

A Rapid Evidence Assessment of Immersive Virtual Reality as an Adjunct Therapy in Pain Management

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Abstract (250 words max)

Objectives: Immersive Virtual Reality (IVR) therapy has been explored as an adjunct therapy for the management of acute and chronic pain among children and adults for a number of conditions. Therapeutic approaches have traditionally involved medication and physiotherapy but such approaches are limited over time by their cost and/or side effects. In this paper we present a rapid evidence review of the effectiveness of VIRE therapy in pain management to date.

Methods: A rapid evidence assessment strategy (REA) was used. CINAHL, Medline, Web of Science, IEEE Xplore Digital Library, and the Cochrane Library databases were screened in from December 2012 to March 2013 to identify studies exploring IVR therapies as an intervention to assist in the management of pain. Main outcome measures were chronic or acute pain and functional impairment.

Results: Twenty research studies were included in total including five RCTs, five randomized crossover studies, five case series studies and five single patient case studies. This included a total of 354 patients. Of these studies only four had a low risk of bias. For acute pain there was strong overall evidence for immediate and short-term pain reduction, whilst moderate evidence was found for short-term effects on physical function. Little evidence exists for IVR therapy in treating chronic pain or long-term benefits. IVR was not associated with any serious adverse events.

Discussion: This review found moderate evidence for the reduction of pain and functional impairment after IVR in patients with acute pain. Further high-quality studies are required for the conclusive judgment of its effectiveness in chronic pain, and to establish safety.

Keywords: virtual reality, VR, immersive environments, chronic pain, acute pain.

INTRODUCTION

Immersive virtual reality (IVR) has now been used in a range of clinical applications. Several studies have asserted positive outcome for patients using IVR for clinical conditions such as anxiety disorders,¹ phobias,² post-traumatic stress disorder,³ eating disorders,⁴ and pain management.⁵⁻¹⁰ Over the last decade some significant successes have been claimed for the use of IVR in the treatment of both acute and traumatic injury pain as an adjunct method for pain control.^{7,8,11-16} Studies reporting its use for other forms of pain and particularly chronic pain are less prevalent, but there is support for work to explore its use for chronic conditions.^{9,17-18} However, the value of IVR in pain management remains an area of potential high impact research, although the current evidence seems diverse and somewhat limited.

Virtual Reality (VR) involves an artificial environment that is experienced by a person through sensory stimuli (usually visual, aural and often touch) delivered by a computer and in which one's actions partially determine what happens in the environment. VR allows individuals to become active participants within a computer generated three-dimensional world (3D) and immersed within this virtual environment. The phenomenon of becoming engaged in an immersive environment (or IVR) provides a powerful tool for behavioural and health scientists/professionals.

VR can be used to immerse patients into a virtual environment by temporarily obscuring their real environment. The sense of immersion in an IVR environment is achieved through visual and auditory stimuli that simulate 3D visual and auditory cues available in the real world, whilst Computer-Generated Imagery (CGI) simulates the visual appearance of the virtual world. Visually, the VR environment is delivered to the user/patient with a Head-Mounted Display (HMD), which presents the computer generated imagery of the VR scene from the perspective of each of the user's eyes. The HMD usually displays stereoptic (3D) imagery, and tracks head motion so that the user seems to move naturally around the virtual space and observe it in a natural manner. Thus, stereoscopic

imagery is presented with the 3D visual depth cues of occlusion, perspective, motion parallax, natural surface textures, all updated interactively in real time. Audio is also simulated in 3D with the head-related transfer function, which enables the HMD wearer to locate simulated sound at a real location in space.

If we compare VR to a videogame, in a traditional video game, users feel they are looking *at* a computer screen, whilst with VR, users feel they are *in* a computer simulation. The combination of real-time 3D tracked imagery presented in stereo enables the user to gain a sense of *immersion* or *presence* inside the 3D virtual world, by presenting the illusion that there is a virtual 3D scene everywhere that the user looks. The literature suggests that immersion is influenced by both visual and audio display qualities.^{19,20,21} Immersion has been defined as: “the extent to which one feels present in the CGI environment, rather than in the real physical environment”^{22,23} and has been measured subjectively through an immersion questionnaire.²⁴ The inclusion of stereoptic imagery is widely thought to be the dominant factor that enhances the immersive experience.²¹ In addition, it has been suggested that other technical factors, such as greater resolution or a field of view (FOV) enhances a sense of immersion. For example, users give higher ratings of immersion in cases where the HMD delivers a wider (>60°) field of view (FOV).²¹ Although indications are that the greater the FOV/peripheral vision provided by IVR imagery, the greater the sense of immersion, other factors that may confound these findings have not yet been definitively explored.

In technical domains, the definition of immersion is primarily based upon technical considerations. However, the technical definition of immersion is limited because it ignores the participant as a co-constructor of the experience. Also, because the technological implementation of VR varies greatly, the conceptual framework underpinning the use of IVR for clinical work in pain that we adopted here was that proposed by Jonathan Steuer in 1992.²² Rather than basing a definition of VR on technology, Steuer's is based on concepts of presence and telepresence.

Presence refers to the sense of being within an environment that is generated by technically mediated means. VR involves human experience in which two technological dimensions are considered to contribute to a sense of presence. The first dimension is vividness, or the production of a sensorially-rich mediated environment. The second is interactivity, defined as a user's ability to engage with the environment and modify its form or alter events through interaction with it. An immersive environment is considered to be a computed environment that elicits a user's sense of *presence* or *being there*. It is an environment that produces an aesthetic perception connected to the ideal of total-immersion in virtual space, and involves the "willing suspension of disbelief."^{19,22,23} Because immersion is a key element differentiating these technologies from other distractive mechanisms like video games, we use the term IVR in preference to VR in this paper

IVR environments are hypothesized to reduce pain via non-pharmacologic attentional and distractive mechanisms, although the exact mechanisms remain unclear.^{16,25} Several theories have been suggested to explain the phenomenon. The well-established Gate Control theory of pain suggests that pain is not a direct result of activation of pain receptor neurons, but rather that its perception is modulated by interactions among different neurons.²⁶ Pain pathways must pass through *nerve gates* within the dorsal horn of the spinal cord that must be open before the pain is perceived in the brain. These gates can be closed by a number of mechanisms, and descending pathways from the brain may close the gate by inhibiting the projector neurons, thereby diminishing pain perception. It is hypothesized that distraction may help cause this.²⁷

More recently, a neuromatrix theory of pain has also been used to support an explanation.²⁶ The neuromatrix theory suggests that pain is a multidimensional experience produced by "neurosignature" patterns of impulses generated by a widely distributed neural network termed the "body-self neuromatrix" in the brain.²⁸ IVR therapy may work by dampening the acuity of the pain modulation system by acting on the signaling pathways of the neuromatrix, producing analgesia.

Gold et al.²⁹ suggested that the use of virtual reality might act directly and indirectly on pain perception in a number of ways, such as; altering signaling pathways involving attention, emotion, concentration, memory touch, and the auditory and visual senses. Engaging in a virtual reality experience may change activity in the body's intricate pain modulation system, which in turn may have an impact on pain perception. Here, the anterior cingulate cortex (ACC) region of the brain is suggested to be of particular significance in mediating pain here.³⁰ The ACC is a complex cortical structure located around the rostrum of the corpus callosum, and is subdivided into two distinct regions based on structure and function.³¹ The ACC is suggested to mediate both attentional processes and emotional reactions in the personal perception of pain.³⁰ It has also been suggested that the ACC activates the periaqueductal gray area of the brain, causing a cascade of signaling events stimulating a descending pain-modulation system and producing analgesia.²⁹

Given these theories, along with the rapidly emerging technologies and clinical work in this field, it would appear that IVR may have potential as a useful non-pharmacological adjunct strategy for patients in a range of pain conditions. With the rapid development of less expensive portable VR systems it may soon be practically feasible for patients to use IVR in their own homes. However, as a potential innovative and new therapeutic intervention for pain control there remain many questions regarding the efficacy of VIREs such as: what level of IVR hardware and software (if any) can provide effective therapy, what are the side effects of IVR, how safe is IVR and what are patient's perceptions of the value of IVR?

There is then, a pressing need to establish the evidence base for the use of IVR and its potential applications, and particularly its potential application to the wider field of chronic pain. Therefore our primary objective for this study was to assess the current evidence for the effectiveness of IVR therapy as an adjunctive therapy for the control of pain. Although studies have been conducted using a variety of technological implementations with a

variety of medical procedures, not all studies have been scientifically rigorous in their design or methodology.³² Given that current research in this area is limited and extends across a diverse range of conditions that use a variety of VR systems, a full systematic review is not feasible at this point in the development of these therapies for pain control. Therefore we elected to undertake a rapid evidence assessment (REA) as a practical approach to structured evidence gathering.

REAs are a combination of rapid review and assessment techniques used in response to a clinical or policy question. An REA is an abbreviated form of systematic review increasingly used to support evidence-based practice. They are useful to determine if an intervention or activity is actually feasible, if it is appropriate (ethically or culturally) or if it relates to evidence of experiences, values, thoughts or beliefs of clients and their relatives, and can provide a quick summary of what is already known about an intervention. REAs use systematic review methods to search and evaluate the literature, but the comprehensiveness of the search and other review stages are limited.³³ In terms of an evidence hierarchy, an REA falls just below a full systematic review in terms of confidence in the findings, but above a scoping and a health technology assessment (see Figure One).^{34,35} It involves a specific and rigorous methodology, but has the advantage that it can be undertaken rapidly across a broader range than a systematic review or meta-analysis. As research into IVRs is in its infancy, and to date the few studies undertaken range across a wide spectrum of conditions, types of pain and VR implementations, an REA offers a useful starting point to examine the evidence to date.

MATERIALS AND METHODS

The UK Civil Service Government Social Research Service (GSRS) established the REA methodology adopted for this study.³⁶ We sought to answer the following question using the REA method: how well do IVR s work as an adjunct intervention in the management of pain? Our multidisciplinary REA team consisted of nurses, physicians, media scholars and computer

scientists. We additionally consulted clinicians working with patients with acute and chronic pain using a Web survey to refine the following sub-questions:

- What level of IVR hardware is required to provide therapeutic effects?
- What type of IVR applications presents the best efficacy for pain management?
- What is the overall evidence of its value in the treatment of acute pain?
- What is the overall evidence of its value in the treatment of chronic pain?
- What are the side effects?
- How safe is IVR?

Data Sources

To facilitate a rapid assessment of the evidence the search attempted to identify all relevant clinical studies published in the English language. Bibliographic sources from Medline, the Web of Science, IEEE Xplore Digital Library and the Cochrane Library databases were referenced to identify studies of IVR therapies developed to assist in the management of pain during the 10 years prior to the end of March 2013.

Study Selection; inclusion and exclusion criteria

The studies identified used IVR therapy as an adjunct intervention in clinical investigations to control acute or chronic pain in adults or children. Inclusion criteria were: studies involving a computer-mediated interactive multimedia environment (including both audio and visual representations) and a motion tracking head-mounted display (HMD) published within the last 10 years. Studies before this time were considered unrepresentative of the contemporary technological developments in the field, while studies including other forms of visual displays were too diverse for comparison and were deemed unlikely to provide the same level of engagement necessary to support an immersive experience. Thus, exclusion criteria extended to studies that did not involve an immersive interactive environment (such as visual imagery, multimedia therapies or *Second Life*), and to studies involving laboratory experiments with healthy volunteers.

Information found in grey literature was also excluded in order to facilitate a rapid review. Once studies had been identified, the next stage was to screen them to check that they met the inclusion/exclusion criteria. This involved two people who reviewed abstracts independently for decisions on final inclusion. The initial search strategy retrieved 91 records. After overlapping and irrelevant articles were deleted, a total of 56 titles were screened. On further examination of the abstracts, 16 of those records were further excluded as they failed to meet the inclusion/exclusion criteria. On further investigation of the 40 remaining articles 20 were then omitted as they did not represent IVR therapies (e.g. studies that used relaxation videos)³⁷ or not did represent adjunct interventions (e.g., experimental studies on healthy individuals.^{9,20,38,39}

Types of Studies

Both qualitative and quantitative studies were identified by the search strategy, comprising randomized-controlled trials (RCTs), randomized crossover studies, case series and case studies. Each study reported pain-related symptoms, or functional or perceptual changes as outcomes.

Types of Participants

Studies selected included pediatric and adult patients with pain resulting from acute/sub-acute and chronic conditions or pain-inducing therapies. consisting of burns and wound dressing changes and dental procedures. The selected studies also included pain resulting from neurological damage, chemotherapy pain in cancer treatment, multiple bone fracture pain, and pain from IV access (both sub-cutaneous implanted port access, and peripheral IV start).

Types of Intervention

Studies using the following range of IVR interventions were included in the review: custom designed computer rendered 3D CGI immersive environments displayed in head mounted displays (HMD) with fields of view (FOV) ranging from 40-70 degrees, three-dimensional motion tracking, and stereo audio representation. Three studies used a two-

dimensional (2D) commercial computer game displayed through similarly equipped HMDs. For the software necessary to render virtual environments, most of the studies used custom-created systems. In particular, 11 of the studies used the Snow World environment created by Hunter Hoffman's research team at the Human Interface Technology Laboratory at the University of Washington (mainly for use with burns patients). One study used a custom-built ice-cream factory environment.¹⁴ Three studies used a virtual gorilla enclosure developed for the Atlanta Zoo,⁴⁰⁻⁴² and four studies used commercial game software, including Disney's *Chicken Little*,^{43,44} Electronic Arts *Need for Speed*,⁴⁵ and Fifth Dimension Technologies *Street Luge Racing*. One study used a *Second Life* botanical garden environment.⁴⁶

Types of Control

Studies that included control subjects (where used) used analgesics alone (including opioids, or non-opioid analgesics by oral or intravenous routes, with intermittent maintenance doses, as required doses, or patient controlled analgesia), Entonox (as required), or local topical analgesics, with no IVR intervention. In all of the controls no VR intervention was used, whilst several studies used an alternative method of distraction method, such as a TV show, or movie (See Table 3).

Types of Outcome Measures

Studies used a wide variety of pain assessment tools. For adults the assessment tools included: the Visual analogue Scale (VAS),⁴⁷ the Visual Analogue Thermometer (VAT),⁴⁸ the Burns Specific Pain Anxiety Rating Scale, (BSPA/BSAR),⁴⁹ the self-reported numeric pain scales (NPRS),⁵⁰ and the Dental Anxiety Scores (DAS).⁵¹ For children assessment tools includes the VAS, FACES Pain Rating Scale, the Children's Hospital of Eastern Ontario Pain Scale (CHEOPS),⁵² the Graphic Rating Scale (GRS)⁵³, or the Faces, Legs, Activity, Cry, Consolability scale (FLACC).⁵⁴ Other than pain assessment three studies with burns patients also used Range of Motion (ROM) as an outcome measure.^{8,11}

Data Extraction and Assessment of Adequacy of VIRE Interventions

Summary data from all of the selected studies was added to a spreadsheet using a data extraction matrix created from the original research questions, and review tools were based upon the Evidence for Policy and Practice Information Centre's (EPPI) review guidelines for extracting data.⁵⁵ This included detailed sections for recording the administrative details, aims and goals of the studies, approach and methods used, sample selection, interventions, analyses of data, ethical considerations, limitations, and outcomes/ conclusions. A final determination of the appraisal tools to be used was made after an initial exploration of the results from the data extraction had been undertaken, and after the number and nature of the published work to be included was established. In accordance with the GSRS REA method the assessment tools used for appraising the studies in the spreadsheet consisted of the following tools:

- 1) The GRSS Weight of Evidence appraisal tool (see Table 1),⁵⁶
- 2) The Maryland Scale of methodological quality (see Table 2),⁵⁷
- 3) The Critical Appraisal Skills Program (CASP) qualitative research appraisal tool (for those studies incorporating qualitative work).⁵⁸

Risk of Bias Assessment

Risk of bias was assessed for all included studies using the Risk of Bias assessment tool from the Cochrane Review Group. This tool was used to explore selection bias, performance bias, detection bias and attrition bias or other specific biases.⁵⁹

Data Analysis

Each of the included studies were each assessed and scored independently by two researcher team members, while a third team member moderated the results when scores differed between the two initial reviewers. As per the REA methodology, studies were grouped into three categories (high, medium, or low quality of evidence) based upon the

overall weight of evidence (GSRs) and Maryland Scale scores. Likewise, risk of Bias was assessed and categorized as low, medium or high for risk.

RESULTS

Description of the Studies

The work in this field is mainly represented by quantitative studies. Out of all of the studies that were included five were RCTs,^{15,35,38,39,54} five were randomized crossover studies,^{8,11-13,46} five were case series studies^{7,14,61-63} and five were single patient case studies.^{6,17,42,64,65} Only two mixed-methods studies were included, both with children: one a case series study combined with a brief interview,¹⁴ and the other an RCT that included a brief narrative interview.⁶⁶ The studies and their weight of evidence scores are summarized in Table 3.

The research studies included a total of 354 patients. Out of those patients 70% were men, although five studies did not report the gender of those taking part. Over half (59%) of the studies were undertaken with children. The majority (55%) of the studies were with patients being treated for burn injuries (during dressing changes or physiotherapy). Three studies were with pediatric patients experiencing pain through sub-cutaneous IV-port access, and one was with initial pediatric IV placement. The remainder represented individual studies of IVR use in patients in the following areas: pain in adults undergoing periodontal scaling,⁴⁶ a child with cerebral palsy undergoing painful post-operative physiotherapy,⁶⁵ pain in adult men with multiple fractures due to traumatic injury,⁶¹ pain in an adult man arising from a surgical urological procedure,⁶⁴ and chronic neuropathic pain in an adult woman following a spinal injury five-years previously. This latter study represented the only case of IVR being used for chronic pain management in the studies we identified.

Quality of Evidence

The overall quality of evidence was varied, but included a number of high-quality evidence studies. The highest quality of evidence was reflected in a number of RCTs and randomized crossover studies, although one case series also scored as a high quality of evidence study. See Figure 2 and Table 3 for a summary. Many of the RCTs were well designed and reported, although sample sizes were generally small. Only one RCT study included samples of more than 50 subjects and over half of the RCTs included had sample size of 20 or fewer participants. The three high-quality evidence crossover studies had samples between 38 and 54 participants. Two crossover studies and six case series studies demonstrated medium quality evidence, again with small cohorts of subjects (1 to 19 participants). One case series (three subjects) and one individual case study scored as low quality evidence studies using the GSRS and Maryland assessment tools. For the mixed methods studies that were included one scored high for quality of evidence,⁶⁶ and the other as a medium evidence quality study overall.¹⁴ Both of these also scored as high-quality studies using the CASP qualitative research appraisal tool.

Risk of Bias

As might be expected where the subject selection opportunity was limited, blinding was not possible, sample size small, and performance bias was possible, the overall risk of bias was generally high in most of the studies examined. Attrition bias was also a factor with several studies noting issues of participant drop out.^{8,15,45,61,63} Overall only four RCTs and two crossover studies were assessed as having a low risk of bias (see Table 3).

DISCUSSION

Work exploring the use of IVR in the management of clinical pain remains relatively new. To date, the leading work in this area has been undertaken by Hunter Hoffman's University of Washington research team, working of in the field of acute pain with burns patients, using their *Snow World* environment. Hoffman et al. described the first evidence supporting the use of VR for acute pain management in 2000.⁵ Other researchers are now

beginning to explore this field with different patient populations. Studies have included both child and adult populations, and some noteworthy findings have emerged that could have significant impact on the management of clinical pain.

Effects of IVR Therapy

The evidence of the effectiveness of IVR as an adjunct therapeutic intervention for acute pain is limited, but growing. In a recent Australian study for example, Kipping et al.⁴⁵ conducted an RCT with 41 adolescent burns patients undergoing conscious wound care procedures. Although they found a statistically significant reduction in nurse-reported pain scores with IVR during dressing removal ($p = 0.02$), they did not find one with dressing application, or with patient self-reported pain scores. Hoffman et al. found more positive results in their 2008 RCT study of 11 adult burns patients.⁶⁰ Patients reported significantly less pain when distracted with VR ($p = 0.017$ and 0.015 respectively for differences with measures of affective and sensory elements of pain). The six patients in this study who reported the strongest illusion of “going inside” the virtual world also reported the greatest effects of IVR on their sensory pain ratings, with self-reported pain scores dropping from a mean of 7.2 in the no-IVR condition to 3.7 during IVR. An RCT exploring the use of IVR in reducing pain during IV cannula placement in children in 2006⁴⁴ also reported an increase in pain in the control condition vs. the IVR condition ($p = 0.05$).

Gold et al. undertook an RCT to investigate the effects of IVR for pain distraction during IV placement in children ($N=20$).⁴⁴ Using the FACES pain scale they reported a fourfold increase in affective pain in the control condition ($p<0.005$) and no significant difference within the IVR condition. Significant association between multiple measures of anticipatory anxiety ($p<0.01$), affective pain ($p<0.05$), IV pain intensity ($p<0.05$) and measures of past procedural pain provided support for the complex interplay of a multimodal assessment of pain perception.

Wolitsky et al. undertook an RCT study investigating the use of IVR for children undergoing implanted IV port access procedures.⁶⁶ This study is of particular interest as the authors also collected quantitative as well as qualitative data. They reported an effective

reduction in pain for children using the IVR compared with children not using the IVR. The qualitative data demonstrated that those who used the IVR were able to recall more details about the clinic visit. The authors conjectured that the children who were less distressed because of the IVR therapy were better able to cognitively and emotionally process what was happening to them.

Gershon et al. in another RCT, randomly assigned children (N=58) to three treatment groups: IVR distraction, PC screen-based distraction and no distraction.⁴¹ The children were undergoing needling to access a subcutaneous implanted IV port (with a local anaesthetic cream). The researchers collected pulse rate before and after the procedure, and pain and anxiety ratings during the procedure using ratings from the child, nurse and parents and means calculated. The authors reported that while the procedure was not considered overly distressing, subjects in the no-distraction group exhibited greater distress compared with the IVR and non-VR distraction groups according to the CHEOPS score ($p<0.05$). However there was no significant difference between groups overall according to VAS scores, possibly because the procedure itself was considered distressing rather than painful. Also the study used nurse/parent reported pain scores, thereby introducing another variable into the assessment of the subject's pain.

In a recent crossover study undertaken by Schmitt et al. where the procedure could be considered both painful and distressing, children with burns injuries undertaking physiotherapy (N=54) were exposed to IVR and no-VR equally during each session.⁸ The intervention/control was randomized and counterbalanced. Subjects reported significant decrease (27%-44%) in pain ratings during the IVR session ($p<0.05$ for each paired comparison), and an increase in reported subjective enjoyment ("fun") during the IVR therapy ($p<0.01$). Worthy of note is that this study reported IVR use over multiple sessions. The magnitude of the analgesic affect was clinically meaningful and was maintained with repeated use. In a crossover study investigating the use of IVR for periodontal scaling and root planning procedures on 38 adult patients, Furman et al.⁴⁶ reported significantly lower VAS scores ($p<0.01$), during IVR compared with movie distraction and no distraction. They also collected data on BP and pulse rates and demonstrated that these were lowest when individuals were exposed to IVR.

Manni et al.¹² and Carrougher et al.¹¹ also used crossover methods to investigate the use of an IVR environment (*Snow World*) for adult burns patients. Both reported favorable findings when using IVR for burns injury related pain. Manni et al. investigated combat-related burns injury in 12 US soldiers undergoing wound debridement and Carrougher et al. investigated IVR use in adults undergoing physiotherapy for burns injury. The Manni study reported significantly reduced pain intensity for patients using the VR; the worst pain dropped significantly from 6.25/10 to 4-5/10 ($p < 0.05$). Pain unpleasantness dropped from a moderate 6.25/10 to a mild 2.83/10 ($p < 0.01$). The patients' subjective perception of *fun* was also assessed with patients (unsurprisingly) rating no-VR as "no fun at all" ($< 1/10$) whilst rating IVR as "pretty fun" (7.5/10). Carrougher et al. (N=39) reported a significant difference between groups. While using VR patients reported less instances of worst pain ($p = 0.004$), less time thinking about pain ($p = 0.008$) and less pain unpleasantness ($p = 0.031$). Improvement in range of motion (ROM) was not statistically significant between treatments ($p = 0.243$). Van Twillert et al.¹³ also undertook a crossover design study with burns patients using the *Snow World* IVR compared to television/conversational distraction, and pharmacological analgesia during burns dressing changes. However, they found no significant pain reductions between TV and IVR, although they did report that the effects of IVR were superior and that 12/19 patients reported clinically meaningful (33% of greater) reductions in pain during IVR distraction ($p < .05$).

Teeley et al.⁶¹, Manni et al.⁷, Patterson et al.⁶³, Morris et al.⁶² and Chan¹⁴ reported case series studies. In their case series Teeley et al. investigated use of IVR in adults receiving treatment for multiple fractures (N=3) and reported a pain reduction from a baseline to day three of 70% to 30% with opioid analgesic use remaining stable. Manni et al. investigated ketamine and no IVR vs. ketamine and IVR in 2 patients undergoing burns treatments. Both patients reported less pain during the ketamine and IVR exposure. In their case series investigating the use of IVR with hypnosis for burn pain in 13 patients, Patterson et al. also reported favorable findings. Descriptive statistics were reported with an overall drop of 11% in pain unpleasantness, a 20% drop in episodes of worst wound care pain, a 29% drop in time patients spent thinking about pain, a 26% drop in anxiety scores and most significantly, a 50% drop in the amounts of

opiates given. Conversely, Morris et al. reported no significant findings when they investigated the use of VR for burns injured patients (N=11) undergoing physiotherapy sessions. They only reported a marginal difference between the two sessions; one used IVR and the other no-VR ($p=0.13$) and no significant difference was found regarding anxiety ($p=0.58$). The differences in these findings could possibly result from different implementations of IVR and socio-cultural aspects of pain. Teeley et al., Manni et al. and Patterson et al. used the *Snow World* IVR with wide FOV HMDs whereas Morris et al. used a low FOV HMD. They also represented very different study populations. Teeley et al., Manni et al. and Patterson et al. studied VR use in USA populations whereas Morris et al. studied VR use in a population in South Africa.

Chan et al.¹⁴ was the only case series included that undertook a study in children (N=8). They investigated the use of IVR for pain relief of burns injury during dressing change using a custom-designed ice-cream factory virtual environment and an HMD. They reported no statistical difference between the groups that were observed for pain before ($p>.05$), during ($p>.05$) and after ($p>.05$) dressing changes. They also included a qualitative *presence* interview to assess immersion, and reported varying levels of immersion (presence categorized as total, partial and simple distraction) among their subjects. They identified no significant correlation between the reported level of immersion and the reported pain intensity.

A number of individual case study reports were also included in the REA, all of them reporting favorable findings: Gershon et al.,⁴¹ Steele et al.,⁶⁵ Hoffman et al.,⁶⁷ Wright et al.⁶⁴ and Oneal et al.¹⁷ Geshon reported on a case study involving an 8-year-old child with acute lymphocytic lymphoma undergoing IV port access procedures in an outpatient clinic. The patient experienced IVR distraction, non-VR distraction, and no-distraction during the needling procedures. Assessment using the CHEOPS scale demonstrated the patient's lowest pain ratings during the IVR condition, and nurses reported the lowest VAS pain and anxiety ratings during the VR condition. Although the authors reported that the pain and anxiety ratings decreased during the IVR condition this needs to be taken with caution as nurse reported pain is not considered accurate; patient self-reporting remains the gold standard for accuracy.^{68,69} (IASP 1995; IASP 2005).

Steele tested the use of IVR on a 16-year-old patient with cerebral palsy undergoing twice daily physiotherapy. While the patient was using IVR therapy the researchers reported pain ratings that were 41.2% less than the pain ratings reported when the patient was not using VR. In a case study undertaken by Hoffman et al. in 2004 a 40-year-old male with 19% total body surface area burns injury used IVR therapy during wound care procedures in a hydrotherapy tank. The authors reported that the patient experienced a decrease in sensory and affective pain ratings and a decreased amount of time thinking about his pain during the procedures. Wright et al. tested the use of IVR therapy on a 67-year-old male with benign prostatic hypertrophy undergoing transurethral microwave thermotherapy. The IVR sessions were reported to have reduced all pain and anxiety measures; the worst pain experienced decreased from severe to mild pain and anxiety ratings went from mild to no anxiety at all. Furthermore the patient reported thinking about pain 50% less with the IVR therapy than without it.

The only study that investigated the use of IVR for a patient with chronic pain was that undertaken by Oneal et al. where a 36 year old female with a five-year history of C4 tetraplegia and upper extremity neuropathic pain was exposed to standard hypnosis sessions and 40-minute IVR augmented hypnosis sessions. During a 6-month trial, the patient's pain intensity ratings and unpleasantness dropped on average 36% and 33% respectively during the IVR augmented sessions. The mean pain intensity ratings went from a baseline of 7.67 to 7.0 post-treatment to 7.5 after one month. Further, the patient reported both no pain and a reduction in pain for 3.86 and 12.12 hours respectively following the treatment sessions. The reductions and duration of treatment effects following IVR augmented hypnotherapy treatments were superior to those following a trial of standard hypnosis.

IVR vs Alternative Therapies

Kipping et al. compared the use of a low FOV IVR setup using commercial games to TV distraction.⁴⁵ Although they found no significant difference in self-reported and nurse reported pain, they did find significantly less rescue doses of Entonox were given to those receiving IVR therapy compared to those receiving standard TV distraction.

Gershon et al.⁴¹ reported a difference between IVR and non-VR distraction based on assessment of pulse data in the children in their RCT study. However, no significant differences were reported between the screen-based intervention and the IVR experience. Children were randomly assigned to the virtual gorilla enclosure IVR (n=22), non-VR distraction (a computer game version; n=15) or treatment as usual with no distraction (n=15). Measures included VAS and CHEOPS, and several different nurses undertook VAS assessment. They acknowledged that this was a study limitation as nurse assessment is not considered as accurate as patient self-reporting.

In the Van Twillert et al. within-subject design study⁷⁰ (N=19) the research team compared standard care (no distraction), VR or a self-chosen distraction method (TV or a non-medical conversation with a nurse) during wound care for burns. Pain was measured using a visual analogue thermometer as well as anxiety using the Spielberger State Trait anxiety inventory. Both VR and TV distraction showed significant pain reductions during the wound care procedure compared to the standard treatment. However, differences between IVR compared to TV distraction were not statistically significant. Limitations to this study include small numbers, the use of several different distractions as well as the difference in age ranges.

Furman et al. compared the use of VR, watching a movie and no distraction (N=38) in adults during periodontal scaling and root planning procedures. A within subject/split method design was undertaken to minimize the effects of confounding factors. Both the VR and movie condition resulted in statistically significant lower reported pain levels compared with the control ($p < 0.001$). As well VR was reported as being statistically significant in reducing pain VAS scores compared with the movie ($p < 0.001$). In this study all participants were adults and were exposed to the same alternative distraction technique, so the comparison of interventions may be more indicative.

The studies had differing results and it is therefore difficult to draw any firm conclusions, this is likely due to different methods, different populations and small numbers. There may be a difference and a more favorable response to VR compared with

other distraction methods, but further comparative studies using larger numbers of participants and more robust methods are required to establish this.

Adverse Effects and Outcomes

It appears from the evidence that IVR is safe and has limited risk with regard to side effects. The only side effect reported in few of the studies was motion sickness.^{8,46,60} In literature discussing effects to simulators and virtual environments, motion sickness is reported as the most common adverse effect,⁷¹⁻⁷³ but This phenomenon has been termed 'cyber sickness.'⁷³

Schmitt et al. in their 2011 study reported that although participants were screened for susceptibility to motion sickness, 16% reported mild nausea. Hoffman et al. also collected data regarding motion sickness during IVR use; the mean nausea ratings were negligible (<1 on a 0-10 scale).⁶⁰ Furman reported that five (13%) of participants experienced mild nausea during IVR exposure.⁴⁶ Gold reported that none of the children reported simulator sickness during or after VR exposure.⁴⁴ The majority of the studies did not screen patients for susceptibility to motion sickness^{14,15,17,41,45,61,64,65,67,70} or collect data or report on motion sickness. Therefore, it is not possible to determine if this was a consistent side effect experienced by participants in the studies reported in this REA.

Hoffman et al. also screened and excluded participants if they had claustrophobia. There is limited discussion with regard to claustrophobia as an adverse effect associated with IVR, although there is evidence of the use of IVR to treat claustrophobia (and other phobias); the discussion of this is beyond the scope of this REA.⁷⁴⁻⁷⁶ Some researchers have also noted that the equipment and HMDs are heavy and uncomfortable for patients to wear for any length of time.⁷⁷

Summary of Main Findings

Evidence of the value of IVR as an adjunct intervention in the management of pain appears to be growing for acute pain, and particularly with burns injuries. There is some evidence of positive results with both adults and children in acute pain conditions, and that this may be more powerful than simple distraction. The wide FOV stereoptic HMDs seem to provide greatest efficacy in promoting immersion. Unfortunately, these are the most expensive implementations of IVR with HMDs costing over \$25,000 each. Likewise, the majority of the larger studies with positive finding used custom designed IVR environments (mainly *Snow World*), and at this stage of development there is not a great range of comparative work with other technological implementations of IVR. For example, it is unknown whether therapeutic immersive results can be achieved with less sophisticated 2D rendered commercial environments in an HMD, using a wider range of interactivity and more opportunity for the user to explore the environment. There is also currently very little evidence of the value of IVR in the treatment of chronic pain. These results support the findings of an earlier review of VR therapies for pain by Maher et al in 2009.⁷⁸

Applicability of Evidence

Currently the majority of studies have been undertaken with highly specialized custom-designed equipment, and a wide variety of technical IVR implementations used. This specialist equipment is expensive, difficult to set-up, hard to keep clean and sometimes unreliable. The subjects included in studies in this review were from a range of acute pain conditions (and one chronic pain condition) although the majority of this work remains in the field of burns injuries pain. These factors make support for the transferability of these findings to more widespread clinical practice difficult to justify at this time; particularly due to the lack of practically usable technical solutions and costs of custom-designed IVR rigs. There is also a lack of substantive work in this area with chronic pain. However, this is a rapidly changing technological field, and lower-cost IVR

implementations that could be used in everyday clinical practice, or patients own homes may become available in the near future.

Limitations of the Review

In all of these studies a wide variety of IVR implementations were involved, and several studies that claimed to be using VR were excluded as the technologies used were not directly comparable and offered experiences where the immersion of the experience was questionable. Different IVR implementations and patient groups also make meaningful comparisons between studies difficult. The exclusion of lab-based studies (such as Hoffman et al.'s 2006 study with 77 patients)²⁰ is also a limitation of this REA, as studies using healthy subjects with induced pain were excluded here. The REA methodology itself is also limited. For example it does not include foreign language studies.

CONCLUSION

The evidence for the use of IVR use for pain control remains fairly immature. A number of high-quality investigations have demonstrated significant potential within specific patient populations and acute pain associated with medical procedures (particularly with burns injuries). There is some good evidence that IVR can work as a useful adjunct intervention in the management of acute pain, but also some conflicting findings, limited evidence of benefits in comparison to other distraction therapies, and very little work substantiating their use in the field of chronic pain. More immersive technical implementations with wide FOV visual displays currently seem to offer the best immersive experience and therapeutic effects. However, there is little clinical evidence to indicate if 2D applications can be utilized to offer significant immersive therapeutic effects, or if commercially available environments (such as immersive computer games) can offer better results than custom-designed environments. There were no significant adverse or side effects, and no safety issues reported in any of the clinical studies explored.

Implications for Practice and Research

New IVR technologies are rapidly decreasing in cost and becoming more broadly availability, moving out of the laboratory setting into more widespread public use. This should support clinicians and researchers to further investigate the usability of IVR in the management of pain. Future studies in IVR would benefit from greater scientific rigor. This should include a clear identification of the type of immersive experience implemented (rather than simply reporting technical equipment specifications), increased sample sizes, and rigorous attention to risk of bias. Clear delineation the population under study (including age, gender, and clinical conditions of treatment) is also important for meaningful comparisons. Larger samples may be difficult to achieve due to the current costs of equipment and with smaller numbers of patients with conditions in specialist areas. Nevertheless, repeat studies, and well-designed crossover studies may help establish a better evidence base for the efficacy of IVR.

Attention to qualitative aspects of the IVR experience would also seem important in research here. Exploring patient's perceptions of the practical value of IVR and their experiences in terms of comfort, usability and any adverse effects is important. Screening for the occurrence of "cyber sickness" should also form a part of future research investigating the use of IVR, to allow for greater understanding of this potential side effect.

The potential for these technologies in the management of chronic pain has yet to be realized, and this is an area that should also be targeted for future work. This may also help contribute to an improved understanding of the nature of acute and chronic pain and its management. In all, IVR is emerging as a potentially significant practical intervention as an adjunctive therapy to pharmacological agents in the control of pain, but there is much work needed to substantiate its value.

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Figures and Tables

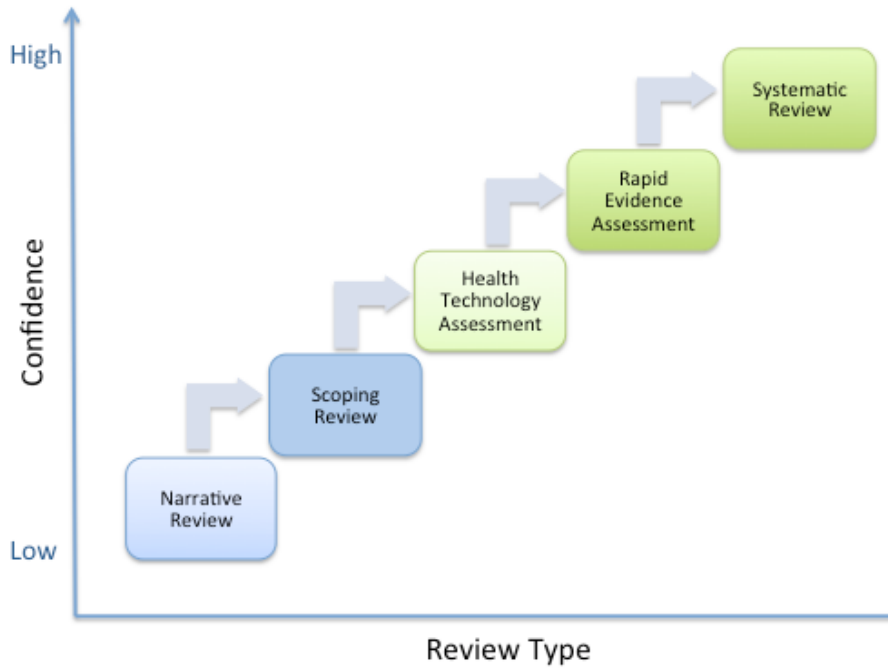


Figure 1: Hierarchy of Evidence

A Rapid Evidence Assessment of Immersive Virtual Reality as an Adjunct Therapy in Pain Management

A: Taking account of all quality assessment issues, can the study findings be trusted in answering the study question(s)?	High trustworthiness = 3 Medium trustworthiness =2 Low trustworthiness =1
B: Appropriateness of research design and analysis for addressing the question, or sub-questions, of this specific systematic review.	High = 3 Medium =2 Low = 1
C: Relevance of particular focus of the study (including conceptual focus, context, sample and measures) for addressing the question, or sub-questions, of this specific systematic review	High =3 Medium =2 Low =1
D: Combined overall weight of evidence (based on A-C)	High =7-9 Medium =4-6 Low =3

Table 1: GSRS Weight of evidence Criteria

Level 1	Observed correlation between an intervention and outcomes at a single point in time. A study that only measured the impact of the service using a questionnaire at the end of the intervention would fall into this level.
Level 2	Temporal sequence between the intervention and the outcome clearly observed; or the presence of a comparison group that cannot be demonstrated to be comparable. A study that measured the outcomes of people who used a service before it was set up and after it finished would fit into this level.
Level 3	A comparison between two or more comparable units of analysis, one with and one without the intervention. A matched-area design using two locations would fit into this category if the individuals in the research and the areas themselves were comparable.
Level 4	Comparison between multiple units with and without the intervention, controlling for other factors or using comparison units that evidence only minor differences. A method such as propensity score matching, that used statistical techniques to ensure that the program and comparison groups were similar would fall into this category.
Level 5	Random assignment and analysis of comparable units to intervention and control groups. A well-conducted Randomized Controlled Trial fits into this category.

Table 2: Maryland Scale of Increasing Methodological Quality

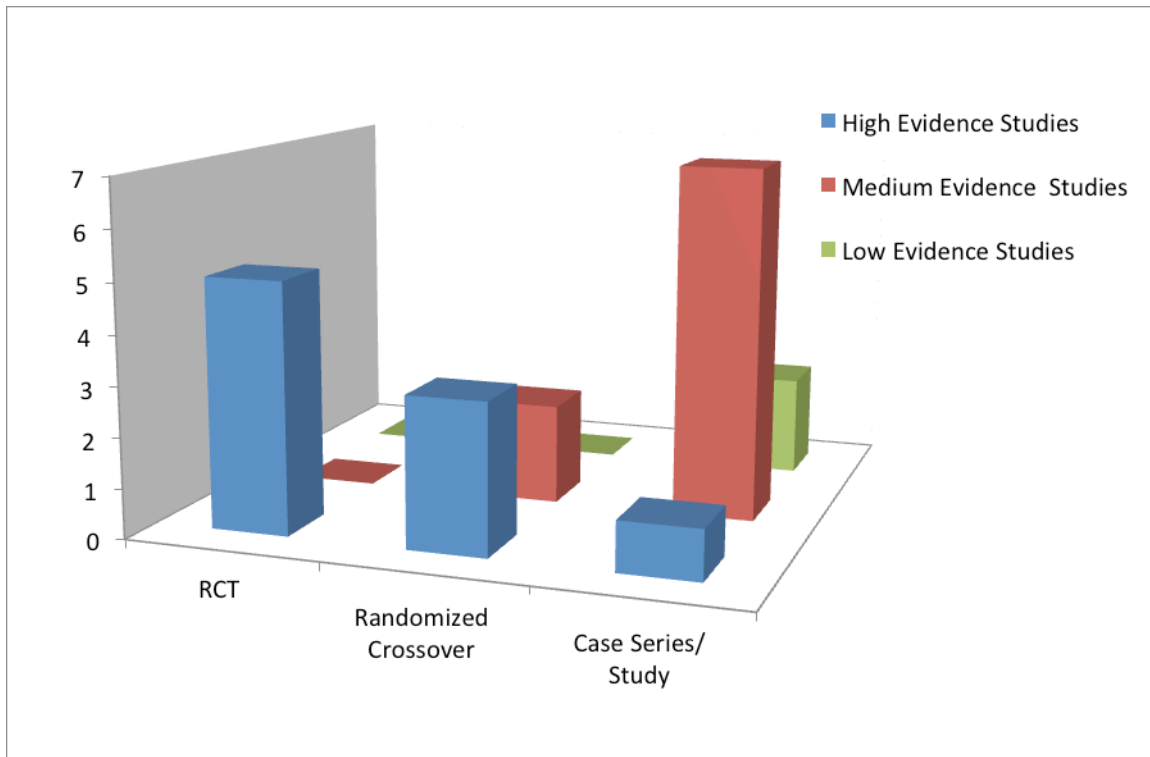


Figure 2: Quality of Evidence