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A Systematic Review of Studies on Virtual Reality Use in Management of Pain

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of article.

Abstract

Background- Virtual reality (VR) is an effective drug-free tool for management of pain. However, its use remains elusive in developing countries like Nigeria.
Objectives: To characterize studies conducted on using virtual reality in managing pain.
Methods: A comprehensive systematic review was conducted for studies done globally from 2000 to 2016. Databases (Google, Pubmed, BioMed Central, Mendeley) were searched to identify eligible studies. Search terms included: Virtual reality, Virtual patients, and management of pain using VR. Data extracted included: Title/authors of articles, objectives, study design, methods, population, age group, primary disease conditions, VR equipment, environments, display technology/ senses needed, country of study, effect of VR plus pharmacologic analgesia, and study outcomes.
Results: Out of 3821 potentially relevant articles identified 24(0.63%) were eligible. Fourteen (58.3%) and 8(33.3%) studies were Randomized Control Trials, and Case Studies/Reports respectively. A total of 8(33.3%) and 3(12.5%) studies were on Burn pain and Phantom limb pain respectively. Seventeen (70.8%) studies had adults as target population. Thirteen (54.2%) studies were done in the USA, 19 (79.2%) were Immersive VR, 15(62.5%) had head mounted display as display technology, and 22 (91.67%) had positive outcomes. VR plus pharmacologic analgesia 8 (33.37%) had positive outcomes. No study was found for Nigeria.
Conclusion: This review demonstrates wide range of characteristics for studies encountered and VR is shown as effective for reducing pain in different disease conditions even when combined with pharmacological analgesia. The absence of studies on management of pain using VR in Nigeria calls for creation of awareness among major stakeholders.

Keywords: Virtual Reality, Pain characterization, Nigeria

INTRODUCTION

Pain is a distressing feeling often caused by intense or damaging stimuli, such as stabbing a toe, burning a finger, alcohol on a cut, and bumping the ‘’funny bone’ ’The International Association for the study of pain states that ‘’Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage (IASP 2016).

Virtual Reality (VR) has been recognized as one of the effective means for the management of pain. It is a state-of-the-art technologically advanced system that allows users to be transported into a ‘virtual world.’ Users are engaged in a fully immersive VR experience through a combination of technologies, including a head-mounted display (HMD), headphones with sound/music and noise reduction, a rumble pad, joystick or another device for manipulation/navigation of the virtual environment (VE). These systems follow the user’s head movements, giving them the illusion of being completely surrounded by a virtual world. Originally, VR technology was solely recognized for its entertainment value; however, in the past years, its application has been expanded to a variety of clinical areas, including pain management, physical rehabilitation and the treatment of psychiatric disorders (e.g., phobias, post-traumatic stress disorder and anxiety disorder).Virtual reality has consistently been demonstrated to decrease unpleasantness, time spent thinking about pain, and perceived time spent in a medical procedure (Gershon *et al* 2000, Li *et al* 2011, Hoffman *et al* 2014; Chirico *et al*2016).

Ultimately, understanding the influences and interactions of these independent variables will lead to optimal patient/VR matching, thus, personalizing the interventions to maximize VR’s pain-attenuating effects. It has been used in different scenarios of managing pain – burns (Hoffman *et al* 2000, Hoffman *et al 2008,* Morris *et al* 2009, Maani *et al* 2011, Hoffman *et al* 2011); Paediatrics (Das *et al 2005,* Dahlquist*et al* 2009, Hoffman *et al* 2014*),;* anxiety disorders (Gershon *et al* 2000; Zimand *et al 2002)* Cancers(Sander *et al* 2002, Schneider *et al* 2011, Chirico *et al*2016), periodontal scaling and root planing procedures. (Furman *et al* 2009), ischemic pain (Hoffman et *al* 2003).

As the field advances, VR may decrease the number of needed treatment sessions, and may reduce or eliminate the need for narcotics during painful procedures. Virtual Reality has shown promise for managing chronic pain and facilitating long-term pain rehabilitation (Schneider *et al* (2011), Li *et al* 2011)). The benefits of VR cannot be overemphasized. Despite the studies found in developed countries, the authors are skeptical about the presence of documented studies of VR use in Nigeria. The objectives of this study were to characterize studies conducted on using virtual reality in managing pain with emphasis on patient category, pain conditions, type of VR equipment, outcomes of study (potency and efficacy), and countries of study.

METHODOLOGY

Study Design

A systematic review was conducted using the five steps outlined by Khan *et al.,* (2003).

These steps include: -

-Framing questions for the review
- Identifying relevant work
-Assessing the quality of studies
-Summarizing the evidence
-Interpreting the evidence

Framing questions for the review:

This systematic review was intended to characterize global studies conducted on using virtual reality in managing pain. The research questions for this systematic review were

1) What are the types of virtual reality equipment used in the management of pain?

2)What type of Pain conditions and patients are managed using VR?

3) What was the outcome (potency/efficacy) of the studies?

4)What study designs and in what countries have such studies been conducted?

Identification of relevant publications

Location of Studies

To capture as many relevant citations as possible, a wide range of medical and scientific databases were searched to identify primary studies on the management of pain using virtual patients. The specific search engines that were used included: Google Search, PubMed, BioMed Central, Mendeley. Articles found in the references of the articles selected for this review were also considered for analysis. Reference lists were hand-searched to identify additional studies.

Search terms that were used included: Virtual Reality, Virtual Patients, Pain Management, Distraction, Analgesia, Interventions. A specific search was also done on the management of pain using Virtual patients in Nigeria.

Selection Criteria

Inclusion Criteria

Articles that are between the years 2000 and 2016; are pain-based and made use of Video game for the intervention of pain. Articles that made use of the effect of VR Intervention on a health-promoting, clinically relevant health outcome. Articles that assessed or compared the difference between an intervention and a control video game

Exclusion Criteria

Articles that are before the year 2000, are not pain-based; do not include virtual reality and articles that assessed the efficacy of some other intervention with computer games as the control were not included.

Data Extraction

The data were extracted independently by one of the authors and superintended by other authors.

Extracted data included: title/authors of the articles, objectives, study type/study design, number of patients, category of patients, age group/age range of patients, the country where studies were conducted, virtual equipment/virtual environments, number of trials, disease condition, methods, outcome measures, results.

Assessing the quality of studies

-The quality of study was improved by ensuring that the review was based on questions clearly stated and well formulated.

-The eligibility criteria used to determine whether studies were included or excluded were clearly specified and predefined.

-The search strategy employed a comprehensive, systematic approach in order to capture all the evidence possible that pertains to the question of interest.

-Additional search strategies that were employed to improve the yield included- studies done in Nigeria, across the world, additional studies from references of the search engines (PubMed, Mendeley, Google, and Biomed Central), identification by an expert in Clinical Pharmacy in the field of studies and articles that may have been missed.

RESULTS

Study Identification and Selection:

a) PubMed Search

PubMed's exhaustive search between 9 August 2000 and 18 June 2016 resulted in 3236 articles from which relevant studies were selected for the review. Their potential relevance was examined and 3178 (98.21%) articles were excluded from the study due to the fact that they were not health-related. The full papers of the remaining 58 (1.79%) citations were assessed to select those primary studies that are directly related to the management of pain in virtual patients. These criteria excluded 47 (1.45%) studies not related to pain management using virtual patients and included 11 (0.33%) studies that were directly related to the use of virtual patients for the management of pain.

b) Google search

Google search between August 2000 and June 2016 yielded 575 articles. Their potential relevance was examined and 555 (96.5%) articles were removed as they were not health-related. The full papers of the remaining 20 articles (3.48%) were assessed to select those primary studies that are directly related to the management of pain in virtual patients. Twelve studies (2.1%) were excluded as they were not related to the management of pain using virtual patients which means only 7 (1.21%) relevant studies were eligible for the review.

c) Supplements

The electronic searches were supplemented by 1 [0.03%] citation from Biomed Central and 9 Citations from Mendeley Research Pool of which 5 [0.13%] citations were considered relevant to the management of different kinds of pain using Virtual Patients.

Figure 1 shows a flowchart of the process of identifying and selecting studies from Google, PubMed, Biomed Central, and Mendeley. Eight studies were involved in the use of virtual reality for burn pain management. Case Materials/ Studies and study designs encountered are as shown in Table 1 and Figure 2 respectively.

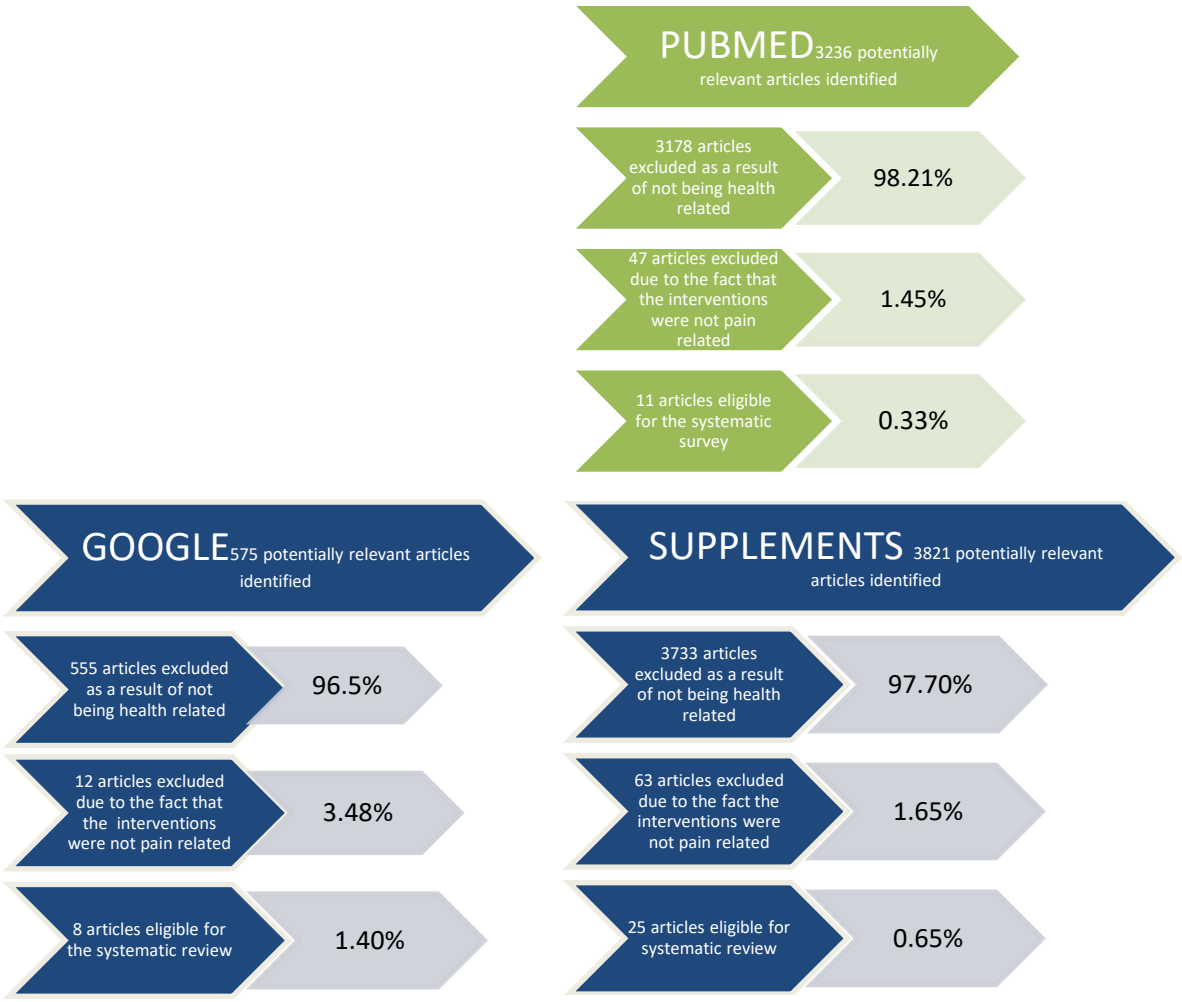

Figure 1: Flowchart of the process of identifying and selecting studies from Pubmed, Google and Biomed Central and Mendeley

Table 1: Case materials and studies used in the systematic review of management of pain in virtual patients arranged chronologically

Author	Study Type	Category of Patients	Type of Pain
Hoffman *et al* (2000)	RCT	Children	Burn Pain
Hoffman et al (2001)	Case Study	Adult	Severe Burn Injury
Hoffman *et al* (2003)	RCT	Adult	Ischaemic Pain
Hoffman et al (2004)	Case Study	Adult	Deep flash burns
Das et *al* (2005)	RCT	Children	Acute Burn Injuries
Gold *et al* (2006)	RCT	Children	Venepuncture Pain
Murray *et al* (2006)	RCT	Adult	Phantom Limb Pain
Oneal *et al* (2008)	Case Report	Adult	Upper Extremity Neuropathic Pain
Simmonds *et al* (2008)	RCT	Adult	Stroke
Carrougher *et al* (2009)	RCT	Adult	Burn Pain
Dahlquist *et al (*2009)	RCT	Adult	Cold Pressor Pain
Law *et al* (2009)	RCT	Children	Cold Pressor Pain

Mercier *et al* (2009)	RCT	Adult	Phantom Limb Pain
Bahat *et al (*2010)	Clinical Trial	Adult	Chronic Neck Pain
Saposnik *et al* (2010)	RCT	Adult	Stroke Rehabilitation
Sato et al (2010)	Case Study	Adult	Phantom Limb Pain
Maani *et al* (2011)	Case Study	Adult	Burn Pain
Schmitt *et al* (2011)	RCT	Children	Burn Pain
Soltani *et al (*2011)	Case Report	Adult	Dental Pain
Tanja-Dijkstra et *al* *(*2012)	Simulation	Adult	Dental Pain
Mosso-Va´zquez *et al* (2014)	Case Study	Adult	Cardiac Surgery
Johnson *et al* (2016)	RCT	Adult	Pain Tolerance
Sikka *et al (2015)*	RCT	Children	Postoperative Pain
Small et al (2015)	RCT	Children	Burn Pain

***RCT-Randomized Control Trial**

Figure 2

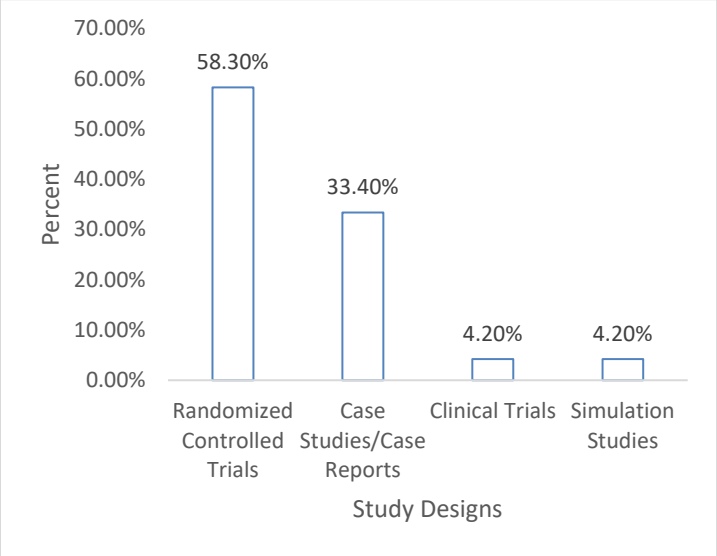

Figure 2-Study Designs Encountered

Studies based on senses, types of virtual reality, virtual world and display technology are as shown in Table 2. Studies by author, objectives, method, search engine and countries are as shown in Table 3. Characteristics of Randomized Controlled Studies, Case Reports, Simulation studies and Clinical Trials encountered are as shown in Table 4.

Figure 3 illustrates the use of the equipment, and scene from the game in 'The efficacy of playing a VR game in modulating pain for children with acute burn injuries' (Das *et al.*,2005)**.** Figure 4 shows Images from the VR in 'Water-Friendly VR pain control during Wound Care' by Hoffman *et al.*, (2001)

Table 2: Studies based on senses, types of virtual reality, virtual world and display technology

Studies	Senses	Type of virtual reality	Virtual world	Display technology
Hofmann *et al* (2000)	Sight	Immersive	Immersive	Head Mounted Display
Hofmann *et al* (2001)	Sight	Immersive	Immersive	Head-Mounted Display
Hofmann *et al* (2003)	Sight	Immersive	Immersive, Interactive	Head-Mounted Display
Hofmann *et al* (2004)	Sight	Immersive	Immersive	Head-Mounted Display
Das *et al* (2005)	Sight	Immersive	Immersive, Computer generated	Head-Mounted Display 2D Computer Monitor
Gold *et al* (2006)	Sight	Immersive	Immersive	Head-Mounted Display
Oneal *et al* (2008)	Sight	Immersive	Immersive	Head-Mounted Display
Carrougher *et al* (2009)	Sight	Immersive	Immersive	Head-Mounted Display
Dahlquist *al* (2009)	Sight	Immersive	Immersive	Stereoscopic Display with glasses
Law *et al* (2009)	Sight	Immersive	Immersive, Explorable	Head-Mounted Display, Stereoscopic display with glasses
Mercier *et al* (2009)	Touch	Augmented	Explorable, Computer generated	2D Computer Monitor
Johnson *et al* (2016)	Sight, Sound	Immersive Interactive	Immersive	Head-Mounted Display 2D Computer Television
Maani *et al* (2011)	Sight	Immersive	Explorable, Immersive	2D Computer Monitor
Mosso Va'zquez *et al* (2014)	Sight	Augmented	Immersive	Head-Mounted Display
Murray *et al* (2006)	Sight	Immersive	Immersive	Head-Mounted Display
Saposnik *et al* (2010)	Touch	Augmented	Computer-generated, Interactive	2D Computer Monitor
Sato *et al* (2010)	Sight, Touch, Sound	Non-Immersive	Interactive, Explorable, Computer generated	2D Computer Monitor
Schmitt *et al* (2011)	Sight, Sound	Immersive	Explorable, Immersive, Interactive	Head-Mounted Display
Sikka *et al* (2015)	Sight	Immersive	Immersive	Head-Mounted Display
Simmonds *et al* (2008)	Sight	Immersive	Immersive, Explorable	Head-Mounted Display
Small *et al* (2015)	Sight	Immersive	Immersive	Head-Mounted Display
Soltani et *al* (2011)	Sight	Immersive	Immersive, Explorable	Head-Mounted Display

Tanja-Dijkstra *et al* (2012)	Sight	Augmented	Explorable, Computer generated	2D Computer Monitor

Table 3: Studies by author, objectives, method, search engine, and countries

Author	Title	Objective	Method	Search Engine	Country
Hofmann *et al* (2000)	Virtual reality as adjunctive pain control during burn wound care in adolescent patients	To determine if the effect of immersive VR may be an effective means of distracting patients from burn pain, particularly in pediatric and adolescent populations.	Standard Pharmacologic Analgesia session followed by Virtual Therapy	Google	USA
Bahat *et al* (2010)	The Effect of Neck Pain on Cervical Kinematics, as Assessed in a Virtual Environment	To compare cervical kinematics during functional motion in patients with neck pain and in asymptomatic participants using a novel VR assessment	Musculoskeletal Physiotherapy followed by Cervical VR assessment	Google	Israel
Schmitt *et al* (2011)	A Randomized, Controlled Trial of Immersive Virtual Reality Analgesia during Physical Therapy for Paediatric Burn Injuries	To compare the effectiveness of adjunctive, immersive VR with that of conventional pharmacologic treatment alone during post-burn physical therapy sessions in the inpatient setting.	Standard Pharmacologic Analgesia/Sedation followed by Physical therapy and Physical therapy with VR	Google	USA
Mosso-Va´zquez *et al* (2014)	Virtual Reality for Pain Management in Cardiac Surgery	To address postoperative anxiety through the application of VR distraction therapy	Vital signs recorded followed by VR simulation using HMD	Google	Mexico
Murray *et al* (2006)	Immersive Virtual Reality as a Rehabilitative Technology for Phantom Limb Experience	To produce virtual facsimiles of amputee's phantom limbs	Virtual Equipment which involves completing a Virtual jigsaw was used	Google	UK
Simmonds *et al* (2008)	Effects of different virtual reality environments on experimental pain threshold in individuals with pain following stroke	The objective of this study were to determine whether different VR environments had a differential effect on pain threshold (PT) in stroke patients with pain, and whether the patient's level of	QSA (Quantitative Screen Testing) was done to assess pain perception to hot and cold stimuli followed by HMD VR involving Snow world	Google	Canada

		interest in the VR influenced Patient Threshold			
Mercier *et al* (2009)	Training with Virtual Visual Feedback to Alleviate Phantom Limb Pain	To assess the individual response to training with visual virtual feedback and to explore factors influencing the response to that approach.	The treatment approach consisted of presenting a virtual image of the missing limb performing different movements while asking the participant to follow these movements as much as he could with his phantom limb. These video images were then digitally inverted and projected on a computer screen. The motor tasks used were the following: flexion/extension of the elbow, prosupination of the forearm, flexion/extension of the wrist, opening/closing the hand, adduction/adduction of the fingers, thumb-to-fingers opposition, flexion/extension of the thumb, grasping an object (such as a glass), precision grip with small objects.	Google	Canada
Das *et al* (2005)	The efficacy of playing a virtual reality game in modulating pain for children with acute burn injuries	This study investigates whether playing a VR game decreases procedural pain in children aged 5-18 years with acute burn injuries.	Administrations of routine pharmacological analgesia or routine pharmacological analgesia coupled with VR were randomly assigned to each half of the burns dressing change	Pubmed	Australia
Tanja-Dijkstra et *al* *(*2012)	Improving Dental Experiences by Using Virtual Reality Distraction	The aim of the current study was to study both immediate and more long-term effects of VR distraction in a simulated dental context.	The simulated dental experience followed by the VR Dental Experience	PubMed	UK
Soltani et *al* *(*2011)	Virtual Reality Hypnosis for Pain Control in a patient with	This case report describes the use of hypnotic analgesia induced through	Pharmacologic Analgesia followed by Virtual Reality	PubMed	Canada

	Gluteal Hidradenitis	immersive three-dimensional computer-generated virtual reality, better known as virtual reality hypnosis (VRH), in the treatment of a patient with ongoing pain associated with gluteal hidradenitis			
Maani*et al* (2011)	Combining Ketamine and Virtual Reality Pain Control During Severe Burn Wound Care: One Military and One Civilian Patient	In this case study, the multimodal combination of ketamine analgesia plus immersive VR, a non-pharmacologic analgesic was explored as well as comparison with analgesic. The rationale for adding adjunctive immersive VR to the standard treatment dose of ketamine was to capitalize on the combined analgesic action of the two treatment modalities.	Pharmacologic Analgesia followed by Virtual Reality	PubMed	USA
Carrougher *et al* (2009)	The Effect of Virtual Reality on Pain and Range of Motion in Adults with Burn Injuries	A prospective, randomized controlled study of the effects of adding VR to standard therapy in adults receiving active-assisted ROM physical therapy pain control, by assessing pain scores and maximal joint ROM (Range of Motion)	Pharmacologic Analgesia followed by the use of adjunctive anxiolytic medications. VR distraction was added to one of the study days, with the order of treatment (VR or no VR).	PubMed	USA
Law *et al* (2009)	Videogame Distraction using Virtual Reality Technology for Children Experiencing Cold Pressor Pain: The Role of Cognitive Processing	This study examined whether increasing the demand for central cognitive processing involved in a distraction task, by involving the child in ongoing, effortful interaction with the distraction stimulus, would increase children's tolerance for	1.Cold pressor apparatus 2.Thermal Feedback system	Pubmed	USA

		cold pressor pain			
Sikka *et al* *(2015)*	Automated Assessment of Children's Postoperative Pain Using Computer Vision	Facial expressions are a sensitive, specific biomarker of the presence and severity of pain, and computer vision (CV) and machine-learning (ML) techniques enable reliable, valid measurement of pain-related facial expressions from video. A CVML approach was developed to measure pain-related facial expressions for automated pain assessment in youth.	A CVML-based model for assessment of paediatric postoperative pain was developed from videos of 50 neurotypical youth 5 to 18 years old in both endogenous/ongoing and exogenous/transient pain conditions after laparoscopic appendectomy. Model accuracy was assessed for self-reported pain ratings in children and time since surgery, and compared with by-proxy parent and nurse estimates of observed pain in youth.	Pubmed	USA
Oneal et al (2008)	Virtual Reality Hypnosis in The Treatment of Chronic Neuropathic Pain	This case report evaluates virtual reality hypnosis (VRH) in treating chronic neuropathic pain in a patient with a 5-year history of failed treatment	First, there was an introduction to the lake. The lake was described her body to the patient, and she was encouraged to become increasingly absorbed in the scene and to let relax. The next section discussed how pain affects her life She was told that images from the past and from the future should start to have a strong connection. Then the patient was given suggestions for sleeping better through the night, and it was also suggested that any exercises she engages in would become easier. It was recommended that she change the experience of her pain to a sense of coolness or numbness, or even forget about it altogether. She was also guided that as her pain improved she would find	Pubmed	USA

			the ability to continue doing things that make her feel better, such as increasing her movement and participating more in life. The lake segment concluded by giving the patient a chance to engage in any other experiences or images that she might like to have, or to give herself positive suggestions of her own.		
Hoffman et al (2001)	The Effectiveness of Virtual Reality Pain Control with Multiple Treatments of Longer Durations	This case study explored whether VR continues to reduce pain when the duration and frequency of VR treatments are increased to more practical level	Pharmacologic Analgesia followed by VR with Pharmacologic Analgesia	Mendeley	USA
Sato et al (2010)	Nonimmersive Virtual Reality Mirror Visual Feedback Therapy and Its Application for the Treatment of Complex Regional Pain Syndrome	A virtual reality mirror visual feedback system was developed and applied it to the treatment of complex regional pain syndrome	Subjects are instructed to focus on the motion of the virtual hand (affected side) on the PC monitor. When subjects intend to reach the target in VE, they extend their FASTRAK-mounted forearm (affected side) into the appropriate position The motion of the virtual hand is manipulated by the nonaffected hand and the affected hand is not allowed to move After successfully grasping the target, subjects move it a distance and then open their fingers to release it	Mendeley	Japan
Gold *et al* (2006)	Effectiveness of Virtual Reality for Paediatric Pain Distraction during IV Placement	The objective of this study was to test the efficacy and suitability of VR as a pain distraction for paediatric intravenous	Standard of care (control), which included a topical anaesthesia spray prior to IV placement, or Standard of care plus	Mendeley	USA

		(IV) placement.			
Hoffman *et al* (2003)	Immersive Virtual Reality for reducing experimental ischemic pain.	This study explored the novel use of immersive virtual environments as a non-pharmacologic pain control technique and whether it works for both females and males.	To minimize the occurrence of excessively high pain levels, the duration of the ischemia was reduced for any participant whose "average pain" measure for the most recent two min period with no distraction reached 50 mm or higher on a 100 mm VAS subjective pain rating at any pain rating prior to the eight min mark. Such participants were immediately placed into the VE for the next two min period.	Mendeley	USA
Small et al (2015)	Virtual restorative environment therapy as an adjunct to pain control during burn dressing changes	To assess the efficacy of the immersive virtual reality system in terms of the following: 1. The effects on the pain experienced by patients during painful procedures requiring multimodal analgesia but not requiring sedation/anaesthesia. 2. The effects on the anxiety experienced by patients during painful procedures not requiring sedation/anaesthesia. 3. The system's ability to generate a sense of presence on the part of the VR users 4. User acceptance experienced by the patients and usability feedback. 5. User acceptance by the clinical staff caring for the patients.	Pharmacologic Analgesia followed by Virtual Reality	Pubmed	UK
Saposnik*et al* (2010)	Effect of Virtual Reality using Wii Gaming	To systematically compare the feasibility and safety of VRWii to	Patients received an intensive program consisting of 8	Pubmed	Canada

	Technology Stroke Rehabilitation	RT in patients with a first stroke within 6 months before enrollment to determine whether VRWii enhances motor recovery after stroke.	interventional sessions VRWii gaming session of 60 minutes each over a 14-day period.		
Johnson *et al* (2016)	Sound can enhance the analgesic effect of virtual reality	1.To determine if sound would have an additive effect, increasing pain tolerance when included with the VR game. 2.To determine if it would have an analgesic effect in its own right separate from any influence of the VR game	Before each condition, the participant's hand temperature was attained using the biofeedback probe. A baseline measure of pain tolerance was taken first Single cold-pressor trials were then completed In the HMD only condition	Pubmed	USA
Hoffman et al (2004)	Water-Friendly Virtual Reality Pain Control During Wound Care	The present case study describes an attempt to use water-friendly VR technology with a burn patient undergoing wound care in a hydrotherapy tub	The patient kept his head still and looked around in the virtual world by moving a fingertip controlled joystick. The patient had the illusion of flying through SnowWorld The snowballs exploded with animations and three-dimensional sound effects upon impact. While in the hydrotank the patient spent three minutes of the procedure in VR and three minutes of the procedure with no distraction By the flip of a coin, he was randomized to receive the VR condition first. Pain ratings and presence ratings, the primary dependent variables, were administered after each of the two treatment conditions during a brief pause in wound care.	Mendeley	USA

Dahlquist*et al* (2009)	Effects of Videogame Distraction using a Virtual Reality Type Head-Mounted Display Helmet on Cold Pressor Pain in Children	To test whether a head-mounted display helmet enhances the effectiveness of videogame distraction for children experiencing cold pressor pain.	1.Cold Pressor Apparatus 2.Thermal Feedback System 3.Virtual Reality Equipment 4.Video Game Equipment	Pubmed	USA

Table 4: Characteristics of studies of VR distraction for reducing pain
a) :**Randomized Control Trials (RCT)**

Author	Sample Population	Type of Pain	Virtual Equipment	Result	Outcome Measure
Schmitt *et al.*, (2011)	6-19 years 64 Patients	Burn Pain	four head-mounted displays (helmets) A PolhemusFastrak (Polhemus, Colchester VT) motion-sensing system.	Assessments on study day one of cognitive pain (44% reduction), affective pain (32% reduction), and sensory pain (27% reduction) were significantly lower ($p < 0.05$ for each paired comparison) in the adjunctive virtual reality condition than in the control condition	Positive
Murray *et al.*, (2006)	67 patients	Phantom Limb pain	A V6 virtual reality head-mounted display (HMD). Data glove and sensors. A PolhemusFastrak monitors head movements and arm/leg movements.	The result was inconclusive	Inconclusive
Simmonds *et al.*, (2008)	10 patients	Stroke Pain	The VR computer was equipped with the ultra-high end NVIDIA Quadro FX 4500 graphics card (512 MB of high-speed GDDR3memory). Head mounted display (HMD).	All VR environments increased pain threshold in comparison to no VR condition	Positive
Mercier *et al.*, (2009)	67 Patients	Phantom Limb Pain	A Virtual image of a missing limb performing different movements was presented and the participant was asked to follow the movements with his phantom limb	Patients reported an average 38% decrease in background pain on a visual analog scale (VAS), with 5 patients out of 8 reporting a reduction greater than 30%. The average pain scores (from the Faces Scale) for	Positive

				pharmacological analgesia only was, 4.1 (SD 2.9), while VR coupled with pharmacological analgesia, the average pain score was 1.3 (SD 1.8).	
Das *et al.*, (2005)	9 patients 5 to 18 years old	Acute Burn Injuries	A laptop (Dell Inspiron 5100, Pentium 4 2.4 Ghz CPU with a Radeon Mobility 7500 Video Card) A head-mount display (HMD)	Average age was 10.0 years (SD 3.7(boys) and 4.1(girls) respectively). Average % of body surface area burnt was 5.3% (SD 3.4%). Average pain scores (from the Faces Scale) for pharmacological analgesia only was 4.1(SD 2.9), while VR coupled with pharmacological analgesia, the average pain score was 1.3(SD 1.8)	Positive
Saposnik*et al.*, (2010)	110 patients 18-85	Stroke Rehabilitation	Description of Wii Gaming Technology—Nintendo introduced a new style of VR (2006) by using a wireless controller that interacts with the player through a motion detection system and avatar (computer user's representation of himself or herself or alter ego) technology.	The mean total session time was 388 minutes in the recreational therapy group compared with 364 minutes in the VRWii group (P=0.75). There were no serious adverse events in any group. Relative to the recreational therapy group, participants in the VRWii arm had a significant improvement in mean motor function of 7 seconds (Wolf Motor Function Test, 7.4 seconds; 95% CI, −14.5, −0.2) after adjustment for age, baseline functional status (Wolf Motor Function Test), and stroke severity.	Positive

Carrougher*et al.*, (2009)	39 Patients 21-57	Burn	VR helmet	VR reduced GRS scores for worst pain, pain unpleasantness, and time spent thinking about pain, relative to the no VR condition (27, 31, and 37%, respectively) Patients experienced little or no nausea during VR. Ninety-seven percent rated their nausea at less than 20 on a 0- to 100mm GRS (0 equals no nausea to while 100 =vomiting); 85% experienced no nausea at all during the VR experiments on the patients.	Positive.
Dahlquist*et al.*, (2009)	39 Patients 21-57 years old	Burn	An adjustable HMD helmet with integrated headphones was used in this study.	Both distraction conditions resulted in improved pain tolerance relative to baseline. Older children appeared to experience additional benefits from using the helmet, whereas younger children benefited equally from both conditions. The findings suggest that virtual reality technology can enhance the effects of distraction for some children.	Positive
Law *et al.*, (2009)	79 Patients 6-15 years old	Cold Pressor Pain	A 5DT HMD 800-26 adjustable head mounted display (HMD) helmet (Fifth Dimension Technologies; Irvine, CA) with a 3D stereoscopic 480,000 pixelcolor display and integrated headphones was connected to the Nintendo Wii TM game system.	As expected, children demonstrated significant improvement in pain tolerance during distraction relative to baseline. Children showed the greatest improvement during the interactive	Positive

				distraction task.	
Sikka *et al.*, (2015)	50 Patients 5-18 years old	Post-Operative Pain	First, facial activity was recorded for 5 minutes as a measure of ongoing pain. Then, video recordings of facial activity were collected as representative transient pain samples when manual pressure was exerted at the surgical site for 2, 10-second periods (typical of a clinical examination, with each press averaging 1.5 to 2.0 inches in depth).	Model detection of pain versus no-pain demonstrated good-to-excellent accuracy (Area under the receiver operating characteristic curve 0.84–0.94) in both ongoing and transient pain conditions. Model detection of pain severity demonstrated moderate-to-strong correlations (r = 0.65–0.86 within; r = 0.47–0.61 across subjects) for both pain conditions.	Positive
Johnson *et al* ., (2016)	32 Patients 20.28 Years	Pain Tolerance	The HMD was an Oculus Rift DK2 with a resolution of 960×1080 pixels per eye, a 100° field of view and a 75 Hz refresh rate. The HMD used low-persistence organic light-emitting diodes, and provided both head-tracking and positional tracking.	A log10 transformation of the data was used as the distributions of the raw scores were not normal (descriptive statistics is provided in table 1). Skew and kurtosis levels between −1 and +1 were considered as tolerable limits. A significant main effect of condition was found ($F_{3,78}=54.53$, $p<0.05$, $\eta^2=0.68$, post hoc power=1.00) indicating that differences in pain tolerance between the conditions were statistically significant.	Positive
Gold *et al.*, (2006)	20 Patients 8-12 years old	Venepuncture Pain	The VE was presented via the 5DT HMD 800, a high-performance professional HMD that provides active matrix LCDs with full SVGA (800x600 x3[rgb]) pixel resolution. An InterSense Inertia Cube2 with a 3-degrees-of-freedom (DOF)	The Faces Pain Scale–Revised revealed that children in the control condition experienced a significant fourfold increase in affective pain following the IV	Positive

			tracker was attached.	placement (t = "3.25*); by contrast, no significant change was detected within the VR condition for affective pain (t = "1.00NS)	
Hoffman *et al* (2003)	22 Patients	Ischaemic Pain	A Silicon Graphics Octane MXE with Octane Channel Option1 coupled with a VR helmet was used to create an immersive, 3-D, interactive, computer simulated environment. A PolhemusFastrakTM motion sensing system with 6 degrees of freedom sensors was used to measure the position of the user's head and hand position. Participants experienced SpiderWorld	Pain ratings increased significantly every two minute during the no distraction phase (zero to eight min) and dropped dramatically during the last two min period when participants were in the virtual environment (a 59% drop for females and a 41% drop for males).	Positive
Small *et al*., (2015)	25 Patients		The prototype consists of a high definition, 32-inch screen, headphones and hand controller (chosen for single-hand use and equipped with a thumb-operated joystick). The use of a head-mounted display was considered. During passive video VRET, participants look at a static image of a virtual seascape. In the active VRET treatment participants are able to navigate the virtual world, traveling in a speed boat. The activity will have multiple sensory inputs, encouraging maximum attention, yet be simple enough to be undertaken by those with impairment due to physical limitations and performance limitations such as opiates, pain and sleep deprivation.	The Result was inconclusive	

b): Case Studies/Case Reports

Author	Sample Population	Type of Pain	Virtual Environment/Virtual Equipment	Result	Outcome Measure
Mosso-Vazquez *et al.*, (2014)	67 Patients	Cardiac Surgery	The simulation consisted of a set of five cyber therapy environments (developed by the Virtual Reality Medical Center in San Diego, CA): Cliff, Dream Castle, Enchanted Forest, Icy Cool World, and Drive, Walk, Bike	Of the 67 patients, 59 patients (88%) reported a decreased level of pain experienced post-therapy. The mean change in the Likert scale was 3.75, which corresponds to a decrease from ‘‘severe’’ to ‘‘moderate’’ or ‘‘moderate’’ to ‘‘light.’’ Physiologically, 25 patients (37.3%) experienced reduced heart rates, 35 (52.2%) experienced reduced mean arterial pressure, and 14 (64%) of 22 patients tested for respiratory rate experienced a reduction.	Positive
Soltani*et al.*, (2011)	1 patient	Hidradenitis suppurativa.	During the VRH treatment, the patient wore a head-tracking VR helmet and earphones that blocked the view and sounds from the surrounding environment, and replaced these with computer-generated sights and sounds. A snow-world environment was used.	The patient’s average pain and anxiety ratings dropped from pre-VRH to one hour after the VRH treatment	Positive
Maani*et al.*, (2011)	2 Patients 21-41 years old.	Electrical Burn	Both patients utilized the VR system consisting of a Voodoo Envy laptop with NVIDIA GForce Go 7900 GTX (512 MB) video card, Intel Core 2 Duo (T7400) CPU @ 2.16 GHz, 2 GB RAM @ 994 MHz (Hewlett-Packard, Palo Alto, CA). While in high-tech VR, each subject followed a predetermined path, “gliding” through an icy three-dimensional (3-D) virtual canyon. Patients used robot-like articulated arm mounted goggles, which do not require wearing a helmet and minimize contact with the patients’ face/head	Compared to ketamine + no VR, both patients reported less pain during ketamine + VR for all three pain ratings. Both patients rated wound care during no VR as “no fun at all”, but those same patients rated wound care during virtual reality as either “pretty fun” or “extremely fun”, and rated nausea as either “mild” or “none”. Results from these first two cases suggest that a moderate dose of ketamine combined with immersive virtual reality distraction may be an effective multimodal analgesic regimen for reducing acute procedural pain during severe burn wound cleanings.	Positive
Oneal*et al.*, (2009)	1 patient 36 years’ old	Upper Extremity Neuropathic	VR Helmet	when investigating pain levels immediately after treatment, the patient's average pain intensity	Positive

		Pain		levels and pain unpleasantness ratings from pre- to posttreatment session, there was a 36% reduction in her average pain intensity and a 33% reduction in her average pain unpleasantness from pre- to post-VRH	
Hoffman *et al.*, (2001)	1 patient 40 years' old	Severe Burn Injury	The research group built a photonic, nonelectrical, water-friendly VR helmet that was custom built for use in the hydrotank. Instead of mounting miniature computer screens in the helmet (conventional VR helmet), with the water-friendly helmet, the virtual images are first converted from electrons to photons via two LCD projectors	On a rating scale of 0 to 10, VR was more effective than a no-distraction control condition. The patient's pain scores decreased from 7 (No VR) to 2 (VR) for sensory pain (worst pain) and decreased from 6 (No VR) to 3 (VR) for affective pain (unpleasantness).	Positive
Hoffman *et al* (2004)	1 patient	severe burn pain	water-friendly VR technology	Decreased the patient's sensory and affective pain ratings and decreased the amount of time spent thinking about his pain during wound	Positive.
Sato *et al* (2010)	5 Patients	Phantom Limb Pain	A personal computer-based desktop virtual reality system was developed for MVF therapy. A virtual environment (VE) was developed using commercially available software, Autodesk 3DS Max (San Rafael, CA).	All patients reported spontaneous pain in the affected limb that increased with movement. The pre-treatment value of the VAS (64 +/- 14) (mean +/- SD) decreased to 31 +/- 26 after consecutive treatment sessions. Four of the five patients (80%) showed 50% reduction of the pre-treatment VAS value. Effective pain reduction (50%reduction)	Positive
Hofmann *et al., (*2000)	16, 17 years 2 patients	Burn Pain	Immersive VR	VR was dramatically more effective than the video game control condition as a non-pharmacologic pain analgesic.	Positive

c): Clinical Trials

Author	Sample Population	Type of Pain	Virtual Equipment	Result	Outcome Measure
Tanja-Dijkstra *et al.*, (2014)	69 Patients 33.1 years old	Dental Pain	The virtual environment (VE) depicted an existing environment, which consists of a coastal path, complete with sea, beach and field areas, originally developed for restorative and rehabilitative environment studies. A VuzixiWear	With the use of Virtual Reality Dental Experience,there was higher level of pain control than normal dental experience.	Positive

			VR920 headset was connected to an Alienware M11X laptop (dual-core, 1.3GHz Intel processor with Nvidia GT540M graphics card) and used to display the VE.		

d): Simulation Studies

Author	Sample Population	Type of Pain	Virtual Equipment	Result	Outcome Measure
Bahat*et al.*, (2010)	**37 years' old**	Chronic Neck Pain	An electromagnetic tracker and an HMD.	Cervical rotations were significantly faster and smoother than flexion and extension movements	Positive

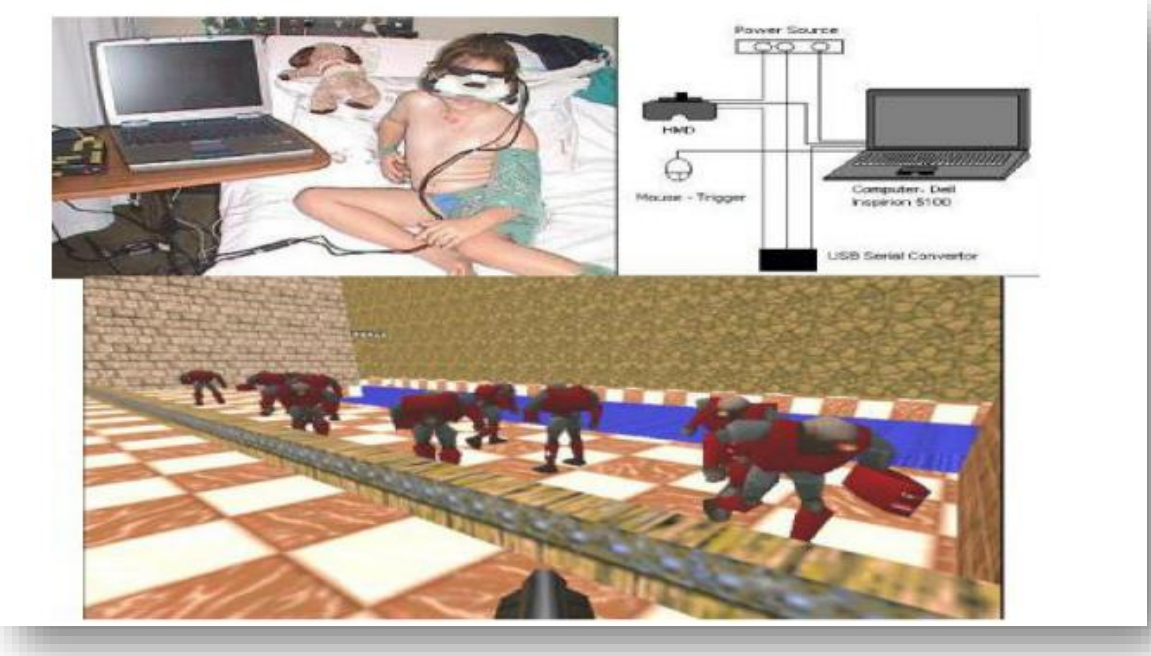

Figure 3: a) Child using the VR equipment. Mechanics of the equipment and scene from the game she is playing adapted from Das *et al* (2005)**.**

Figure 4: Images from the Virtual Reality in 'Water-Friendly Virtual Reality Pain Control During Wound Care' adapted Hoffman *et al.,* (2001)

Study outcomes and quality

An outcome was considered "positive" if the VR intervention was superior to the control based on significance criteria for that study. Otherwise, the outcome was "negative." Of the 24 studies eligible of the systematic review. Twenty-two (91.67%) studies had a positive outcome while two (8.33%) were inconclusive.

DISCUSSION

The systematic review synthesized the results of the 24 studies, each of which tested the ability of a virtual equipment to promote health and/or ameliorate disease. It finds that virtual equipment have been evaluated for a wide variety of health-related purposes among participants of all ages, most commonly for their ability to treat patients physically and psychologically. In addition, they were studied with respect to health education, disease self-management, distraction from pain, and promotion of the increased physical activity. Of these areas, studies of Virtual Reality involving physical or psychological therapy successfully achieved their purpose, whereas those that aimed to improve disease management were least successful. Basically, this systematic review cast a wide net with regard to the topic, aiming to discover the various categories of Pain to which Virtual Reality has been applied. It was more selective in terms of quality and unique in its rigor, having adhered closely to correct guidelines related to search criteria, study selection, data extraction, and data synthesis.

The strongest evidence of the potency of VR distraction comes from studies of experimental pain. VR distraction was clearly shown to provide relief to patients undergoing cold-pressor pain (Law *et al*., (2009)). Because experimental pain is relatively mild, time-limited, and has no health implications, the extent to which these studies generalize to the treatment of clinical pain is unclear. On the other hand, in an experimental pain study, the treatment protocol and pain stimulus can be standardized to a much greater degree than is possible in a clinical setting. That is, every participant experienced the identical pain stimulus and every participant can be administered an identical intervention. This would not be the case in a clinical study where patients would likely experience different types or levels of Pain and a treatment protocol might not need to be altered to suit the medical needs of the patient. In an experimental pain study, it is easier to regulate potential confounding variables such as demand characteristics and lack of blindness in observer ratings. Thus, clinical pain studies may have greater generalizability, but experimental pain studies permit better experimental pain control.

As for investigations of clinical pain, evidence of the efficacy of VR distraction was most clear-cut in studies of burn wound care. Hofmann *et al.,* (2000). Hoffman *et al.,* (2001), Das *et al.,* (2005), (2009) Schmitt *et al*., (2011) Carrougher*et al.*)

However, in these studies, it is possible that the null findings may have been due either to the use of less sophisticated VR technology. Murray *et al.,* (2006) or small sample size resulting low statistical power. Small *et al*., (2015)

Indeed, a clear pattern evident in this systematic review is that immersive VR technology is very effective in reducing pain and anxiety; specifically, all but one of the 24 studies that utilized a head-mounted display helmet reported a significant effect on at least one indicator of pain.

More research is needed on a variety of fronts. First, future studies should compare the effectiveness of Virtual Reality distraction with well-established psychological methods of pain management such as hypnosis and cognitive-behavioral interventions. Such research can help to determine whether the benefits of using VR Equipment to relieve various kinds of Pain problems outweigh the monetary costs.

Secondly, there is a need for self-report measures which provide an index of the person's pain perception and careful attention to the quality of outcome measures. Visual analog or graphic-rating scales in which the person rates pain intensity and unpleasantness along 0-10 scales are examples that were included in some of the studies. Observational measures provide an index of the person's pain behavior (grimacing, crying, and moaning). Self-report and observational measures offer complementary information. Both types of measures are valuable, as long as specific instruments are reliable and valid.

Lastly, Researchers need to be mindful of the nature of the virtual environments used in their VR Distraction interventions. Sophisticated VR technology goes to waste if VR environments lack appeal. Researchers are encouraged to measure the presence and fun produced by their Virtual Environments and to conduct appropriate analyses of the moderator function of these variables on treatment outcomes. Studies for Nigeria can be improved by the creation of awareness, incorporating VR studies into the curriculum, educational interventions, and the introduction of VR to health workers.

The present systematic review is limited by its inclusion of only RCTs, Clinical Trials, Case Reports/Case Studies. It is possible that other Virtual Reality interventions are highly successful but were reported using other methods.

CONCLUSION

Based on the evaluations of the 24 studies, the results point to the potential efficacy of Virtual Reality Therapy in the management of Pain. The findings of the systematic review indicate that VR distraction is an effective intervention for reducing pain. This comprehensive systematic review demonstrates that Virtual Reality Distraction is effective for reducing various types of pain. Virtual Reality(VR), in conjunction with Pharmacological analgesia can be particularly useful in reducing pain and anxiety in patients compared with Pharmacologic analgesia alone or other forms of distraction and management of different types of Pain that is resistant to the conventional Pharmacological therapy.

Based on the result of the research on management of pain using Virtual Patient in Nigeria, there was no study found which indicates that the use of Virtual Patients for the management of pain has not been done in Nigeria.

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