Review Article

Virtual reality for acute and chronic pain management in adult patients: a narrative review

A. Chuan,[1,2] **J. J. Zhou,**[3] **R. M. Hou,**[4,5] **C. J. Stevens**[6] and **A. Bogdanovych**[7]

1 Associate Professor, 4 Lecturer, Faculty of Medicine, University of New South Wales Sydney and Ingham Institute of Applied Medical Research, Sydney, NSW, Australia
2 Consultant, 3 Resident, Department of Anaesthesia, Liverpool Hospital, Sydney, NSW, Australia
5 Consultant, Department of Pain Medicine, Liverpool Hospital, Sydney, NSW, Australia
6 Director and Professor, 7 Senior Lecturer, MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Sydney, NSW, Australia

Summary

Virtual reality is a computer-generated environment that immerses the user in an interactive artificial world. This ability to distract from reality has been utilised for the purposes of providing pain relief from noxious stimuli. As technology rapidly matures, there is potential for anaesthetists and pain physicians to incorporate virtual reality devices as non-pharmacological therapy in a multimodal pain management strategy. This systematic narrative review evaluates clinical studies that used virtual reality in adult patients for management of acute and chronic pain. A literature search found 690 citations, out of which 18 studies satisfied the inclusion criteria. Studies were assessed for quality using the Jadad and Nottingham-Ottawa Scales. Agreement on scores between independent assessors was 0.87 (95%CI 0.73–0.94). Studies investigated virtual reality use: intra-operatively; for labour analgesia; for wound dressing changes; and in multiple chronic pain conditions. Twelve studies showed reduced pain scores in acute or chronic pain with virtual reality therapy, five studies showed no superiority to control treatment arms and in one study, the virtual reality exposure group had a worsening of acute pain scores. Studies were heterogeneous in: methods; patient population; and type of virtual reality used. These limitations suggest the evidence-base in adult patients is currently immature and more rigorous studies are required to validate the use of virtual reality as a non-pharmacological adjunct in multimodal pain management.

Correspondence to: A. Chuan
Email: dr.chuan@iinet.net.au
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Twitter: @AlwinChuan; @KateStevArtsSci

Introduction

The experience of pain is mediated by: biological; emotional; social; cultural; and psychological inputs. Pharmacological therapy and invasive procedures, such as nerve blocks, are primary analgesia options but have well-known side-effects. To minimise these complications, non-pharmacological therapy may be added as part of a multimodal analgesia plan to reduce the need and dosage of medications [1]. One type of non-pharmacological therapy is the use of virtual reality to deliver or support pain-related psychological treatments.

Virtual reality is the creation of an artificial computer-generated environment to replace real-world sensory inputs. The virtual reality environment is presented to a patient's eyes and ears through a head-mounted display and interaction is made possible through hand controllers and sensors to track head movements. The use of virtual reality for analgesia was first described in 2000 [2], during

Figure 1 A readily accessible, consumer grade, high-fidelity virtual reality setup. A high-end gaming laptop allows the software to run with: high resolution graphics; low latency; and high refresh rates. The head-mounted display allows for immersive visuals and audio. Tracking sensors are integrated into the headset, removing the need for the setup to be in a fixed location. Hand controllers allow participants to interact within the virtual reality environment. This setup is easily transportable between clinical areas.

acute burns dressing changes. Subsequently, the most common type of pain psychological method delivered through virtual reality is distraction from painful stimuli. Typically, this distracting content is a computer game or watching a captivating video clip. Patients report less pain due to the temporary shift in attention from the noxious stimulus and also have: increased pain tolerance; an improvement in mood; or a general sense of fun [3].

Like all recent electronic devices, rapid technological advances have made virtual reality equipment: more affordable; easily portable; yet able to provide greater levels of realism. An example of a modern-day high-fidelity, high-end virtual reality setup from our institution is shown in Figure 1. This setup, on a wheeled cart, allows for both clinical applications as well as research. The realism provided by a high fidelity system is termed the immersiveness of the virtual reality environment. Studies using most recent virtual reality technology may thus increase the intensity of distraction and hence provide a greater analgesic effect.

As anaesthetists and pain physicians, this combination of portability and lowered financial outlay has opened an opportunity for novel options to complement our traditional pharmacological methods of providing analgesia. We thus performed a systematic narrative review and evaluated clinically-relevant studies that used virtual reality for analgesia in adults, categorised by acute and chronic pain applications. We originally intended to perform a meta-analysis but deferred due to the heterogeneity of included studies. The terminology used in virtual reality research may be unfamiliar to clinicians and we therefore listed definitions for commonly encountered terms in Table 1. We summarise the important findings and provide suggestions in areas requiring future research.

Methods

An electronic literature search was performed using: Medline; PubMed; and PsychINFO databases (July 2019). The following search string was used: virtual reality AND (analgesia OR pain); unlimited date from database inception. Articles: in the English language; available as full-text; describing original research (not editorials, correspondence, conference abstracts or review articles) were included. With an emphasis on evaluation of clinically impactful studies, articles were excluded if: quantitative pain and analgesia outcomes were not reported; case reports or case series had less than 10 patients; randomised controlled trials had less than 10 patients in the virtual reality intervention arm; and studies with healthy volunteers (not patients). Hand searches of references in retrieved articles were screened for relevant studies. We excluded articles that focused exclusively on paediatric patients, as this review has recently been performed [4].

Publications were screened against the above criteria by authors JZ and AC to generate a list of eligible studies. These studies were rated for risk-of-bias independently by authors JZ and RH using the Jadad scale [5] for randomised controlled trials and the Newcastle-Ottawa scale [6] for observational studies. The Jadad scale uses specific criteria for appropriate randomisation, blinding and outcome adjudication, providing a maximum score of five. The Newcastle-Ottawa scale similarly provides a maximum

Table 1 Definitions of terminology commonly used in virtual reality research

Augmented reality	Computer-generated images that are overlaid onto the user's visual field of the real-world.
Virtual reality	In contrast to augmented reality, an entirely created three-dimensional multisensory environment replacing the real-world. The user participates and interacts within this artificial space.
Immersion	The ability to exclude real-world visual and aural cues, usually via a head-mounted display and headphones. This is distinct from traditional television or computer screens, which do not block real-world sensory inputs. Further factors that create high levels of immersion include: high fidelity graphics that closely resembles real-life; high graphics resolution; directional audio; and a large field of view mimicking normal vision.
Presence	Subjectively measured (user reported) sense of immersion, allowing the user to easily 'forget' that this is a computer-generated simulation. More immersive experiences create a greater sense of 'buy-in' by the user, enhancing the feeling of being transported from the real into the virtual world.
Head-mounted display	A device worn over the head that projects the computer graphics. Can range from spectacles-like devices to full headsets. More immersive head-mounted displays will incorporate headphones for audio and completely encase the visual field to exclude the real-world.
Head position tracking	Some head-mounted displays have accelerometer and gyroscope sensors to determine head position and adjust the computer visual field to compensate. Other head-mounted displays require external position sensors set up in a room to track position, but have an advantage that users may physically walk in the real-world and this is reflected in the virtual world.
Interactivity	Level of participation allowed by the user in the virtual reality environment. Original virtual reality experiences were passive and simply re-projected two-dimensional videos into the head-mounted display (analogous terms include: 'virtual theatre'; 'fish tank virtual reality'; or 'virtual reality rides'). Interactive virtual reality allows users to pick up objects using hand motion controllers and move within the virtual space, improving presence.
Feedback	Further sensory input may be used to enhance and integrated into the virtual reality experience. Examples include haptic feedback (vibration or resistance delivered to hand controllers or chest plates) and biofeedback (physiological data such as heart rate displayed back to the user).
Refresh rate and latency	Motion sickness is associated with stuttering of the video (inadequately slow refresh rate) and slow responses to user inputs (long latency). As rules of thumb, refresh rates of > 60 frames per second and latencies < 20 ms reduces risk of virtual reality-induced sickness. These are typically only found in high end virtual reality systems.
High-fidelity virtual reality	A mixture of objective and subjective measures of whether a system can smoothly and realistically project the virtual world to the user. Objective metrics define hardware minimums as: modern high end systems have > 60 frames per second refresh rate and < 20 ms latency; graphics resolution of at least 1080 × 1440 pixels per eye; field of view > 90°; and a fully enclosed head-mounted display to maximise immersion. Subjective metrics are the extent of presence felt by the user, measured through questionnaires.

score of nine stars, based on robustness of trial design and reporting. Reviewers were trained in the use of the Jadad and Newcastle-Ottawa scales in an iterative, three-round process involving trial scoring and discussion to improve scoring consistency. A two-way, mixed-effect, average measures, absolute agreement, intra-class correlation coefficient (ICC 2A,*k*) measured consistency of Jadad and Newcastle-Ottawa scale scoring between reviewers. Formal meta-analysis was not performed as studies were heterogeneous for: methods; patient population; and virtual reality intervention performed. Statistical analysis was performed using SPSS version 24 (IBM Corp, Armonk, NY, USA).

Results

Initial database and hand searching of bibliographies produced 690 records as illustrated in Figure 2. Eighteen studies met the inclusion criteria. There were nine studies each, when categorised by acute pain (Table 2) and chronic pain (Table 3) conditions. There was high agreement of Jadad and Newcastle-Ottawa scale scores between the two reviewers, ICC = 0.87 (95%CI 0.73–0.94). The median (IQR [range]) score for all randomised controlled trials (RCT) was 3 (3-3 [2-5]) and for all observational studies was 6 (5-7 [4-8]). All RCTs were unblinded. Frequent methodological issues were identified. A diverse range of virtual reality equipment and software were used and the duration of intervention ranged from 30 min of a single instance of virtual reality exposure, to weekly for 3 weeks. The descriptions of specific studies are discussed below and summarised in Tables 2 and 3.

Acute pain

Four studies were performed to measure the influence of virtual reality on peri-operative pain and discomfort. Guo et al. [7] conducted an RCT comparing virtual reality with no

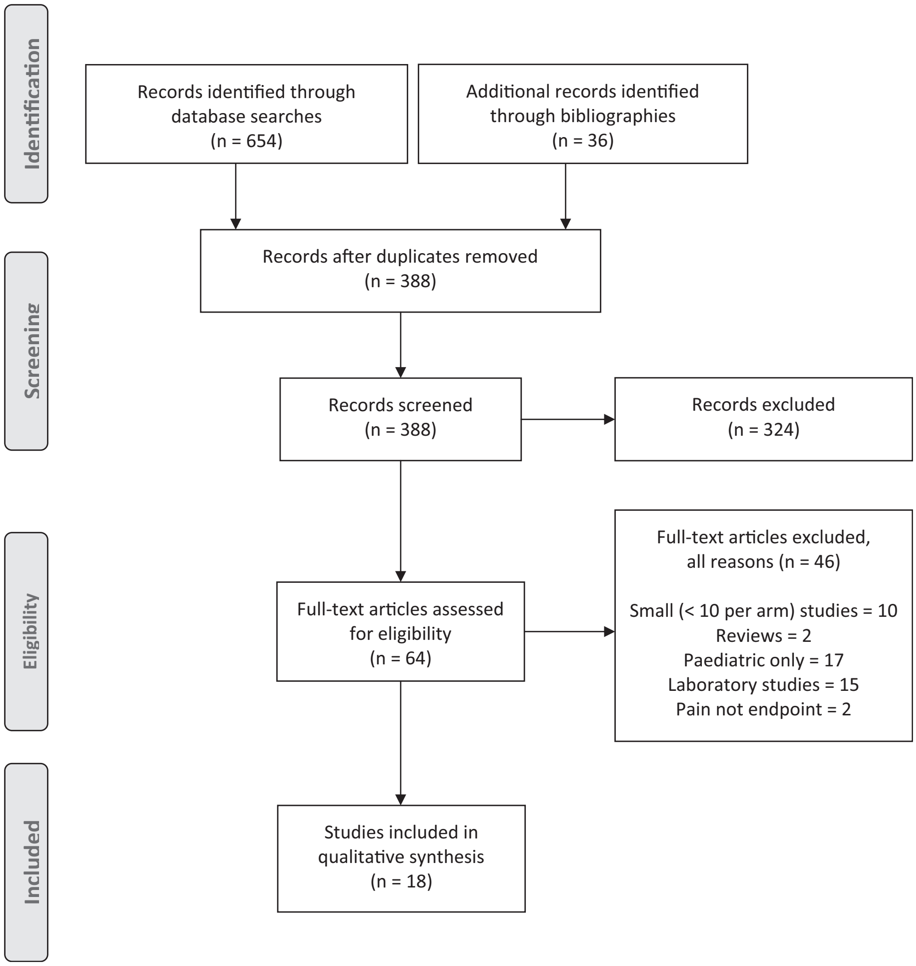

Figure 2 Flow diagram of study selection.

pharmacological or psychological intervention, during postoperative wound dressing changes after hand trauma surgery. The virtual reality intervention was limited to 5 min during the dressing change. It was a virtual theatre of a pre-recorded video that was delivered through a non-commercial head-mounted display. Walker et al. [8] conducted an RCT assessing virtual reality as an adjunct to lignocaine intra-urethral topical anaesthesia during outpatient flexible cystoscopy. The virtual reality intervention consisted of patients shooting snowballs at objects, controlled using a mouse, within the SnowWorld interactive game (Human Photonics Laboratory, University of Washington, Seattle, WA, USA). This software was originally designed as distraction therapy for burn wound dressing changes. Furman et al. [9] performed a crossover study comparing: an interactive virtual reality game; a virtual theatre (non-interactive) video; and no virtual reality exposure, for patients undergoing moderate to severe awake intra-oral surgery. The interactive virtual reality game was Second Life (Linden Lab, San Francisco, CA, USA), delivered through a commercial head-mounted display. All patients were rotated through each of the three arms during their surgery and thus a carryover bias cannot be excluded in this study. The last study by Mosso-Vazquez et al. was an observational trial of analgesia in the first postoperative day after open cardiac surgery [10]. Performed in the cardiac intensive care unit, patients received 30 min of virtual theatre, virtual reality exposure. However, the type of cardiothoracic surgery was not controlled and postoperative sedation and analgesia use was not reported. Three of these four peri-operative studies concluded that reduced pain scores were associated with the use of virtual reality, whereas the flexible cystoscopy study by Walker et al. found no difference with average or worst pain scores compared with intra-urethral local anaesthesia alone.

A pilot RCT by Frey et al. [11] investigated the use of virtual reality as primary analgesia during the first stage of labour. In a crossover design, 28 healthy primiparous

Table 2 Studies investigating the use of virtual reality for peri-operative analgesia and acute pain

Reference	Study design	Sample size (number male)	Age; years (reported measure)	Study characteristics	Control care description	Virtual reality hardware and treatment	Pain outcomes	Jadad (/5) or NOS (/9)
Guo et al. [7]	RCT	98 (85)	18–65 (range)	Hand trauma surgery postoperative wound dressing changes. VR vs. control care.	No intervention.	Afanda non-interactive distraction VR video. HMD type not explicitly defined.	VR reduced averaged VAS.	2/5
Walker et al. [8]	RCT	45 (45)	VR 38 (mean) Control 47 (mean)	Intra-operative adjunct for outpatient flexible cystoscopy. VR and control care vs. control care.	Topical urethral 2% lignocaine gel.	SnowWorld interactive game during cystoscopy. HMD type not defined.	No difference in VAS scores	3/5
Furman et al. [9]	Within-subjects, crossover RCT	38 (17)	46 (mean)	Intra-operative adjunct for dental surgery. Rotated through 3 arms: VR, non-VR movie, and no-VR.	Local anaesthetic. No-VR: HMD removed. Non-VR: animated children's movie.	Second Life interactive game. Silicon Graphics Octane V8 commercial HMD.	VR reduced average VAS.	1/5
Mosso-Vázquez et al. [10]	Observational	67 (42)	Not described	Day 1 postoperative pain relief after open cardiac surgery.	No control group. Analgesia management not described.	30 min non-interactive videos (Cliff, Dream Castle, Enchanted Forest, Icy Cool World, Drive/ Walk/Bike). HMD type not defined.	VR reduced pain rated on a Likert scale.	5/9
Frey et al. [11]	Within-subjects, crossover RCT	28 (0)	19–38 (range)	First stage labour analgesia. Patients alternated between control care and VR.	Unmedicated labour, no interventions.	Ocean Rift interactive game. Smartphone powered (Samsung Galaxy S7) HMD (Samsung GearVR)	VR reduced: time spent thinking about labour pain; worst labour pain intensity; and labour pain unpleasantness (NRS).	3/5
Sharar et al. [12]	Within-subjects, crossover RCT./ Adult data extracted	36	19–65 (range)	Acute burns wound dressing changes. VR and control care vs. control care.	Long acting and short acting opioids.	SnowWorld interactive game. nVisor SX commercial HMD with Polhemus Fastrak position tracking system.	VR reduced: worst VAS pain score; pain unpleasantness; and time thinking about pain.	3/5
Faber et al. [13]	Observational	36	28 (mean)	Acute burns wound dressing changes. Duration for at least 2 days after admission.	Analgesia including opioids as necessary.	SnowWorld interactive game. Cybermind Hi-Res900-3D commercial HMD with Polhemus Fastrack position tracking system.	VR reduced VAS pain scores.	6/9
Carrougher et al. [14]	Within-subjects crossover RCT	39 (35)	21–57 (range)	Acute burns wound dressing changes. Duration for at least 2 days after admission. VR and control care vs. control care.	Long acting and short acting opioids.	SnowWorld interactive game. NVis Nvisor commercial HMD	VR reduced worst VAS pain scores.	3/5
Konstantatos et al. [15]	RCT	86	VR 36 (mean) Control 41 (mean)	Acute burns wound dressing change.	Intravenous morphine PCA, with oral morphine.	Virtual Medicine non-interactive video (hypnosis and guided relaxation tutorial). Dressing change without analgesia but rescue morphine after dressings completed. HMD type not defined	VR increased: worst pain; and pain intensity VAS scores.	3/5

HMD, head-mounted display; NOS, Newcastle-Ottawa Scale; NRS, numerical rating scale; PCA, patient controlled analgesia; RCT, randomised controlled trial; VAS, visual analogue scale; VR, virtual reality.

Table 3 Studies investigating the use of virtual reality for analgesia in chronic pain conditions

Reference	Study design	Sample size (number male)	Age; y (reported measure)	Study characteristics	Control care description	Virtual reality hardware and treatment	Pain outcomes	Jadad (/5) or NOS (/9)
Jones et al. [16]	Observational	10 (5)	56 (mean)	Complex regional pain syndrome; idiopathic peripheral neuropathy; or diabetic neuropathy. Repeated VR exposure over 3 weeks.	No control group. Analgesia management not described.	Cool! interactive game. 20 min VR session (3 weeks, average 30 h). Oculus Rift or Vive commercial HMD	VR reduced: NRS pain scores.	8/9
Bani Mohammad et al. [17]	RCT	80 (0)	30–70 (range)	Stage 1–4 breast cancer patients. Post-surgical chronic pain and/or chemotherapy associated pain.	Intravenous or oral opioid given when requested.	Ocean Rift interactive game or Happy Place non-interactive video. HMD type not defined.	VR reduced: VAS pain scores and state anxiety scores.	2/5
Jones et al. [18]	Observational	30 (10)	35–79 (range)	Cervical/thoracic/ lumbar spine pain; hip pain; interstitial cystitis; myalgia; or neuropathy.	No control group. Analgesia management not described.	Cool! interactive game exposure for 5 min. Oculus Rift commercial HMD or DeepStream stereoscopic viewer.	VR reduced: NRS pain scores.	6/9
Jin et al. [19]	Within-subjects, crossover RCT	20 (4)	30–75 (range)	Unknown chronic pain aetiology. Control care followed by VR treatment.	Regular self-distraction for pain.	Cryoslide interactive game for 10 min (one session). Oculus Rift HMD.	VR reduced: VAS pain scores.	2/5
Wiederhold et al. [20]	Observational	40	22–68 (range)	Unknown chronic pain aetiology.	No control group. Analgesia management not described.	VR environment populated with relaxing natural environment images. HMD type not defined.	VR reduced: average VAS score.	5/9
Sarig-Bahat et al. [21]	RCT	32 (10)	41 (mean)	Chronic idiopathic or post-traumatic cervical neck pain.	30 min kinematic range of motion training using a laser pointer. < 3 months home-based range of motion exercises (30 min, 3 times a week). Physiotherapy supervision.	30 min session: 15 min VR, customised range of motion training software and 15 min of laser pointer kinematic training. Home-based (non-VR) range of motion exercises as for control care. Commercial HMD with Wrap 1200VR motion tracking sensors.	VR reduced: neck pain VAS scores.	4/5
Sarig Bahat et al. [22]	RCT	90 (27)	48 (median)	Chronic cervical neck pain. three groups: control; laser pointer; and VR training.	Control: no training. Laser pointer: 20 min kinematic range of motion training using a laser pointer and 4 weeks home-based laser pointer range of motion exercises (20 min, 4 times a week).	20 min VR, customised range of motion training software. Oculus Rift commercial HMD with motion tracking sensors. Home VR training regimen as per laser pointer group.	VR and laser pointer reduced: neck pain VAS scores.	4/5
Thomas et al. [23]	RCT	52 (27)	VR 24 (mean) Control 27 (mean)	Chronic lower back pain.	Range of motion using physical medicine ball.	Three 15 mi sessions of customised range of motion training software (Virtual Dodgeball). Stereoscopic projection onto traditional television screen, using Samsung 3D Shutter glasses.	No difference in pain scores	3/5
Garcia-Palacios et al. [24]	RCT	61 (0)	23–70 (range)	Fibromyalgia	Outpatient visit to a rheumatologist.	Six 2 h sessions: group cognitive-behavioural therapy including three 20 min positive emotion control sessions using VR projected onto screen, with the EMMA programme.	No difference in pain scores	4/5

HMD, head-mounted display; NRS, numerical rating scale; NOS, Newcastle-Ottawa Scale; VAS, visual analogue scale; VR, virtual reality.

labouring women were given in sequence either: no intervention; or virtual reality exposure using a smartphone-powered head-mounted display (GearVR, Samsung, Seoul, South Korea) and interacted with the Ocean Rift scuba diving game (Picselica Ltd, Denbighshire, UK). Statistical adjustment was used to minimise carryover effects, but blinding was not performed. Worst labour pain intensity and anxiety were reduced with virtual reality exposure, without increased side-effects. A primary motivation for the study was feasibility and the authors used commercial lower-cost virtual reality equipment and software.

The remaining four studies investigated virtual reality use for wound dressing changes in acute burns patients. The earliest study by Sharar et al. [12], reported pooled results from three concurrent studies and included paediatric patients. This study was included in our review as 36 of the recruited patients were adults (aged 19–65 y), representing 41% of their sample population and sub-analysis was performed for the adult patients. Patients were provided with a commercial head-mounted display and the SnowWorld game. They were exposed in a crossover trial design to one session each, with and without virtual reality, during dressing changes. Similar equipment setups were used in Faber et al. [13] and Carrougher et al. [14], which followed up patients over 48 h of dressing changes. Partial data from Carrougher et al. were pooled in the Sharar et al. study. Lastly, the RCT by Konstantatos et al. [15] used a custom designed hypnosis and guided relaxation tutorial as electronically delivered cognitive-behavioural therapy (Virtual Medicine Pty Ltd, Victoria, Australia). Whereas the first three acute burn patient studies found a reduction in worst pain scores after virtual reality exposure, the results may have been influenced by: a lack of blinding; carryover effects; differences in total body burns area in recruited patients; and the presence of confounding analgesic and anxiolytic medications. In contrast, the latter study by Konstantatos et al. found that pain intensity, as well as worst pain experienced, was unexpectedly higher compared with patients without virtual reality exposure [15].

Chronic pain

In an observational pilot study, Jones et al. recruited patients with chronic neuropathic pain [16], defined broadly as: complex regional pain syndrome; idiopathic peripheral neuropathy; or diabetic neuropathy. Patients received weekly virtual reality sessions of 20 min duration for 3 weeks, using an Oculus Rift and Vive head-mounted display (Oculus VR, Irvine, CA, USA) and the Cool! interactive game (Firsthand Technology, San Francisco, CA, USA). This is the first study examining the impact of longer term virtual reality exposure. Whereas pain scores were reduced, there was no effect on: depression; anxiety; or catastrophising.

An RCT by Bani Mohammad et al. [17] found that pain and anxiety scores were reduced in breast cancer patients who received virtual reality with morphine compared with those who received morphine alone. The patients recruited represented a heterogenous group with Stage 1 to 4 cancer and a mixture of being: post-surgical; receiving only chemotherapy; or having both treatment modalities. Patients were also exposed to two different virtual reality experiences: Ocean Rift or a non-interactive Happy Place relaxation video (Wenderdalck, Stockholm, Sweden).

In three studies [18–20], the chronic pain diagnosis was not defined. All three studies used dissimilar methods and equipment. Jones et al. conducted an observational study utilising the Cool! interactive game, delivered using either an Oculus Rift head-mounted display or a non-immersive, lower fidelity stereoscopic viewer [18]. Jin et al. performed a crossover trial of a virtual reality intervention (Cyroslide interactive game, Archiact VR, Vancouver, Canada) and control (traditional distraction techniques employing listening to music, reading books or self-meditation) in chronic pain patients [19]. Wiederhold et al. conducted an observational trial of virtual reality in chronic pain patients, but the virtual reality software and equipment type were incompletely described [20].

The remaining four studies investigated virtual reality use for chronic musculoskeletal pain. Two RCTs from the same research group investigated the use of virtual reality to augment range of motion training in chronic cervical neck pain. Traditional physiotherapy exercises used laser pointers affixed to patients' heads as a visual guide of actual and aspirational cervical range of motion. Sarig-Bahat et al. [21] used a specialised head-mounted display with kinematic sensors to track head movements, whereas the patient played a custom-made interactive virtual reality game. In this pilot study, the authors found broad improvements from virtual reality exposure including: improved range of motion; reduced kinesiophobia; and reduced pain scores, compared with traditional training alone. However, their subsequent RCT [22] in 2018 replicated the primary outcome of a greater range of motion but did not demonstrate a difference in pain scores between the virtual reality and traditional training groups. Two possible reasons for this discrepancy of results are that there was less physiotherapy involvement and a 29% loss to follow-up rate in their 2018 study, compared with their 2015 pilot study.

Thomas et al. [23] also investigated the use of virtual reality range of motion training in patients with chronic lower back pain. This RCT compared the use of a custom-made game where patients handled a virtual medicine ball, compared with the traditional exercise of using a physical medicine ball. The virtual reality effect was created using a non-immersive, low fidelity, stereoscopic projection onto a television screen. However pain scores, as well as range of motion and degree of kinesiophobia, were not different between the virtual reality intervention and traditional training groups.

In an RCT of chronic fibromyalgia patients, Garcia-Palacios et al. [24] compared cognitive-behavioural therapy where the activity management component was delivered using virtual reality, compared with routine care where patients had outpatient visits to review medications with a rheumatologist. Although patients in the interventional group reported higher functional quality of life, there was no difference in pain scores when compared with routine care patients. The results from this study may have been affected by patients not having individual head-mounted displays, instead viewing virtual reality as non-immersive content projected onto a white screen. This content was one component of a care bundle consisting of pain education, outpatient psychologist sessions and group therapy, further confounding any impact from using virtual reality.

Discussion

This review found that using virtual reality for adult pain management is currently in an early phase of research. Studies included in this review have explored the use of virtual reality in diverse applications ranging from: wound dressing changes (post-surgical and burns trauma); intra-operative pain management; labour analgesia; and multiple types of chronic pain. Using this relatively novel technology for analgesia has produced encouraging results, such as a reduction in pain scores. However, enthusiasm to integrate virtual reality as a clinical tool should be cautioned by methodological biases in the existing literature. These biases include heterogeneity of virtual reality hardware equipment; multiple types of virtual reality software resulting in patients experiencing different levels of immersion, presence and interactivity; lack of blinding; differences in duration of virtual reality therapy sessions; and heterogeneity of recruited patient populations.

There were two studies that utilised virtual reality as a distraction in the context of awake surgery without sedation: flexible cystoscopy in Walker et al. [8] and oral surgery in Furman et al. [9]. However, both studies were unconvincing in demonstrating if virtual reality reduces pain. Walker et al. suggested a lack of effectiveness was due to using older, less immersive virtual reality setup with reduced distraction. Whereas Furman et al. did find a positive benefit, a higher quality study addressing methodological issues including: proper randomisation; blinded allocation; and reducing carryover biases is necessary. Moreover, these studies were arguably attempting to use virtual reality for anxiolysis or avoiding intravenous sedation, but were instead powered for analgesia and used pain scores as primary outcomes. In contrast, Chan et al. [25] investigated whether propofol sedation requirements were reduced by virtual reality distraction in their study of lower limb total joint arthroplasty under intrathecal and peripheral regional anaesthesia blocks. Future studies on sedative-sparing effects of virtual reality should use: drug consumption; pre- and post-anxiety scales; or patient satisfaction questionnaires as more appropriate endpoints.

Another study of direct relevance to anaesthetists was the successful use of virtual reality for first stage labour analgesia by Frey et al. [11]. Benefits include: low cost; portability; accessibility; and non-invasiveness of the smartphone-based hardware. This novel study was a proof-of-concept pilot trial and was compared with no analgesia. Any subsequent RCT should logically compare virtual reality vs. established therapies.

The most frequent application for virtual reality was during wound dressing changes, with the aim of reducing pain and hence opioid-related adverse effects. Of this, the largest sample sizes were from studies on burns-related trauma in adults; similar to that found by Eijlers et al. [4] in their review of paediatric uses of virtual reality. The study by Konstantatos et al. is noteworthy as the authors did not use distraction (i.e. playing games or watching a video) but instead focused on delivery of pain education. The advantage of teaching self-hypnosis and relaxation techniques would be that burns patients may continue to utilise these pain management strategies during future wound dressing sessions, thus reducing reliance on virtual reality. The authors found that pain was worse after the intervention and they hypothesised that more virtual reality sessions were likely necessary given that educational uptake is slower and subject to variability in participant anxiety and cognitive states.

The efficacy of virtual reality in chronic pain studies was similarly affected by nuances. Of the three studies with negative outcomes, there was a high rate of loss to follow-up for one study [22], and the remaining two studies [23, 24] were likely affected by use of low-fidelity, non-interactive and non-immersive virtual reality. All three attributes of virtual reality influence the magnitude of benefit. In a laboratory study using experimental pain, higher fidelity software provided more analgesia than lower fidelity and better than non-virtual reality controls [26]. Participants interacting within a virtual reality environment have better analgesia than those passively watching [27, 28]. Lastly, the degree of virtual reality immersion is more effective than the same content delivered by traditional two-dimensional television screens [29, 30].

The study by Jones et al. is a singular study investigating repeated, longer duration, virtual reality sessions for chronic pain [16]. However, these sessions were still based on distracting virtual reality games, which are best suited for painful, but transient stimulus. Chronic pain by its nature is not transient and has a distinct pathophysiology from acute pain. It is conceivable that cognitive-behavioural therapy delivered by virtual reality is better suited for chronic pain than distraction therapy. Two studies in this review did attempt behavioural therapy (Konstantatos et al. for acute pain [15] and Garcia-Palacios et al. [24] for chronic pain) but with mixed results and limitations in their conclusions. The role of repeated virtual reality distraction therapy might have clinical applications where acute pain commonly persist for days, such as after major surgery or major trauma.

In conclusion, the evidence base for using virtual reality requires broadening with more methodologically robust studies. As the technology matures, the cost of higher fidelity and interactive virtual reality systems has declined and can now be purchased as consumer retail products. Validation studies of the virtual reality hardware and software should occur, including measuring quality of immersion and presence. Virtual reality is an exciting new non-pharmacological therapy, and future studies should help define its applications and effectiveness as an adjunct in multimodal pain management.

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