



Virtual Reality as a Clinical Tool for Pain Management

Ali Pourmand¹ · Steven Davis¹ · Alex Marchak¹ · Tess Whiteside¹ · Neal Sikka¹

© Springer Science+Business Media, LLC, part of Springer Nature 2018

Abstract

Purpose of Review To evaluate the use of virtual reality (VR) therapies as a clinical tool for the management of acute and chronic pain.

Recent Findings Recent articles support the hypothesis that VR therapies can effectively distract patients who suffer from chronic pain and from acute pain stimulated in trials. Clinical studies yield promising results in the application of VR therapies to a variety of acute and chronic pain conditions, including fibromyalgia, phantom limb pain, and regional specific pain from past injuries and illnesses.

Summary Current management techniques for acute and chronic pain, such as opioids and physical therapy, are often incomplete or ineffective. VR trials demonstrate a potential to redefine the approach to treating acute and chronic pain in the clinical setting. Patient immersion in interactive virtual reality provides distraction from painful stimuli and can decrease an individual's perception of the pain. In this review, we discuss the use of VR to provide patient distraction from acute pain induced from electrical, thermal, and pressure conditions. We also discuss the application of VR technologies to treat various chronic pain conditions in both outpatient and inpatient settings.

Keywords Virtual reality · Acute pain · Chronic pain

Introduction

Virtual reality (VR) is the artificial construction of a 3D environment via computer technology [1]. Traditional VR systems include a head-mounted device (HMD) with 3D-enabled goggles, sensory input devices, headphones, and/or body tracking sensors which, together, allow for a multisensory experience [2•, 3]. HMD tracks an individual's head movements to create an experience of movement through the simulated environment [1, 4]. VR therapies have become increasingly important as a multidisciplinary tool in the field of pain management [1, 2•, 5]. VR therapy provides a sense of presence, allowing individuals to feel that they are a part of the virtual

environment, and incorporates interactive scenarios to engage the subject in the environment [6••]. VR software provides settings (e.g., peaceful scenes or gaming scenarios) where the patient can assume an interactive avatar to experience presence in the environment [6••]. These interactive and immersive VR techniques are more effective in reducing pain than non-immersive techniques, such as traditional screen viewing or gaming with a 2D screen [5].

Pain is a reaction to noxious stimuli and, according to gate control theory, is regulated by non-nociceptive-gated mechanisms within the spinal cord that work to augment or attenuate perceived pain [7]. Distracting stimuli can attenuate a perceived pain through downregulating nociceptive neural signaling [8]. Unlike many analgesics, which disrupt the C-fiber pathway that relays nociceptive signals to the central nervous system, VR affects pain perception via attention, concentration, and emotional alteration [1]. The immersive environments created by VR diminish the pain experience by up-regulating non-painful neural signaling [2••].

The Centers for Disease Control (CDC) reports half of opioid overdose result from prescription narcotics, and opioids have now surpassed traffic-related injuries as a cause of

This article is part of the Topical Collection on *Psychological and Behavioral Aspects of Headache and Pain*

✉ Ali Pourmand
pourmand@gwu.edu

¹ Department of Emergency Medicine, George Washington University School of Medicine and Health Sciences, 2120 L St., Washington, DC 20037, USA

death in the USA [9]. VR distraction therapy may provide an alternative or adjunct to current pain therapies, offering a new strategy in the effort to curb a national opioid epidemic.

Materials and Methods

PubMed was searched with keywords “virtual reality pain”, yielding 347 articles, of which 187 were published in English and within the last 5 years. Ninety-four remained after screening for articles describing virtual reality use in chronic and acute pain, of which 28 described VR immersion therapy included in this review. Duplicate studies and studies unable to be accessed were not included.

Acute Pain

Recent studies have tested the effectiveness of VR immersion as a mechanism to distract subjects from acute pain induced via electrical, thermal, and pressure stimuli. These studies suggest that distraction provided by VR may be effective in diminishing perception of procedural pain and acute pain episodes (Table 1) in response to some noxious stimuli.

Pressure Pain

In a randomized, double-blinded study, Smith et al. determined that using VR to alter social and emotional context had no effect on pain sensitivity ($p = 0.48$). They concluded

Table 1 Use of immersive virtual reality in the treatment of acute pain

Study	Design	<i>n</i>	Findings	VR study description
Smith et al. [10]	Randomized, double-blind	25	The tolerance of pressure pain was not impacted by the emotional or social context of VR ($p = 0.48$).	Using a HMD and headphones, subjects were immersed in five environments plus control: social positive, social neutral, social negative, pleasant, and threatening (using Oculus Rift Dk2). Pressure pain thresholds were determined at baseline, in each of the five environments, and after the procedure.
Weeth et al. [11]	Crossover	32	Subjects with virtual arm protection had decreased perception of electrical stimuli vs. virtual-uncovered and neutral arm states ($p < 0.001$).	Using a HMD, subjects saw a virtual arm in three different states: uncovered, neutral with sleeve, and armored. Subjects were given increasing electrical stimuli in each condition.
Demeter et al. [12]	Crossover	62	Patients in VR condition showed significantly greater pain tolerance vs. control condition ($p < 0.001$).	Subjects underwent two trials in random order during which thermal pain was delivered. One trial was done with the subject wearing VR “EyeToy” immersive reality goggles, and the control trial was done without VR.
Gutierrez-Maldonado J et al. [13]	Crossover	45	Subjects in a VR condition had significantly higher pain thresholds ($p < 0.05$) and pain tolerance ($p < 0.01$).	Participants submerged their non-dominant hand in cold water under VR and non-VR conditions. The VR intervention included 3D glasses displaying a stereoscopic figure that could be manipulated by the subject to create a pleasant environment.
Johnson et al. [14]	Crossover	32	Among subjects in a VR simulation, pain tolerance scores were lowest in the baseline condition (no VR), then higher with sound only, still higher with HMD only, and highest in with sound plus HMD ($p < 0.05$).	Participants completed four cold-presser trials under different conditions: no HMD and no sound (baseline), sound only, HMD only, and HMD plus sound. The HMD displayed <i>Radial-G</i> , an interactive racing game with first-person perspective. The player is seated in a virtual spaceship and races around a track alone, with the speed and direction of the virtual vehicle controlled via a patient-driven input device (e.g., the arrow buttons on a keyboard).
Sharar et al. [15]	Crossover	74	Subjects in immersive VR condition reported significantly decreased pain intensity ($p < 0.001$).	Subjects were given an 18-min sequence of electrically and thermally induced pain on distal extremities while wearing a HMD immersing them in a “Snow World.” Subjects followed a path through a canyon and threw snowballs using a patient-driven input device (e.g., handheld mouse).

that further research should be done on manipulating the source and meaning of the pain stimulus, instead of the emotional state of an individual [10].

Electrical Pain

In a crossover study examining the effect of virtual projections of limbs on the perception of pain, Weeth et al. reported a decrease in pain experienced on a virtual-protected (armored) arm when compared to the virtual-uncovered (bare skin) and neutral (with a shirt) arms ($p < 0.001$) [11].

Thermal Pain

In a study enrolling 62 subjects conducted by Demeter et al., the authors showed pain tolerance to be significantly higher when subjects wore VR-immersive goggles ($p < 0.001$) [12]. Gutierrez-Maldonado et al. conducted a trial under similar conditions in which subjects reported significantly higher pain thresholds ($p < 0.05$) and pain tolerance ($p < 0.01$) with VR immersion therapy in which subjects interacted with and manipulated a stereoscopic figure [13]. In a trial involving 32 participants, Johnson et al. studied thermal pain threshold during a cold pressor test under four VR conditions: baseline (no HMD and no sound), sound only, HMD only, and HMD plus sound. Pain tolerance was measured by the total number of seconds the participant kept their non-dominant hand submerged in ice water during each VR condition. Pain tolerance scores were lowest in the baseline condition followed by the sound-only condition and then the HMD-only condition. The highest pain tolerance was in the sound plus HMD VR condition ($p < 0.05$), suggesting that the use of sound in VR is an important component of the immersive experience [14].

Multiple Pain Stimuli (Thermal and Electrical)

Sharar et al. examined how immersing subjects in an interactive VR gaming world would provide a distraction to acute electrical and thermal pain stimuli. Subjects reported significantly decreased pain intensity ($p < 0.001$) associated with less anxiety, a more enjoyable experience, and a greater feeling of presence during VR immersion [15].

Chronic Pain

Chronic pain is defined clinically as pain lasting more than 3 months and/or beyond the time of expected healing [16]. It is a prevalent and often-disabling condition, yet pharmacological treatments can be ineffective or insufficient to successfully manage symptoms [17]. Recent studies have investigated the use of VR in reducing pain in patients suffering from varied chronic conditions (Table 2).

SIAS Syndrome

Pekyavas et al. compared the use of VR to a home exercise program in patients with subacromial impingement syndrome (SIAS). Patients in both groups reported a decrease in pain intensity ($p < 0.05$) after 6 weeks, with the VR group showing greater improvement in SAIS symptoms and shoulder movement [18].

Fibromyalgia

Botella et al. studied six women with fibromyalgia, who reported improved functional status following VR treatment. Importantly, participants continued to improve in the 6-month follow-up period, suggesting the long-term benefits of VR for significantly reducing pain in patients with fibromyalgia [19].

Chronic Migraine

de Tommaso examined the effect on pain perception of virtual environmental settings in patients who suffer from chronic migraines when stimulated with laser-evoked potentials. Results showed a reduction in VAS values for both control and migraine patients when immersed in a sea-view waiting room compared to a regular waiting room, though only the chronic migraine group results showed statistical significance ($p < 0.039$) [20]. Shiri et al. studied VR and biofeedback treatment in pediatric patients with chronic headaches. Patient pain ratings, daily functioning, and quality of life significantly improved as measured at 1- and 3-month post-treatment ($p < 0.05$) [21].

Phantom Limb Pain

In a clinical trial assessing the use of VR in alleviating phantom limb pain (PLP), Ortiz-Catalan et al. reported significant improvements in all metrics of PLP (intensity, frequency, duration, and intrusion) after 12 VR sessions. The authors reported a 47% decrease in weighted pain distribution, 32% decrease on the numeric rating scale, and 51% decrease for pain rating index. Improvements in perceived pain were seen at the 1-, 3-, and 6-month post-treatment follow-ups, suggesting the potential for motor execution with VR as a non-invasive treatment option for PLP [22].

Miscellaneous

In a study of 30 patients with chronic pain syndromes, Jones et al. reported a 60% decrease in subjective pain rating during a 5-min VR session, and a 33% decrease in pain rating remained after the VR session was completed ($p < 0.001$) [23••]. Two studies by Wiederhold et al.

Table 2 Use of immersive virtual reality in the treatment chronic pain

Study	Design	n	Findings	VR study description
Pekyavas et al. [18]		30	Patients reported a decrease pain intensity in both groups ($p < 0.05$), with the Wii group reporting significantly better results for Neer test, SRT, and SAT ($p < 0.05$).	Subjects with SIAS were randomized into home exercise program or VR exercise gaming with Nintendo Wii (a 3D program that creates VR movements). VR boxing, bowling, and tennis were used for bilateral shoulder elevation and movement, rated by scapular retraction test (SRT), scapular assistance test (SAT), and Neer Test. Pain intensity was rated using visual analogue scale (VAS).
Botella et al. [19]	Randomized, controlled clinical study	6	Average FIQ ratings decreased slightly from pre-test (58.05) to post-test (53.01), with greater improvement at the 6-month follow-up (46.90).	Female subjects with fibromyalgia (FM) were immersed in 10.2-h VR sessions with relaxing natural environments (e.g., beaches, meadows). The scenes were projected onto a large screen with speaker systems. A patient-driven input device (e.g., handheld mouse) was provided for navigation. Pain intensity was evaluated via FM Impact Questionnaire (FIQ).
de Tommaso et al. [20]		32	VAS values increased in the RH group and increased in the IH group, for both the control and chronic migraine subjects. However, only the chronic migraine group reached statistical significance ($p < 0.039$) as compared to RH group.	Using a HMD, subjects with and without a history of chronic migraines experienced laser-evoked potentials (LEPs) during immersive VR simulation. One group was immersed in a regular hospital (RH) waiting room setting while the other was in an ideal hospital (IH) waiting room, with a window overlooking the sea, comfortable furniture, and natural light.
Shiri et al. [21]	Prospective single-arm open-label pilot study	10	Pain, daily functioning, and quality of life significantly improved at 1- and 3-month post-treatment ($p < 0.05$).	Pediatric subjects participated in 10 sessions where they watched a screen displaying a virtual representation of themselves and a representation of their pain as a colored area on their forehead. As they stared at the screen and were instructed to relax, they watched as the size and color of the area faded.
Ortiz-Catalan et al. [22]	Single group, clinical trial	14	Patients reported a 47% decrease in weighted pain distribution, 32% decrease on the numeric rating scale, and 51% decrease for pain rating index ($p = 0.0001$). Improvements partially maintained at 1-, 3- and 6-month follow-ups. Two of the four patients on pain medication reported a lower intake.	Electrodes were attached to monitor GSR (galvanic skin response). Pain was measured using VAS and quality of life via PedsQL. Subjects with upper limb amputation and phantom limb pain (PLP) were immersed in 12 VR sessions, during which electrodes were attached to their affected limbs to predict movement via myoelectric pattern recognition. This allowed for voluntary control of a virtual limb. A VR racing game was viewed on a large computer screen, and a car was driven by phantom movements. Pain was assessed via the McGill Pain Questionnaire and the present pain intensity scale.
Jones et al. [23••]		30	Pain ratings were reduced from baseline by 60% during the VR session and by 33% after the VR session ($p < 0.001$).	Using a HMD (Oculus Rift DK2) and headphones, subjects were immersed in 5-min VR sessions via the application Cool! and interacted with various landscapes orbs and fish at otters, who would then burst into flames, make sounds, and change colors. Pain was assessed via VAS.
Wiederhold et al. [24]		6 34	Patients reported a 75.8% drop in pain intensity during the VR session ($p < 0.05$). Patients reported decreased pain during VR session. ($p < 0.05$ to $p < 0.001$). Pulse rates were significantly reduced with VR ($p < 0.05$).	Using a HMD and physiological sensors, participants experienced a 15-min VR session simulating pleasant and calming environments (e.g., forest, beach, mountain). Soothing music and natural sound effects, such as wind and swaying branches, were added. Pain ratings were obtained using self-report questionnaires.
Jim et al. [25]	Crossover	20	Cryoslides significantly reduced perceived pain in VR group versus control group.	Using a HMD (Oculus Rift DK2) and headphones, subjects played the VR game Cryoslides, with 4 min of sliding in an ice cave followed by 6 min of sliding in an ice world. The player could hit creatures with snowballs using a patient-driven input device (e.g., handheld mouse). Pain intensity was rated using VAS.
Garett et al. [26]	Case Study	8	Five patients reported reduced pain during the VR experience, but no difference in post-exposure pain scores was observed. One patient reported short-term mobility improvement.	Subjects with chronic pain were immersed in a virtual environment (e.g., solar system, under-water landscape) via HMD.

demonstrated the effectiveness of 15-min VR sessions in patients who reported average daily pain ≥ 4 on numerical rating scale (NRS) for 3+ months. In the pilot study, six patients reported a 75.8% decrease in pain intensity ($p < 0.05$) with VR. An additional 34 subjects reported a decrease in pain with VR in a follow-up study ($p < 0.05$ to $p < 0.001$). The authors reported an associated decrease in heart rate during the VR session ($p < 0.05$), further suggesting improved patient comfort with VR [24]. Jin et al. described an analgesic effect using the VR game “Cryoslides” on 20 patients with chronic pain. Cryoslides significantly reduced perceived pain compared to the self-directed control group utilizing traditional pain-distraction techniques (e.g., yoga, meditation) [25]. Their findings suggested that Cryoslides can be used effectively as an analgesic intervention for chronic pain management to lessen pain intensity during acute pain exacerbations. In a case study with chronic pain subjects in immersive virtual environments, Garrett et al. report that five of eight subjects experienced reduced pain during VR, though no sustained difference post-exposure was observed. This evidence is suggestive of the short-term efficacy of VR in chronic pain but provided no evidence for longer term benefits [26].

Combination of Acute and Chronic Pain in Currently Hospitalized Patients

Two recent studies examined the use of VR in undifferentiated hospitalized patients reporting pain of varying chronicity and intensity. Tashjian et al. conducted a 6-month non-randomized, comparative cohort study of the analgesic effect of 2D distraction therapy versus 3D VR distraction therapy in 100 medical inpatients who reported a pain score of $\geq 3/10$. The control cohort viewed a 2D nature video on a high-definition bedside TV screen, while the intervention cohort received a 3D VR immersion experience (Pain RelieVR) designed to reduce pain using the Samsung Gear Oculus VR headset. Pain RelieVR is an immersive, 360° game wherein users attempt to shoot moving targets within a fantasy environment. The mean pain reduction in the VR cohort was greater than in controls ($p = 0.008$). A total of 35 (65%) patients in the VR cohort achieved a pain response versus 20 patients in the control group (40%, $p = 0.01$) [27]. A second study conducted by Mosadeghi et al. examined the analgesic effects of VR distraction therapy in 30 hospitalized patients. Study participants selected from the VR environments using Samsung Gear VR goggles, with options for ocean exploration, Cirque du Soleil, or a tour of Iceland. A majority of users described the experience as pleasant and capable of reducing pain and anxiety [28].

Qualities of Effective Virtual Reality in Pain Management

Won et al. described five characteristics of virtual reality interventions necessary for effective distraction therapy and pain reduction. First, among these characteristics is presence, the sense of immersion in the environment that allows for a realistic experience and directs a subject’s attention from adverse stimuli. Increased presence in a given scenario is associated with a more effective VR experience and reduction in pain [6••]. As a side note, children have a higher sense of presence due to their inability to more effectively separate fantasy and reality. Thus, adults and children may require different types of VR to induce high levels of presence and allow for the most successful VR experience [6••]. Second, interactivity describes the degree of engagement a participant has in a virtual scenario and is determined by the sensory input and user interface with the software. Interactivity encourages physical involvement, and pain tolerance. Third, social interaction in the VR environment can augment distraction from pain. Fourth, customization offers participants autonomy to choose a scenario most suited to their needs and preferences. Finally, embodiment of the virtual avatar describes the degree to which physical movements translate to the virtual movement of the avatar and allows participants to feel immersed in the virtual world [6••].

Limitations

This review is limited by the relatively small number of studies, in particular the small number of large, randomized, and blinded studies. We included the use of non-immersive VR systems in clinical applications only where immersive trials did not exist. The authors believe that immersive VR gaming techniques provide a greater reduction in pain than do non-immersive techniques. Finally, few studies have investigated VR distraction therapy in the long-term management of chronic pain. This represents a need for further clinical research in this area.

Conclusion

Non-pharmacological adjuncts like VR have become an increasingly important option for effective pain management. The current epidemic of opioid misuse has increased a sense of urgency for identifying effective non-opioid analgesia. The current evidence presented in this review demonstrates the potential for VR distraction therapy to provide effective analgesia for patients experiencing varied pain across many settings. The 28 articles reviewed here support the hypothesis that virtual reality can distract patients to reduce pain and anxiety. The evidence shows effective VR use for short-term

pain relief in both acute and chronic pain. VR distraction providing immersive environments wherein patients interact with the virtual scenario appear most effective. As VR system cost has fallen in recent years, immersive VR is increasingly used as an adjunct therapy and may soon allow for patient-directed analgesia in the outpatient setting. While current studies yield promising results for the use of VR distraction in acute and chronic pain, further research is needed to determine the degree of therapeutic effectiveness and to identify the potential for long-term treatment of pain.

Compliance with Ethics Standards

Conflict of Interest Ali Pourmand, Steven Davis, Alex Marchak, Tess Whiteside, and Neal Sikka declare no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

•• Of major importance

- Arane K, Behboudi A, Goldman RD. Virtual reality for pain and anxiety management in children. *Can Fam Phys* 2017;63(12):932–934 and 935–937.
- Li L, Yu F, Shi D, Shi J, Tian Z, Yang J, et al. Application of virtual reality technology in clinical medicine. *Am J Transl Res*. 2017;9(9):3867–80. **A good review of the different VR modalities available for clinical use includes therapeutic effects and advantages/disadvantages.**
- Gerardi M, Cukor J, Difede J, Rizzo A, Rothbaum BO. Virtual reality exposure therapy for post-traumatic stress disorder and other anxiety disorders. *Curr Psychiatry Rep*. 2010;12(4):298–305.
- Pourmand A, Davis S, Lee D, Barber S, Sikka N. Emerging utility of virtual reality as a multidisciplinary tool in clinical medicine. *Games Health J*. 2017;6(5):263–70.
- Li A, Montano Z, Chen VJ, Gold JI. Virtual reality and pain management: current trends and future directions. *Pain Manag*. 2011 Mar;1(2):147–57.
- Won AS, Bailey J, Bailenson J, Tataru C, Yoon IA, Golianu B. Immersive Virtual Reality for Pediatric Pain. *Children (Basel)* 2017;4(7):<https://doi.org/10.3390/children4070052>. **This source provides a strong explanation of the qualities of a VR device and treatment that make it effective.**
- Melzack R. Pain mechanisms: a new theory. *Science (New York, NY)*. 1965;150(3699):971–9.
- Triberti S, Repetto C, Riva G. Psychological factors influencing the effectiveness of virtual reality-based analgesia: a systematic review. *Cyberpsychol Behav Soc Netw*. 2014 Jun;17(6):335–45.
- Dowell D, Haegerich TM, Chou RCDC. Guideline for prescribing opioids for chronic pain—United States. 2016 JAMA. 2016 Apr 19;315(15):1624–45.
- Smith A, Carlow K, Biddulph T, Murray B, Paton M, Harvie DS. Contextual modulation of pain sensitivity utilising virtual environments. *Br J Pain*. 2017;11(2):71–80.
- Weeth A, Muhlberger A, Shiban Y. Was it less painful for knights? Influence of appearance on pain perception. *Eur J Pain*. 2017 Nov;21(10):1756–62.
- Demeter N, Josman N, Eisenberg E, Pud D. Who can benefit from virtual reality to reduce experimental pain? A crossover study in healthy subjects. *Eur J Pain*. 2015 Nov;19(10):1467–75.
- Gutierrez-Maldonado J, Gutierrez-Martinez O, Loreto-Quijada D, Nieto-Luna R. The use of virtual reality for coping with pain with healthy participants. *Psicothema*. 2012 Nov;24(4):516–22.
- Johnson S, Coxon M. Sound can enhance the analgesic effect of virtual reality. *R Soc Open Sci*. 2016;3(3):150567.
- Sharar SR, Alamdari A, Hoffer C, Hoffman HG, Jensen MP, Patterson DR. Circumplex model of affect: a measure of pleasure and arousal during virtual reality distraction analgesia. *Games Health J*. 2016 Jun;5(3):197–202.
- Treede RD, Rief W, Barke A, Aziz Q, Bennett MI, Benoliel R, et al. A classification of chronic pain for ICD-11. *Pain*. 2015 Jun;156(6):1003–7.
- Kroenke K, Krebs EE, Bair MJ. Pharmacotherapy of chronic pain: a synthesis of recommendations from systematic reviews. *Gen Hosp Psychiatry*. 2009;31(3):206–19.
- Pekyavas NO, Ergun N. Comparison of virtual reality exergaming and home exercise programs in patients with subacromial impingement syndrome and scapular dyskinesia: short term effect. *Acta Orthop Traumatol Turc*. 2017;51(3):238–42.
- Botella C, Garcia-Palacios A, Vizcaino Y, Herrero R, Baños RM, Belmonte MA. Virtual reality in the treatment of fibromyalgia: a pilot study. *Cyberpsychol Behav Soc Networking*. 2013;16(3):215–23.
- De Tommaso M, Ricci K, Laneve L, Savino N, Antonaci V, Livrea P. Virtual visual effect of hospital waiting room on pain modulation in healthy subjects and patients with chronic migraine. *Pain Res Treat*. 2013;2013:515730.
- Shiri S, Feintuch U, Weiss N, Pustilnik A, Geffen T, Kay B, et al. A virtual reality system combined with biofeedback for treating pediatric chronic headache—a pilot study. *Pain Med*. 2013;14(5):621–7.
- Ortiz-Catalan M, Guðmundsdóttir RA, Kristoffersen MB, Zepeda-Echavarría A, Caine-Winterberger K, Kulbacka-Ortiz K, et al. Phantom motor execution facilitated by machine learning and augmented reality as treatment for phantom limb pain: a single group, clinical trial in patients with chronic intractable phantom limb pain. *Lancet*. 2016;388(10062):2885–94.
- Jones T, Moore T, Choo J. The impact of virtual reality on chronic pain. *PLoS ONE* 2016;11(12). **This serves as a great example of a VR study with an immersive interactive gaming platform resulting in relatively strong statistics demonstrating the effectiveness of the treatment on a good size sample pool.**
- Wiederhold BK, Gao K, Sulea C, Wiederhold MD. Virtual reality as a distraction technique in chronic pain patients. *Cyberpsychol Behav Soc Networking*. 2014;17(6):346–52.
- Jin W, Choo A, Gromala D, Shaw C, Squire PA. Virtual reality game for chronic pain management: a randomized, controlled clinical study. *Stud Health Technol Informatics*. 2016;220:154–60. <https://doi.org/10.3233/978-1-61499-625-5-154>.
- Garrett B, Taverner T, Masinde W, Gromala D, Shaw C, Negraeff M. A rapid evidence assessment of immersive virtual reality as an adjunct therapy in acute pain management in clinical practice. *Clin J Pain*. 2014 Dec;30(12):1089–98.
- Tashjian VC, Mosadeghi S, Howard AR, Lopez M, Dupuy T, Reid M, et al. Virtual reality for management of pain in hospitalized patients: results of a controlled trial. *JMIR Ment Health*. 2017 Mar 29;4(1):e9.
- Mosadeghi S, Reid MW, Martinez B, Rosen BT, Spiegel BM. Feasibility of an immersive virtual reality intervention for hospitalized patients: an observational cohort study. *JMIR Ment Health*. 2016;3(2):e28.