, the absence of active control groups, and a lack of blinding, are prevalent in much of the existing literature on mindfulness interventions. These limitations make it challenging to draw definitive conclusions about the actual effectiveness of mindfulness (Creswell, 2017; McClintock et al., 2019). For instance, a systematic review indicated that mindfulness-based stress reduction led to short-term improvements in pain intensity among patients with chronic back pain, but failed to sustain these effects in the long term (Anheyer et al., 2017). Therefore, mindfulness has the potential to reduce pain in certain conditions, but further research is needed to gain a comprehensive understanding of optimal ways to use it. Future research should include high-quality clinical RCTs that assess formal mindfulness practices before, during, and after interventions, and examine treatment effects during follow-up periods to identify the most effective approaches. In this context, the utilization of VR in conjunction with mindfulness appears promising for better comprehending the potential of this technique. Indeed, out of the eight studies included in this review, four were RCTs and one was a non-RCT, featuring moderate to large sample sizes (ranging from 40 to 250 patients) and thus a high-quality design. Interestingly, all these studies demonstrated significant outcomes in reducing pain intensity among patients dealing with chronic pain, showing the increased potential of mindfulness when combined to VR intervention.

Overall, despite the potential benefits of hypnosis, meditation, mindfulness, and relaxation for the management of pain, the existing literature is limited in terms of high-quality studies supporting their efficacy. The evidence is generally low to moderate, with inconsistent findings. Indeed, the 18 clinical RCT analyzed in this review reported varied outcomes. Regarding meditation, three trials demonstrated a significant reduction in pain (Groninger et al., 2021; Payne et al., 2022; Venuturupalli et al., 2019), while two yielded non-significant results (Garrett et al., 2020; Haisley et al., 2020). In the case of mindfulness, all four RCTs indicated a decrease in pain (Aivaliotis et al., 2020; Darnall et al., 2020; L. Garcia et al., 2021; Groenveld et al., 2023). For relaxation, one trial revealed a trend for pain reduction (Menekli et al., 2022), two exhibited no significant difference (Brown et al., 2020; McCune et al., 2023), and one surprisingly reported an increase in pain (Konstantatos et al., 2009). Lastly, for hypnosis, only one trial exhibited a significant pain decrease (Patterson et al., 2010), with the remaining four producing non-significant results (Gullo et al., 2023; Rousseaux, Dardenne, et al., 2022; van den Berg et al., 2023; Wiechman et al., 2022).

Among MBTs techniques, hypnosis stands out as the only one currently validated with stronger evidence for pain management. This review suggests that combining MBTs with VR technology may offer comparable effectiveness to traditional MBTs with a practitioner and potentially offer additional benefits for meditation, mindfulness, and relaxation. This approach could enhance patient enrollment in clinical studies, sustain their interest over an extended period, and facilitate more high-quality research trials. While VR & MBTs combined hold promise for managing acute and chronic pain, further research is essential before its widespread application in clinical or home settings. It is important to note that the use of VRH does not exhibit the same promising effects. Moreover, in opposition with MBTs, VR requires a purchase for practical implementation, potentially adding to the challenges associated with its use.

Limitations & Perspectives

Despite the promising findings in the reviewed studies, several limitations are frequently encountered. These include small sample sizes, the absence of control groups, a lack of blinding and randomization, reliance on self-reported pain assessments or numeric pain scales, issues like dropouts or mortality, and an insufficient number of VR sessions to achieve optimal outcomes. Furthermore, a notable proportion of these studies fail to report effect sizes, which complicates the assessment of the significance of their results. In the case of hypnosis, specific limitations were observed, particularly concerning the absence of hypnotizability testing. This underscores the critical need for more extensive and rigorous research, incorporating larger sample sizes and randomized controlled designs, to gain a more comprehensive understanding of the potential of both VR and MBTs in pain reduction.

One limitation worth noting is the substantial variability in the design and frequency of VR sessions, which makes it challenging to establish the appropriate VR dosage and the optimal timing for its application. Specifically, while it is evident that VR should be utilized at various intervals and over extended periods to achieve positive effects in patients with chronic pain, determining the precise timing for its use in acute pain situations is considerably more complex. In this review, the included studies employed VR either before and/or after an intervention, or even during the intervention itself. However, none of these different approaches consistently yielded superior results, as all these designs exhibited both statistically significant and non-significant outcomes. Consequently, establishing a standardized design for the application of VR appears to be a complicated task.

Furthermore, there is a notable concern regarding the presence of publication bias, indicating a heightened risk that the available published literature may disproportionately represent studies with positive or statistically significant outcomes, potentially skewing the overall understanding of the subject under investigation.

Concerning the limitations for this review, one involves the classification of various MBTs types. Identifying distinctions between them can be challenging, given their apparent similarity in technique execution. Furthermore, some studies labeled under a specific intervention type incorporated various forms of MBTs, such as mindfulness, meditation or relaxation techniques involving meditation. As a result, the categorization of the included studies relied solely on the authors' provided keywords, and certain studies might have potential overlap with multiple categories. Additionally, the screening of studies and data extraction were carried out by a single author. While efforts were made to ensure thoroughness and accuracy in this process, the lack of independent verification by at least two reviewers may introduce the possibility of bias. Additionally, relying on a single author for these tasks may have introduced subjectivity in decision-making regarding study inclusion and data interpretation. To address this point, a common agreement between three authors (M.L., A.B., A.V.) was made after the extraction process regarding the inclusion of each of the studies. Therefore, future reviews should consider involving multiple authors to independently assess study eligibility and extract data, thereby enhancing the robustness of the review findings. Moreover, regarding the screening process, it is noteworthy that duplicates across the three databases were not compared, thus details about the number of duplicates that were removed is not available.

As a perspective, it appears essential to delve into additional MBTs variants. For instance, considering the well-established pain and anxiety reduction benefits associated with music (Kavak Akelma et al., 2020; Santiváñez-Acosta et al., 2020), its integration into VR experiences could be a promising avenue. Nevertheless, there is a notable lack of literature on this topic, with only one study demonstrating the feasibility of VR-based music therapy in palliative care. This particular study demonstrated that combining preferred music with a preferred VR environment not only garnered high patient satisfaction but was also deemed feasible within the context of this specific patient population (Brungardt et al., 2021).

Lastly, it is essential to acknowledge that the quality of VR technology significantly influences the ability to create a strong sense of presence and distraction (Hoffman et al., 2006). Research conducted by Hoffman et al. (2006) revealed that the perceived reduction in pain was more substantial in a VR when using "high technology" compared to "low technology" VR. These differences included variations in field of view, graphical resolution, head-tracking, and sound integration. However, it is noteworthy that none of the studies reviewed here specifically addressed or tested variations in the quality of VR technology. As VR becomes more cost-effective and equipment prices decrease, it has the potential to evolve into a self-management tool for patients in both healthcare facilities and home settings. Therefore, selecting the best quality VR technology may enhance the sense of presence and immersion in the virtual world, ultimately diverting attention away from pain. Furthermore, exploring alternative forms of VR is also feasible. One such example is mixed reality (MR), characterized by the augmentation of the real-world environment with virtual data presented on a single display, facilitating interactions through diverse means (Milgram & Kishino, 1994). MR sets itself apart from VR by incorporating the presentation of the actual surroundings, while also providing opportunities for interaction within this reality. As a result, MR presents supplementary benefits, including a multisensory, heightened realism, coupled with a dynamic experience tailored to individual needs.

Conclusion

Everybody experiences pain at some point in life, and if it lasts for a long time, it could be detrimental to one's health and well-being. However, today's clinicians still struggle to alleviate it in some patient populations. Additionally, it is well known that using opioids and other medications can have a negative impact on a patient's health and may lead to serious side effects and dependence. Complementary approaches to pain management are therefore desperately needed. VR and MBTs are increasingly being researched and demand attention. This scoping review contributes to demonstrating that, when used together, these techniques can potentially lessen a patient's perception of pain, in both acute and chronic settings. Nevertheless, there is still a lack of research on this combination, and studies are of poor quality, making it difficult to understand the full potential of these therapies. To better understand the effects of VR and MBTs on patient wellbeing and to incorporate them into routine clinical practice, more studies with a randomized, controlled protocol are therefore urgently needed.

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Virtuelle Realität in Kombination mit Mind-Body-Therapien zur Schmerzbehandlung: Eine Übersichtsarbeit

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Zusammenfassung: Einzeln eingesetzt haben virtuelle Realität (VR) und Mind-Body-Therapien (MBT) das Potenzial, Schmerzen bei verschiedenen akuten und chronischen Erkrankungen zu lindern. Obwohl ihre Kombination zunehmend eingesetzt wird, gibt es keine Studie, die eine konsolidierte Darstellung von VR und MBT bietet. Ziel dieser Studie ist es, einen Überblick über die Wirksamkeit von VR in Kombination mit MBTs (d. h. Meditation, Achtsamkeit, Entspannung und Hypnose) zur Verringerung von Schmerzen bei gesunden Freiwilligen oder Patienten zu geben. Wir haben eine Übersichtsrecherche in der Literatur unter Verwendung von PubMed, Science Direct und Google Scholar durchgeführt und 43 Studien einbezogen. Die Ergebnisse der Studien belegen, dass VR in Kombination mit MBT eine praktikable, gut verträgliche und potenziell nützliche Methode zur Schmerzlinderung ist. Ihre Kombination wirkte sich auch positiv auf Angst, Stimmung und Entspannung aus. Die unzureichende Erforschung dieser VR/MBT-Kombination und der Mangel an multidimensionalen Studien verhindern jedoch ein umfassendes Verständnis ihres vollen Potenzials. Es sind daher mehr randomisierte, kontrollierte Studien mit Protokollen zur Bewertung der Nutzbarkeit erforderlich, um die Auswirkungen von VR/MBT auf das Wohlbefinden der Patienten besser zu verstehen und sie in die klinische Routinepraxis einzubeziehen.

La réalité virtuelle combinée aux thérapies corps-esprit pour la gestion de la douleur : Une revue de la littérature

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Résumé: Utilisées séparément, la réalité virtuelle (RV) et les thérapies corps-esprit (TCE) ont le potentiel de réduire la douleur dans diverses affections aiguës et chroniques. Bien que leur combinaison soit de plus en plus utilisée, aucune étude n'offre une présentation consolidée de la RV et des MBT. Cette étude vise à proposer une vue d'ensemble de l'efficacité de la RV combinée aux MBT (c'est-à-dire la méditation, la pleine conscience, la relaxation et l'hypnose) pour réduire la douleur ressentie par des volontaires sains ou des patients. Nous avons procédé à un examen approfondi de la littérature en utilisant PubMed, Science Direct et Google Scholar et avons inclus 43 études. Les résultats des études montrent que la RV combinée aux MBT est une méthode faisable, bien tolérée et potentiellement utile pour réduire la douleur. Leur combinaison a également eu un effet positif sur l'anxiété, l'humeur et la relaxation. Cependant, l'insuffisance de la recherche sur cette combinaison RV/TMB et le manque d'études multidimensionnelles empêchent une compréhension globale de leur plein potentiel. Il faut donc davantage d'études contrôlées et randomisées, avec des protocoles d'évaluation de la facilité d'utilisation, pour mieux comprendre les effets de la RV/CTM sur le bien-être des patients et les intégrer dans la pratique clinique de routine.

Realidad virtual combinada con terapias cuerpo-mente para el tratamiento del dolor: Una revisión exhaustiva

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Resumen: Cuando se utilizan por separado, la realidad virtual (RV) y las terapias mente-cuerpo (TMC) tienen el potencial de reducir el dolor en diversas afecciones agudas y crónicas. Aunque su combinación se utiliza cada vez más, ningún estudio ofrece una presentación consolidada de la RV y las MBT. El objetivo de este estudio es proponer una visión general de la eficacia de la RV combinada con las MBT (es decir, meditación, atención plena, relajación e hipnosis) para disminuir el dolor experimentado por voluntarios o pacientes sanos. Se realizó una revisión exhaustiva de la bibliografía mediante PubMed, Science Direct y Google Scholar y se incluyeron 43 estudios. Los resultados de todos los estudios apoyan que la RV combinada con MBT es un método factible, bien tolerado y potencialmente útil para reducir el dolor. Su combinación también tuvo un efecto positivo sobre la ansiedad, el estado de ánimo y la relajación. Sin embargo, la insuficiente investigación sobre esta combinación de RV y MBT y la falta de estudios multidimensionales impiden una comprensión exhaustiva de todo su potencial. Por lo tanto, se necesitan más estudios controlados aleatorizados, con protocolos de evaluación de la utilidad, para comprender mejor los efectos de la RV/TMC en el bienestar de los pacientes e incorporarlos a la práctica clínica habitual.

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