A Survey on the Effectiveness of Virtual Reality-based Therapy and Pain Management

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***Abstract*—Virtual reality refers to the technology used to create multi-sensory three-dimensional environments that can be navigated, manipulated, and interacted by a user. This paper's objective is to categorize the most common areas that use virtual reality (VR) for managing pain (psychological and physical). To our knowledge, this is the first survey that summarizes all of these areas in one place. This paper reviews the conducted studies that used VR for psychological treatment, especially with phobias. Also, this paper summarizes the current literature on using virtual reality interventions for managing acute, chronic, and cancer pain. Based on the review, virtual reality shows great potential for controlling acute pain - such as pain associated with burn wound care. However, limited studies only investigated the impact of using virtual reality on patients with chronic pain. The findings indicated that VR distraction has a great impact on pain and distress related to cancer and its treatments. This paper also discusses the challenges and limitations of the current research. Notably, the identified studies recommend VR distraction as a promising adjunct for pain reduction and psychological treatment. However, further research needs to be conducted to determine under what conditions VR distraction will provide more analgesic effects.**

***Keywords*—Virtual reality; mental health; cancer pain; distraction; pain management**

I. Introduction

Pain is a sensory and emotional experience, which affects negatively physical, mental, and social function [1]. The definition of pain - according to the International Association for Study of Pain (IASP) [2], is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage". Most hospitalized patients experience pain, which can be acute or chronic [3]. Acute pain is associated with an injury to the body and developed slowly or quickly. It can last for a few minutes to six months and goes away when the injury heals. On the other hand, chronic pain persists for more than six months beyond the expected time for recovering [4]. Another type of pain that occupies a separate category is cancer pain, patients with cancer frequently suffer from pain related to the disease itself and/or pain caused by treatment such as chemotherapy, radiation, and other painful procedures [5]. Cancer pain has components of both acute and chronic, this makes experts of pain categorize it in a separate class [6]. Managing the pain associated with painful medical procedures is still one of the greatest challenges in health care. Accordingly, it is valuable for all health care institutions to understand the benefits of managing pain during these medical procedures.

The most commonly used approach to manage pain is the pharmacological methods relying largely on opioids [7]. However, the analgesic effects of these methods diminish with repeated use and may cause many unwanted physical side effects and different types of mental disorders [8], [9]. Therefore, researchers pay great attention to non-pharmacological methods as alternatives for managing pain related to painful medical procedures [8]. Non-pharmacological approaches include physical methods (e.g. positioning, pressure, hot and cold treatments) and cognitive-behavioral methods (e.g. guided imaginary, relaxation techniques, and distraction activities such as music, reading, and video games) [10], [11], [12].

Recently, distraction is the most common method of non-pharmacological techniques for pain management. Distraction is an effective technique that diverts the attention of patients away from painful stimuli to decrease the experienced pain [10]. Melzack and Wall [13] explained the logic of why distraction reduces pain by presenting the gate control theory. Their theory states that the perception of pain will be reduced if the patient is well distracted. Due to the efficacy of distraction interventions, there is a growing interest to propose more immersive and interactive distraction interventions, such as using VR for pain control.

VR refers to technology that involves immersive and interactive three-dimensional (3D) computer-generated environments. VR systems have two main characteristics: immersion and presence [14]. Immersion strongly depends on the VR system's interface and display [15]. VR presence depends on the user's perceived value of seeing, hearing, touching the virtual world. Presence makes users feel while being in the virtual world as if they were in a real-world [16]. VR systems use multi-sensory to enhance the immersive experience. The multi-sensory embeds sensors in HMD to control users' virtual visual and audio content based on users' head position [17]. During the last years, VR distraction gains massive popularity as an alternative for pain management. Accordingly, many successful trials have been conducted for managing pain during painful medical procedures [18] as well as the treatment of many psychological disorders such as phobias [19].

Previous reviews of research have presented many controlled investigations of the effectiveness of VR distraction for managing pain. However, none provided the most common areas in health care that use VR distraction. To this aim, we categorize for the first time the major areas that use VR interventions for pain management and treatment. This will help to determine the main characteristics of the conducted studies to be considered in future research. This survey indicated two main categories based on the type of pain: psychological and physical. Through the article, a literature review of the conducted studies that used VR for the treatment of many types of phobia was provided. Also, presents the effect of using VR distraction for managing acute, chronic, and cancer pain. Moreover, we present the key findings of these studies and limitations that need more research work.

Through the following sections, our paper summarizes the clinical use of VR interventions for managing pain and psychological treatment. Section 3 includes the literature review on using VR for many mental health treatments especially phobias. Research studies that were conducted to measure the effect of using VR for acute pain management are presented in Section 4. Then Section 5 presents the research papers that studied the impact of VR on patients with chronic pain. Section 6 summarizes the research studies which were performed for managing cancer pain. Finally, the challenges and limitations of using VR distraction in health care along with conclusions are included in Section 7 and 8, respectively.

II. Method of Survey

This survey aims to summarize and highlight the most common areas that use VR interventions for pain management. To this aim, literature searches of web-based scientific databases were conducted to include studies that used VR for managing physical pain as well as including studies that used VR for treating many psychological disorders (phobias). In this survey, we restrict the searches to include studies that use different ways of investigating the efficacy of VR distraction. We were interested to include the studies that used VR distraction under different model designs (within or between-subjects). Also, we included studies that used different conditions where VR distraction was used alone or was compared with at least one alternative intervention or no-treatment control condition in reducing pain. We selected these studies of different settings to show that VR distraction is a promising tool for managing pain. A broad literature search of the IEEE Xplore, Science Direct, Google Scholar, Scopus, and MedLine databases as well as an examination of other reviews in this area. We performed the search using as main terms “virtual reality distraction”, “pain management”, “VR for cancer”, and “chronic”.

In addition, there were no date restrictions to be able to search all citations in each database. We include all the retrieved studies that investigated the impact of immersive VR distraction during painful medical procedures. Also, the reference lists of all retrieved papers were reviewed to identify other relevant articles. We excluded the studies in which it was not possible to identify how VR was used and failed to be used in comparative data. The studies in this survey are organized into the following four groups, according to the type of pain: (a) psychological pain; (b) acute pain; (c) chronic pain; and finally (d) cancer pain. A total of 39 studies were analyzed and included in this survey (see Fig. 1).

III. Virtual Reality for Mental Health

The standard methods used for mental health treatment are Cognitive behavioral therapy (CBT) and Vivo exposure therapy. CBT is a type of talking therapy that aims to help patients learn some strategies for dealing with their phobia. On the other hand, patients in Vivo will face a feared object, situation,

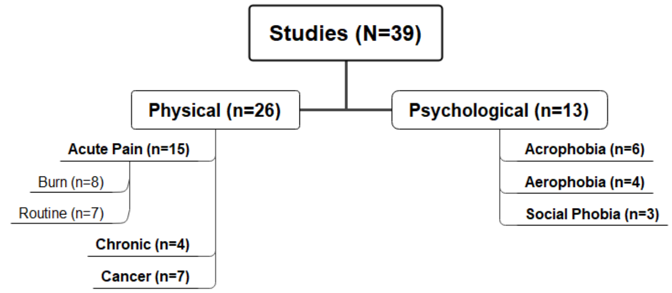

Fig. 1. Summary of the Included Studies.

or activity in real life. Vivo type of treatment is impractical, difficult, and sometimes dangerous. Recently, VR technology provides an alternative solution for Vivo exposure, with better safety and cost-effective characteristics. In this section, we will focus on the most common types of phobias; fear of heights (*acrophobia*), flying phobia (*aerophobia*), and *social phobia*, and review the conducted VR studies for treating them. Table I summarizes the characteristics of the included studies.

A. VR for Acrophobia Treatment

Since the mid of 1990’s many studies were conducted to explore the effect of using VR interventions to treat acrophobia [33]. Rothbaum et al. [20] conducted one of the studies in this area, involving twenty participants, who suffered from acrophobia. Through the study, participants were assigned to treatment using VR exposure therapy against the waiting list. Participants in VR therapy experienced three different conditions for eight weekly sessions. Three different self-reported questionnaires were used to measure the VR treatment impact. Only ten participants completed the treatment sessions. The results from all assessment measures indicated that there was a significant reduction in means of all questionnaire scores for the VR group.

Valuable results from the conducted studies in the 90s opened the door for further research in this era. After a few years, another acrophobia study was conducted by Emmelkamp et al. [21] to compare VR exposure against Vivo exposure therapy. Thirty-three patients participated in the extended study and were divided randomly into two equivalent groups: the VR group and the Vivo group. All participants attended three sessions of treatment per week, each session lasted for one hour. Both groups showed improvements in anxiety and avoidance even after 6 months of follow-up. Results from this study revealed that the two types of therapy showed a significant improvement in anxiety and avoidance. The VR therapy was found to be more effective concerning the attitudes towards heights questionnaire. The main finding from this study is that VR treatment had the same effect as Vivo exposure.

Research studies started to focus on investigating whether the type of VR may affect its analgesic effect. Krijn et al. [22] conducted a study to compare the effect of using different types of VR exposure on thirty-seven patients with acrophobia. Participants were partitioned randomly into three groups: (1) VR group (using HMD), (2) VR group (using CAVE), or (3) control list group. The treatment included

TABLE 1. KEY FEATURES OF STUDIES USED VR FOR MENTAL HEALTH TREATMENT

Study	Sample	No.Sessions	Conditions	Findings	Disorder Treated
Rothbaum et al. [20]	20 students mean 20 years	8 sessions	VRE* / WL*	Acrophobia decreased for VR compared to WL	Acrophobia
Emmelkamp et al. [21]	33 patients mean 43 years	3 sessions 6 months follow up	VRE / Vivo	No differences in anxiety and avoidance for VR and Vivo	Acrophobia
Krijn et al. [22]	37 patients mean 50.6 years	3 sessions 6 months follow up	VRE(HMD)/ VRE(CAVE)/ WL	Acrophobia reduced for both VR groups with no differences in effect between them	Acrophobia
Suyanto et al. [23]	10 patients 21-25 years	4 tests	VRE	Reduced acrophobia when use VR exposure therapy	Acrophobia
Freeman et al. [24]	100 patients mean 30 years	6 sessions 4 Weeks follow up	Automated VR / C*	Automated VR reduced acrophobia compared to C	Acrophobia
Donker et al. [25]	74 patients 18-65 years	9 sessions 3 months follow up	VRE / WL	Acrophobia decreased consistently with the challenge presented in self-guided VR exposure	Acrophobia
Rothbaum et al. [26]	49 patients mean 40 years	8 sessions 6-12 months follow up	VRE / SE* / C	VRE and SE were equally effective greater than C	Aerophobia
Muhlberger et al. [27]	45 patients 25-65 years	1 sessions 6 months follow up	VR-mot*/VR-no-mot*/CBT*	VR treatment reduced aerophobia compared to CBT	Aerophobia
Rothbaum et al. [28]	83 patients mean 40 years	8 sessions 6-12 months follow up	VRE/ SE/ WL	VRE and SE were equally effective compared more than WL	Aerophobia
Tortella-Feliu et al. [29]	60 patients mean 36 years	6 sessions one year follow up	VRE/ CAE-T*/ CAE-SA*	Three treatment conditions were equally effective	Aerophobia
Klinger et al. [30]	36 patients 18-65 years	12 sessions	VRE / CBT	VRE was more effective than CBT	Social phobia
North et al. [31]	16 students	5 sessions	VRE / C	VRE reduced social phobia compared to C	Social phobia
Kampmann et al. [32]	60 patients mean 37 years	10 sessions 3 months follow up	VRE/ Vivo/ WL	VR was effective in treating social phobia	Social phobia

*VRE-virtual reality exposure; WL-waiting list; C-control; SE-standard exposure; VR-mot–VR motion simulator; VR-no-mot–VR without motion simulator; CBT-cognitive behavioral therapy; CAE-T–computer aided exposure with a therapist; CAE-SA–self-administrated computer aided exposure;

three 1.5 hour sessions. Gradually, participants who used VR were exposed to four different virtual environments. Using a (0-10) scale, patients rated their anxiety during exposure therapy. Results from self-reported questionnaires such as the acrophobia questionnaire showed that both groups (1 and 2) significantly improved compared to the third group. Also, there was no notable difference in results between groups (1) and (2). These results proved that VR therapy using an HMD had the same impact as using the CAVE.

According to the encouraging benefits of VR, there is an ongoing body of research to explore its treatment capabilities. Recently, ten patients aged (21-25) years participated in a study that integrated VR with Kinect to evaluate the efficacy of VR for reducing acrophobia [23]. The virtual system used in the study was a simulation game called "Acrophobia Simulator". The game included three different stages where difficulty was increased gradually. Participants experienced the VR application using Google cardboard. After the VR experience, the application was assessed using the state-trait anxiety inventory measurement. According to the results, patients reported a decrease in anxiety levels and an increase in improvements towards heights.

A year later, Freeman et al. [24] conducted another study to investigate whether VR technology can be used to automate acrophobia. One hundred patients participated and were divided randomly into two groups the automated VR group and the control group. The VR intervention used was "Now I Can Do Heights" which was developed for use without the help of any therapist. The treatment using VR included six sessions over two weeks with a VR experience last for 30 minutes. Many different measurements were used to assess the VR experience and data were collected. The results indicated a significant decrease in anxiety and acrophobia scores for those who used VR compared to the control group.

Recently, another clinical study was conducted to investigate the efficacy of using fully self-guided VR therapy delivered via low-cost VR hardware [25]. Totally seventy-four patients aged (18-65) years who suffered from acrophobia symptoms participated. Participants were randomized into two groups either the VR group or the wait-list group. Participants experienced a VR system called "Zerophobia", which consisted of six animated modules that differed in the engaging level. The VR therapy started from module three and the time range among modules was between 5 and 40 minutes. The game included a series of tasks with increasing levels of challenge (5 levels). The study included around nine sessions over three weeks. In case of decreasing anxiety levels, participants can experience VR in a standing-up fashion. A different set of questionnaires were used to assess the experiment. The results showed that a linear pattern existed between the anxiety score and the difficulty experienced at each level of the game (most reduction of anxiety occurred during level five). Moreover, it was shown that this fully self-guided application can be effectively used in the home setting.

B. VR for Aerophobia Treatment

Other several experimental studies also found encouraging results when used VR for treating aerophobia. In one study, conducted by Rothbaum et al. [26] forty-nine patients with aerophobia participated and randomly were assigned to one of three groups. The groups were: (1) a VR group that used a virtual airplane, (2) a standard exposure group who used an actual airplane, or (3) a waiting list group with no treatment. In

VR exposure patients experienced flying in a virtual airplane with different weather conditions, where the standard group experience actual flying using a stationary plane. Both groups (1) and (2) showed a significant improvement compared to the waiting list control with no notable differences between the same two groups. According to the 12 monthly follow up, results showed that the short-term VR treatment had a lasting effect with no need for relapse sessions.

Later on, one study was conducted to investigate the efficiency of one session VR treatment by Muhlberger, Wiedemann, and Pauli [27]. Forty-five patients with aerophobia participated and were randomly partitioned into three cognitive treatment groups: VR exposure with motion simulation (VR-mot), VR exposure without motion simulation (VR-no-mot), or cognitive treatment alone. All participants received cognitive therapy for 50 minutes. Both VR groups (VR-mot and VR-no-mot) used an HMD and experienced four VR flights with a 5-10 minute break between flights. Post-treatment and 6 months follow-up, results showed that there was a reduction in fear of flying for both VR exposure groups in contrast to the cognitive treatment group. The results of the two VR exposure groups were also compared and recorded that motion simulation didn't improve the treatment effects.

After the success of their previous research, authors Rothbaum et al. [26] conducted another study on eighty-three patients [28]. Randomly, participants were divided into three groups (1) therapy using VR (VRE), (2) therapy using standard Vivo (SE), and (3) waiting group (WL). The treatment duration lasted for six weeks including eight individual sessions. Over the first four sessions, both VRE and SE groups received the same treatment techniques and methodology. For the remaining sessions, the VRE group experienced VR exposure therapy and on the other hand, the SE group received the Vivo exposure therapy. Many self-reported questionnaires such as fear of flying inventory (FFI) were used to assess this clinical trial. Results indicated that there wasn't a significant difference between both VRE and SE groups. However, both groups significantly differed from the WL group. Also, after the follow-up period, the conducted analysis revealed that participants in both VRE and SE groups were more likely to fly (12.7) times over the WL group.

Another study was conducted to compare the efficacy of using VR exposure therapy against computer-aided therapy [29]. Sixty patients with aerophobia were eligible to participate in the study. The participants were randomly assigned to either (1) VR exposure therapy, or (2) computer-aided exposure with therapist (CAE-T), or (3) self-dependent computer-aided exposure (CAE-SA). Treatment using VR exposure included different scenarios with different situations gradually increased in difficulty through sessions. Therapists attended all CAE-T exposure sessions, where patients received six sequences of different tasks and were asked to rate fear at the end of each sequence. The final group received the same treatment as the CAE-T group except it was self-administrative. Results showed that there was no significant difference between the three treatment methods, they were equally effective in reducing the fear of flying disorder. Also, this study suggested that the therapist rule can be excluded during computer-based treatments.

C. VR for Social Phobia Treatment

Through last years, VR also helps people who suffered from social anxiety disorders. VR Therapy is promising for these patients as it provides different situations that are difficult to be handled in real life. Klinger et al. [30] conducted a study to compare VR therapy to cognitive therapy with thirty-six patients participated. Participants in the VR therapy attended 45 min sessions for 12 weeks where the VR intervention included four different scenes. After each session, all participants from both groups performed some tasks in vivo for practicing. Results indicated that patients treated using the VR therapy significantly improved as well as those in the cognitive group.

According to the considerable efficacy of VR therapy, another study was conducted with sixteen students who participated and were assigned to either the VR therapy group or the comparison group [31]. The VR therapy included a virtual environment for public speaking with a virtual wooden stage and a speaker's stand. A microphone attached to the HMD was used for speaking and generating the simulated echo in the hall. On the other hand, a simple VR scene was used to treat participants in the comparison group. Also, participants were motivated to control their fear using either visualization methods or self-exposure conditions. Both groups attended 10-15 min sessions for five weeks. Results indicated that anxiety symptom significantly reduced for those who used the VR intervention in contrast to the comparison group.

Kampmann et al. [32] conducted a study to investigate the effect of using VR exposure therapy for social phobia treatment. Sixty participants were divided randomly into three groups: (1) VR exposure therapy (VRET), (2) Vivo exposure therapy (iVET), and (3) waiting group. Participants during the VRET treatment sessions received different one-to-one and group situations to reduce their social anxiety symptoms. On the other hand, participants in Vivo exposure experienced real-life situations. Information from the statistical analysis revealed that both VRET and iVET improved compared to the waiting list group. However, results indicated that iVET is more efficient than VRET. This was because participants in iVET experienced a variety of social situations compared to VRET. So, this study suggested using the same situations with all active groups to be able to generalize results. Other several VR interventions were developed and effectively used to treat other types of phobia such as fear of driving [34], [35], [36] and fear of spiders [37], [38], [39].

Notably, VR-based treatments for different mental health problems have observed positive findings. The results of the presented studies showed that VR therapy is as effective as Vivo therapy. However, VR therapy has many key features over Vivo; it is a stable application, cheap and controlled, can be used repeatedly, can experience difficult situations safely, and provide more confidentiality. Also, findings indicated that using HMD or CAVE to deliver VR therapy resulted in an equal treatment impact, but HMD VR is cheap, easy, and more appropriate compared to the CAVE VR. Another key issue revealed from the controlled studies is that VR therapy is more effective than cognitive-behavioral therapy. Finally, as the cost of VR software and hardware has decreased, VR therapy may become increasingly available.

IV. VR FOR ACUTE PAIN MANAGEMENT

VR provides a unique distraction with multisensory, immersive, and interactive environments. Therefore, VR is effectively used in various types of health care applications especially for managing pain associated with different medical procedures. A lot of research studies have been conducted to explore the relationship between immersion and VR distraction effects. The findings of these studies reported that VR is a promising alternative for managing acute pain related to burn wound care and other routine medical procedures. Through this section, we will present the literature on using VR distraction interventions for managing acute pain. We will focus on presenting the conducted studies for reducing pain in patients with severe burn pain and other types of routine medical procedures (see Table 2).

A. *VR for Burn Pain Management*

Wound care after burn injury is one of the most painful medical procedures. In favor of wound healing, it is required to repeat the procedure of wound care dressing changes regularly. Treatment of severe burns usually includes tanking sessions, which required the removal of old bandages and dead skin in a hydro tank, then taking a dose of antibiotics and putting a new bandage. Patients with severe burns can also experience extreme pain due to physical therapy exercises, which play an important role during treatment and afterward. This may discourage patients especially children from complying with their physical therapy [55]. VR technology gains a growing interest as an alternative for managing pain in adolescents with burn injuries, as indicated by many successful controlled studies with children and adults [56].

Hoffman et al. [40] investigated the effect of using VR for severe burn pain management. The study included eleven patients aged (9-40) years who suffered from severe burns and required burn wound dressing changes in a hydrotherapy tank. To ensure safety, the study was conducted using a custom fiber optic VR system suitable for water use. The virtual environment used in the study was "SnowWorld" [57], which is the first environment designed for distracting burn patients. The 6-minutes wound care session for each patient is divided into two equivalent portions. During one portion, the patient used VR distraction for pain relief. The patient spent the other portion of the session without any distractor. Randomly, patients were assigned to one of two conditions: VR-first or VR-last. All patients reported that while being in VR they spent less time thinking about pain. Besides, patients with severe pain intensity showed a reduction of pain by (41%) while being in VR compared to the control condition. The study results indicated that VR distraction has a great impact on reducing pain associated with the wound care procedure.

Kipping et al. [41] through another study demonstrated the effectiveness of using VR system "off-the-shelf" with adolescents undergoing burn wound care. The main research questions included whether "off-the-shelf" VR is more effective than the standard distraction, besides investigating the impact of using VR on wound care procedures length. The randomized controlled trial included forty-one adolescent participants aged (11-17) years. Patients were assigned to one of two groups: the VR group (VRG) or the standard distraction group (SDG). The trial ensured applying the same medical procedures with all participants and to be conscious during their wound care dressing change. According to the results from the nursing staff, patients in the VR group experienced less pain during wound care dressing compared to the other group. Concerning the length of treatment, participants who used VR required a lower time for the dressing process (10 minutes) against (12 minutes) for the standard group.

In a related study, thirty adolescents aged (10-17) years participated and were divided into three groups: VR active distraction (SnowWorld VE), passive distraction (watching a movie) and standard care [42]. To include patients with facial burns, the VR group used a helmet device with a tripod instead of using the HMD. To assess pain Adolescent Pediatric Pain Tool word-graphic rating scale (APPT-WGRS) measurement was used [58], which is a 100-millimeter line word graphic scale to rate pain scores. The results showed that the VR distraction group reported a significant reduction in pain in contrast to the other two groups. Besides, the only group that reported a decrease in pain perception during burn wound care compared to pre-procedure pain was the VR distraction group.

Brown et al. [43] used a multi-model VR inspired intervention titled "Ditto" with manual control. The Ditto medical device is suitable for children aged (3-12) years and is used to distract the child during medical procedures by using interactive games or stories. The child in the preparatory phase of the device should know details of the medical procedures to reduce his fear and distress. Participants in this study were assigned to either the Ditto distraction group or the standard practice group. Before and immediately post to the burn wound care process, data from physiological measures and other scales were recorded. Results showed that patients receiving Ditto distraction recovered faster than those in the standard group by an average of two days. Moreover, self-reported pain and anxiety in pediatric patients who used Ditto decreased compared to the other group.

Overall results from the conducted studies showed that VR is an effective tool for reducing pain in burn patients. These results along with the availability of VR technology have motivated authors to investigate whether low-cost VR distraction will be effective as well. One study with inexpensive Oculus Rift goggles was on a boy aged eleven years during his occupational treatment [44]. He suffered from severe electric and flash burns on different parts of his body. For three consecutive days, he received three treatment sessions included one 20-minute session with no VR, then one with VR, and finally a session with no VR. The patient reported less pain perception and reduced discomfort, besides feeling more fun during physical therapy when used VR. Another related study was conducted to evaluate the effect of using inexpensive VR technology on patients with burn injuries [45]. Ten adult patients from an outpatient clinic participated in this study during their burn wound care procedure. Both patients and providers completed a satisfaction survey that summarized their experience with VR. Results proved that distraction using inexpensive VR technology is effective during burn wound care and/or dressing changes.

Through the last two decades, enormous studies showed that VR has great potential for managing pain associated with burn care procedures in both adolescents or adults. However,

TABLE 2. KEY FEATURES OF STUDIES USED VR FOR ACUTE PAIN MANAGEMENT

Study	Sample	No.Sessions	Conditions	Findings	Pain Type
Burn Injury					
Hoffman et al. [40]	11 patients 9-40 years	1 session	VR* / C*	VR reduced extreme burn pain compared to C	Burn injury
Kipping et al. [41]	41 patients 11-17 years	Not provided	VR / SD*	Mean pain scores for SD was higher than VR	Burn injury
Jeffs et al. [42]	30 patients 10-17 years	1 session	VR/ PD*/ SC*	The mean pain scores for PD was the highest	Burn injury
Brown et al. [43]	75 patients 4-13 years	Not provided	Ditto / SD	Pain and anxiety levels for Ditto were lower than SD	Burn injury
Hoffman et al. [44]	A boy aged 11 years	3 sessions	VR+SC / SC	VR reduced pain intensity and pain unpleasant compared to SC	Burn injury
Ford et al. [45]	10 patients mean 40 years	1 session	VR	Inexpensive VR is also effective during burn wound care	Burn injury
Khadra et al. [46]	15 patients 2 months-10 years	1 session	ProVR*	ProVR was an effective in reducing pain in children $\leq$ 4 years	Burn injury
Hoffman et al. [47]	48 patients 6-17 years	4 sessions	VR / C	Children's worst pain decreased when used VR	Burn injury
Routine Procedures					
Gold et al. [48]	57 patients 8-12 years	1 session	VR(HMD)/ VR(Desktop)/ SD/ C	VR via HMD is more effective than the other three groups	Blood draw
Gold et al. [49]	20 patients 8-12 years	1 session	VR / SC	SC felt pain of IV* placement four-times greater than VR	IV placement
Piskorz and Czub [50]	38 patients 7-17 years	1 session	VR / C	Pain and stress during blood draw reduced with VR	Blood draw
Hoffman et al. [51]	Two patients 51-56 years	1 session	VR / SD / C	VR reduced dental pain compared to other groups	Dental
Furman et al. [52]	38 patients mean 45 years	1 session	VR / SD / C	VR provided an analgesic effect greater than SD and C	Dental
Aminabadi et al. [53]	120 patients 4-6 years	3 sessions	VR / C	VR decreased pain and anxiety compared to C	Dental
Tanja-Dijkstra et al. [54]	69 patients mean 33 years	1 session	AVR* / PVR* / C	AVR increased presence more than PVR, AVR achieved the least aware of the surroundings	Dental

*VR-VR distraction; C-control; SD-standard distraction; PD-passive distraction; SC-standard care; ProVR-projector-based VR
AVR–active VR; PVR–passive VR; IV–intravenous

using VR to control pain in children aged less than 4 years has not been studied as much. One pioneering study was conducted by Khadra et al. [46], which used a projector-based VR system to distract children suffered from burn injuries. Fifteen children with ages ranged from two months to ten years were participated. The research group developed a 3D video game called "Bubbles" to be used in the study. The difficulty level of the game was consistent with the child's age. The game was started once the wound care session was started. This projector-based VR distraction was combined with the standard care medications. The VR experience involved only one session and the pain was assessed through five time periods. Results proved the feasibility and acceptability of the proposed VR system for managing procedural pain in children less than 4 years.

Many burn patients who have burns on their heads can't receive the VR intervention using an HMD. To solve this issue, a recent study was conducted and used for the first time a new portable water-friendly VR system especially for patients with severe burns [47]. The study included forty-eight patients aged (6 - 17) years. The study used a within-subject design where each patient experienced either VR or control conditions for five minutes during the same wound care session. The order of receiving the conditions was randomized. Patients played "SnowWorld" during the VR proportion, while received the standard wound care in the other proportion. The study used the graphic rating scales (GRS) to keep track of the worst pain, pain unpleasantness, and time spent thinking about pain. Post to the wound care session, each patient rated the pain intensity experienced in both conditions. The patient's worst pain score significantly decreased from (8.52) during standard care to (5.10) while using VR. For pain unpleasant score, it was decreased from (6.40) during the standard care against (3.47) while using VR. Also, patients spent less time thinking about pain when using VR.

B. VR in Routine Medical Procedures

Stress and anxiety in pediatrics are common symptoms associated with most hospital procedures especially needle-related procedures. VR offers a great opportunity for distracting patients during routine painful medical procedures [59]. Gold et al. [48] conducted a trial including fifty-seven participants aged (8-12) years to explore the effect of using VR distraction during the procedure of blood draw. Children were divided into four groups: (1) perceiving VR using an HMD, (2) perceiving VR using a desktop, (3) standard distraction, or (4) control group. For achieving visual occlusion, all participants received blood draw by passing their arm through a wall. Many self-reported and observational scales were used to assess pain before and post to the procedure. Results showed that participants in the HMD based VR group reported a reduction in pain compared to the other three groups. Also, children reported less pain during the procedure when used the HMD VR compared to the other two distraction groups. The same author performed another randomized control trial on twenty children requiring intravenous (IV) placement [49]. Randomly, children were assigned to one of two groups: (1) VR group, or (2) standard care group. For participants who received VR, the experience started 5 minutes before the IV placement and lasted for 5 minutes after. On the other hand, a local anesthetic spray was used with participants in the standard control group without receiving any VR intervention. The results showed that the children who used VR didn't report any increase in pain after the IV placement compared to a four-time increase for the other group.

Lately, many authors have designed a VR game with difficulty levels adjusted with the child's age. Also, they used the concept of multiple object tracking (MOT) in their game hence attracting most of the child's attention. The study involved thirty-eight patients aged (7-17) years during their blood draw in a clinic for pediatric [50]. Participants were partitioned into two groups: (1) VR group, or (2) control group. Children in the VR group started using the VR intervention just before the blood draw and continued until after the procedure was finished. On contrarily, children in the control group didn't receive any distraction during the blood-draw procedure. Both groups were asked to describe their blood draw experience and provide a report that included stress level and pain score. Results indicated that there was a significant reduction in pain for participants who used VR compared to the standard control group. Those who used VR reported a (59%) reduction in pain intensity score against the other group.

VR's unique characteristics also attracted authors to investigate its efficacy in controlling the pain related to different dental procedures. Many controlled studies demonstrated the impact of using VR on dental pain. Hoffman et al. [51] conducted a study involving two dental patients to explore the analgesic effect of VR. Each patient received his dental treatment under three different situations: (1) VR distraction, (2) standard distraction, or (3) control condition. Both patients spent an equal interval of time in each condition, besides the order of conditions was random. Both patients rated their pain intensity and provided the time spent thinking about the medical procedure. Patient 1 reported a mild pain score (1.2) during VR compared to severe pain (7.2) during the other conditions. On the other hand, patient 2 reported no pain score (0.6) during VR against mild pain (3.3) in the standard condition and moderate pain (4.4) during the control condition.

In a close study, thirty-eight dental patients participated and each one experienced three different treatment conditions: (1) VR distraction, (2) watching a movie, or (3) control condition [52]. The sequence of treatment conditions for each patient was chosen randomly. During the study, participants were asked to report their pain intensity and unpleasantness level using the visual analog scale (VAS). The mean VAS scores for VR, standard, and control groups were (1.76 vs 2.57 vs 3.95) respectively. Results also revealed that both distraction conditions (VR and watching a movie) led to a significant pain reduction in comparison with the control condition.

To date, a few research studies were conducted to investigate the impact of VR on children with dental pain. Aminabadi et al. [53] presented one study to explore the effect of using VR technology for distracting pediatric patients during dental treatment. The study included one hundred and twenty children aged (4-6) years partitioned randomly into two groups. The treatment procedure included three sequential sessions where all children in both groups received fluoride therapy in their first session. During the second session, groups 1 and 2 received restorative treatment procedures with and without VR respectively. Finally, the third session included the same treatment procedures as the second session with exchanging groups 1 and 2 conditions. To assess pain intensity a "Wong Baker FACES" scale was used and measured after each session for both groups. Results demonstrated that VR interventions can be used successfully to decrease pain severity and anxiety during dental procedures. For both groups, the pain intensity scores were lower when using VR (group1: 1.89, group2: 2.05) compared to sessions without VR (group1: 3.00, group2: 3.05).

The valuable benefits of using VR for dental pain reduction motivated other authors for further research. Another study was conducted including sixty-nine adult patients, randomly they were assigned to one of three conditions: active VR, passive VR, or control [54]. Besides, at the beginning of the study participants were divided into two groups according to their dental anxiety (high and low). A simulated dental area was established with heart rate measured during the treatment and blood pressure measured immediately after finishing. Participants in the active VR group reported a higher presence (mean 6.21) against (mean 5.16) for the passive VR group. Also, results showed that distraction from VR could influence the patient's memory after the treatment sessions ended.

As a whole, the presented studies in this section showed that VR distraction is an effective adjunct for controlling pain during burn wound care and routine medical procedures. Due to the nature of burns, a lot of studies used specially designed hardware to deliver VR. However, the findings of these studies supported the analgesic effect of VR on pain reduction. Besides, low-cost VR proved to be effective and hence may become more affordable. Also, VR distraction was used safely and effectively with children less than four years. Furthermore, studies indicated that the impact of interactive VR was greater than the passive one. Finally, immersive VR distraction showed a reduction in pain than non-immersive VR.

V. VR for Chronic Pain Management

Unlike acute pain, the duration of chronic pain starts from six months and continues after the expected period of recovery [4]. Chronic pain may include chronic headache, back or limb pain, and also complex regional pain syndrome. Despite the large number of studies that support the efficacy of VR for reducing acute pain, limited was conducted for the use of VR with chronic pain [60], [61]. In one pilot study, Sato et al. [62] investigated the effect of using VR for reducing complex regional pain syndrome in adults. Five adult patients aged (46-74) years with complex regional pain syndrome participated and experienced a non-immersive VR system along with mirror visual feedback. The study included four to eight outpatient sessions. Results indicated that four out of the five patients reported (50%) less pain. The authors recommended conducting further research studies with larger samples to be able to generalize these results.

Another study was conducted to explore the use of VR as an alternative therapy for reducing chronic pain [63].

Participants were forty patients aged (22-68) years exposed to a 15-minute VR session using an HMD. The pain scores of patients were measured before and during the VR experience, but not after the experience was completed. To assess pain, data from self-reported measures, heart rate, skin temperature, and pain intensity rates were collected. Patients reported that their pain ratings significantly decreased while exploring the VE (mean pain score approximately 0.8) compared to the control condition (mean pain score approximately 2.3). Results from the study suggested that VR can be effectively used for reducing chronic pain.

Jones, Moore, and Choo [64] conducted a study on thirty patients aged at least 18 years to investigate the impact of using VR applications for controlling chronic pain syndromes. The patients who participated in the study were exposed to a VR experience for five minutes. The VR application used in the study was called "COOL!", and there were two ways to deliver VR one using HMD and the other using DeepStream 3D Viewer. Participants were asked to assess their pain intensity prior to, during, and after the VR session using the 0-10 numerical rating scale. Participants reported a decrease in pain intensity by (60%) from pre-session during VR session, and a decrease in pain intensity by (33%) from pre-session to immediately after the VR session was completed.

The same author continued his research by conducting another study to answer the question previously posed in [64]. The research question was about whether longer VR sessions will result in a larger analgesic effect when used repeatedly with chronic pain. This pilot study included ten patients aged at least 18 years old primarily diagnosed with one of the chronic neuropathic pain types [65]. Participants delivered three 20-minute VR sessions (COOL! intervention) in three consecutive weeks. The 0-10 numerical rating scale was used to measure the pain severity experienced by patients before, during, and immediately after the VR session. Patients reported significant analgesia during and immediately after the VR session with decreased pain intensity (65% reduction during VR session and (45%) after the session). Overall, based on the results from the presented studies, VR interventions can be effectively used for controlling chronic pain [66].

VI. VR for Cancer Pain Management

Cancer patients usually experience pain as a common consequence of both the disease and its treatment. Today, chemotherapy is the leading cancer treatment. However, physical symptoms such as fatigue, pain, sleep disturbances, and other symptoms frequently start during the administration of chemotherapy sessions. As a result, cancer patients frequently suffering from distress, depression, and helplessness leading to incomplete treatment with decreasing chances of recovery. VR distraction interventions showed great potential in decreasing pain related to common painful cancer procedures whether diagnostic or treatments (see Table 3).

Many studies have been conducted to investigate the usability and analgesic capabilities of VR for reducing cancer pain. Schneider and Workman [67] performed a study on eleven children aged (10-17) years during receiving their chemotherapy session. This study included three different VR scenarios: Magic Carpet, Seventh Guest, and Sharlek Holmes. Children used the VR application for 5 minutes before the chemotherapy session to get familiar with it. The VR experience continued until the end of the session and then the VR headset was removed. Most of the children preferred the seventh guest scenario because its graphics were clear, easy to use, and included little instructions used. Results indicated that (82%) of the children preferred treatment with VR compared to previous chemotherapy treatments and they are interested in using VR in future treatments.

There is a scientific concern about the influence of VR on time perceived by patients during receiving their chemotherapy treatment. Many studies proved that experiencing VR interventions during receiving the chemotherapy treatment decreased the amount of perceived treatment time compared to the actual elapsed time. In one study, twenty adult women aged (18-55) years participated during their chemotherapy session for breast cancer [68]. This study used a within-subject design where each participant experience VR therapy and control conditions. Randomly, participants were divided into two groups (A and B). The difference between the two groups was whether exposed to the VR intervention in the first treatment session or the second. During the session without VR, participants were provided with different standard care methods. This study included three different VR scenarios: sea diving, walking in a museum, and solving a mystery. The symptom distress (SDS) and revised piper fatigue (PFS) scales were used to assess pain in this study. The lowest scores of the two scales (SDS: 16.6 and PFS: 1.85) occurred immediately after the chemotherapy session while using VR. Besides, the patients reported a lower estimated time duration while using VR (42 minutes) compared to the actual treatment time (67 minutes). No significant changes in both measures were reported after two days of follow-up. These results showed that using VR technology resulted in a significant reduction in symptom distress and fatigue during chemotherapy treatment.

Cancer patients essentially use ports and venous puncture of a vein for delivering chemotherapy. Gershon et al. [69] performed a study on fifty-nine children aged (7-19) years during their port access procedure. Children who participated were divided into three treatment groups including (1) distraction using VR group, (2) standard distraction group, or (3) control group. Both groups (1 and 2) experienced the same intervention called "Virtual Gorilla" [75] where the VR group used an HMD and the standard group used a computer monitor. For 5-minutes before the port access process, participants in groups (1 and 2) started using their distractors, while the control group did nothing. According to the information provided by the pulse rate measurement, there was a notable difference between all groups during the port access procedure (VR: 96.3, standard: 103.8, and control: 110.3). Depending on that study's finding, distraction using the illusion of VR has potential benefits in reducing pain during painful medical procedures.

Schneider and Hood [70] conducted another study that conformed the findings from [68]. This study included one hundred and twenty-three adult patients who suffered from different types of cancer. The authors used the same methodology and assessment measures as in their previous study. Participants reported that while using VR, they perceived a lower estimated time (47 minutes) against the actual chemotherapy

TABLE 3. KEY FEATURES OF STUDIES USED VR FOR CHRONIC AND CANCER PAIN MANAGEMENT

Study	Sample	No.Sessions	Conditions	Findings	Pain Type
Chronic					
Sato et al. [62]	5 patients 46-74 years	6 session	VRMVF*	VRMVF reduced chronic pain by more than 50%	Chronic pain
Wiederhold et al. [63]	40 patients 22-68 years)	1 session	VR*	VR reduced level of pain and anxiety	Chronic pain
Jones et al. [64]	30 patients 35-79 years	1 session	VR	VR decreased the sensation of chronic pain	Chronic pain
Jones et al.[65]	10 patients at least 18 years	3 sessions	VR	Reduction in pain ratings occurred using VR	Chronic pain
Cancer					
Schneider and Workman [67]	11 patients 10-17 years	1 session	VR	VR improved the chemotherapy treatment session	Cancer pain
Schneider et al. [68]	20 patients 18-55 years	2 sessions	VR / C*	VR reduced the distress and fatigue of chemotherapy	Cancer pain
Gershon et al. [69]	59 patients 7-19 years	1 session	VR / SD* / C	Lower ratings of pain when using VR	Cancer pain
Schneider and Hood [70]	123 patients mean age 54 years	2 sessions	VR / C	VR reduced the perceived time of chemotherapy	Cancer pain
Nilsson et al. [71]	42 patients 8-15 years	1 session	VR / C	Non-immersive VR provided a decrease in observational pain	Cancer pain
Schneider, Kisby, and Flint [72]	137 patients at least 18 years	2 sessions	VR / SC*	VR led to an underestimation of chemotherapy duration	Cancer pain
Birnie et al. [73]	17 patients 8-18 years	1 session	VR	VR increased sense of presence and hence reduced pain	Cancer pain
Sharifpour et. al [74]	30 patients mean age 14.8	8 session	VR / C	A significant reduction in pain scores for the experimental groups against the control group	Cancer pain

*VRMVF–VR mirror visual feedback; VR–VR distraction; C–control; SD–standard distraction; SC–standard care

treatment time (58 minutes).

Nilsson et al. [71] conducted a study to evaluate the effectiveness of using a non-immersive VR application for reducing pain during different needle-related procedures. Forty-two children and adolescent patients aged (5-18) years who were diagnosed with one of the childhood cancers participated during receiving their therapy. The participated subjects were divided into two groups, the first used a VR distraction intervention and the second didn't receive any distraction. The VR application used was a 3D game called "The hunt of the diamonds", which presented on a desktop monitor rather than using an HMD. To assess the observational pain experienced by the participants, the FLACC scale was used [76]. The FLACC pain scores for the VR group did not increase during the medical procedure compared to the control group. With respect to the heart rate scale, there was no significant difference between the two groups. The results of the interviews conducted with patients who used VR recommended that the VR application should be consistent with the patient and the medical procedure.

Another related study was conducted to explore the influence of many variables such as age, gender, and other variables on time perceived by cancer patients during receiving their chemotherapy while using VR applications [72]. Patients participated aged at least 18 years old and diagnosed with breast, colon, or lung cancer. Randomly, participants received the VR distraction intervention during either the first treatment session or the next. During the treatment session without VR, patients received any type of standard care techniques. The anxiety and fatigue ratings were assessed before and post to the two conditions (VR and standard care). Also, the researcher of the study recorded the estimated time perceived by each patient while using VR and compare it with the actual treatment time. According to the results, there was a significant reduction in time perceived by patients with an average of 23 min with breast, 12 min with colon, and less than 4 min with the lung.

Again another study proved that using VR technology during needle-related procedures offered promise for pain and distress reduction [73]. The study included seventeen participants aged (8-18) years who suffered from cancer and their treatment required the insertion of an implantable venous access device (IVAD). The study included three cycles for testing the usability of VR distraction capabilities and the participants were assigned to one of these cycles. Participants in the first cycle, experienced the VR application before their IVAD insertion to guarantee the application safety and if it may result in any side effects. While through cycles 2 and 3, participants were exposed to the VR application while inserting their IVAD device. After procedure completion, which lasted for 5 to 10 minutes, all participants were required to have a 5-min interview to evaluate the functionality of the VR distraction intervention. Concerning the baseline pain and symptoms scale which is a 0-10 numeric scale (0-no pain, 10-high pain), (70%) of patients reported no pain and (29%) reported mild to moderate pain intensity. Both nursing staff and patients reported that the distraction from VR has great potential in decreasing pain and distress related to the IVAD access procedure.

Recently, another study was conducted to assess the efficacy of using VR therapy for reducing chemotherapy-related pain symptoms [74]. The study included thirty adolescents with different types of cancer. Using a between-subject design, participants were randomly assigned to (1) the experimental VR group or (2) the control group. The experimental group received VR for 30 minutes once a week for two months. On the other hand, the control group didn't experience any distraction interventions. Participants in VR watched a VR movie that included a journey to the depths of the ocean and deliver it using a Samsung gear headset. Different pain measurements were used to assess the perceived pain. Also, these data were maintained after two intervals of follow-up (7 days and 1 month). Results indicated a significant reduction in pain intensity and anxiety scores for the VR group compared to the control group. This is another study to prove that VR technology had a significant positive effect on patients with cancer pain.

The findings of the controlled studies we discussed in this section indicated the efficacy of VR distraction in reducing chronic as well as cancer pain. Chronic pain is a common health problem that needs effective distraction techniques for managing. However, limited research studies have been conducted for exploring the effect of using VR in chronic pain. The presented studies provided the efficacy of using VR for a short time duration. As chronic pain is persistent, there is a need to investigate the effect of usage for repeated and long time durations. So, VR distraction can be used successfully with patients in their homes. Also, more research on exploring the duration of the analgesic effect of VR is important. Chronic and cancer pain share a common limitation, their studies neither compare VR with other distraction techniques nor control conditions. Comparing VR with other distractions is valuable to adjust the VR applications accordingly to obtain higher analgesic effects. Moreover, most of the cancer studies used a within-group design. Using the between-group design will help to ensure the efficacy of VR distraction. Finally, patients with cancer increase every day, and cancer pain is combined with many emotional and behavioral problems that need to be managed effectively. VR distraction may become an essential tool for managing and reducing cancer pain. According to all studies mentioned in this survey and others which can be found in [77], [78], VR technology proved to be a promising distraction tool with unique characteristics for controlling pain associated with different medical and clinical procedures.

VII. Discussion

We categorized the most common areas that use VR technology for managing pain as shown in (Fig. 2). Based on the referred studies in this survey and other identified reviews, we found that VR can be used in one of two directions. The first one is using VR in many psychological treatments, while the other is using VR for reducing physical pain. The most well-known area in psychology that makes benefits from the illusion of VR is treating phobias, and there is continuing research to generalize using it. On the other hand, VR is effectively being used for controlling many types of physical pain: 1-acute, 2-chronic, and 3-cancer pain. Also, growing research studies is being conducted to investigate deeply the analgesic effect of VR for managing physical pain. One day, VR will be used widely in many applications that assist the healthcare sector.

According to the presented studies, we found that all studies in psychological treatment used specially designed VR environments and an HMD to deliver VR. For studies that used VR during burn wound care, many of them utilized a “SnowWorld” environment [40], [42], [44], [47], and others used specially designed VR environments [41], [43], [45], [46]. All of the studies for burn wound care used specially designed HMD to experience VR, except for one study that used normal HMD [45] and excluded patients with face and/or neck burn injury. The HMDs of type i-glasses were commonly used to deliver VR during dental procedures [51], [52], [53], [54], and other routine medical procedures used normal HMD [48], [49], [50]. All routine medical procedure studies used specially designed environments, except [51] used “SnowWorld” system. The other category of studies that used VR for chronic pain management used specially designed VR environments and an HMD to deliver VR [62], [63], [64], [65]. Only one study used a non-immersive computer-based VR system [62]. Variations of VR hardware were used with cancer patients during receiving their chemotherapy treatment. Some used the i-glasses HMDs [67], [68], [70], [72], while [69], [73], [74]used normal HMD, and [71] used a standard personal computer. All of these studies used specially designed VR environments. Tables 4 and 5 summarize the VR hardware and software used in the presented studies.

The main challenge found is that the observations can’t be generalized. For each pain type, each study used a different procedure with different settings along with different sample sizes. This is why we can’t generalize the results from the conducted studies. The results of controlled studies showed that VR technology has the potential in treating different types of phobias. Most of these studies indicated that VR therapy has the same analgesic effect as Vivo therapy [21]. However, VR therapy is considered a stable application, cheap, and controlled. Also, it can be used repeatedly, can experience difficult situations safely, and provide more confidentiality. These features can encourage conducting more research to support using VR therapy. Also, studies that compared VR(HMD) against VR(CAVE) revealed that they are equally effective [22]. With the decreasing cost of VR technology, VR(HMD) will be cheap, easy, and more appropriate compared to VR(CAVE). Another key issue reported from the controlled studies is that VR therapy is more effective than cognitive-behavioral therapy [30].

Besides, many considerable issues were found in the presented studies. First of all, most of the research studies involved a small number of participants [23], [40], [45], [46], [62], [65], [67]. So, further research studies with a larger number of participants have to be conducted to confirm the efficacy of VR distraction in managing pain. Another issue, most of the studies depended on self-reported scales or observational scales to assess pain related to the medical procedure [24], [32], [49], [70]. To ensure a reliable assessment of pain, future studies should use other physiological or behavioral measures along with subjective ones. When designing a future VR study, it is valuable to consider comparing the effect of using VR against other standard distraction techniques [20], [31], [40], [64], [68]. Comparing VR therapy with other distraction techniques will help to determine the appropriate mechanisms of using VR interventions that will result in the most distraction effect. Moreover, future studies should develop new VR applications consistent with the patient’s pain threshold and the pain type [65], [47]. Consequently, these applications will ensure the best analgesic effect of VR distraction.

A scientific research question about using VR for managing pain is that the VR analgesic effect could decrease due

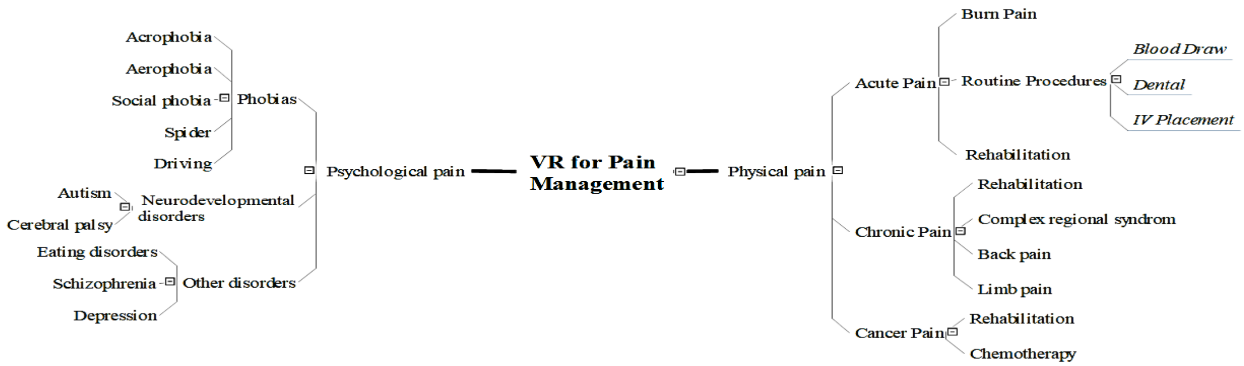

Fig. 2. VR for Pain Management in Healthcare.

to repeated use. To investigate this issue, few studies were conducted and showed that the effect of using VR interventions was not lost across repeated exposures [79], [80], [81]. However, more research is needed to ensure these findings. Thus, further research studies with a larger sample size along with applying VR intervention repeatedly are required to investigate the benefits of using VR for long-term treatment [45], [68], [72], [71]. Other scientific questions that need more investigation in future studies include whether VR therapy will effectively distract patients especially children during longer medical procedures [50] and if longer VR sessions will be more effective than the shorter ones [64].

Several studies have reported that VR technology has a promising ability to reduce acute pain. VR distraction provides an effective alternative for reducing pain during burn wound care and routine medical procedures. Despite using different types of VR hardware with burn patients [44], [46], the findings indicated the effectiveness of VR in reducing pain. Besides, using low-cost VR technology proved to be effective for managing pain. Hence VR distraction may become more available [45]. Also, VR distraction was used safely and effectively with children less than four years [46]. In contrast, few studies assessed the effect of using VR with chronic pain. The presented studies proved the efficacy of using VR for a short time duration [63], [64]. Further research is needed to investigate the effect of using VR distraction repeatedly and for long time durations [64], [65].

Pain from cancer is different; it is complex and has multidimensional sensory, affective, cognitive, and behavioral components [82]. Cancer-related pain can result from the disease itself, medical treatments such as chemotherapy and radiation therapy, and needle procedures such as blood draws, port access, and lumbar punctures [83], [84]. Also, as a result of chemotherapy patients experience some physical symptoms such as nausea, anxiety as well as depression, helplessness, and difficulty in concentrating [85]. To date, most cancer-related pain can be effectively managed using pharmacological and non-pharmacological strategies [86]. However, emotional and behavioral problems such as sleep disorders, procedural distress, restriction of social activities, and depression still need to be controlled especially for children with cancer [84]. VR provides a multisensory three-dimensional experience that diverts the attention of the patient away from painful stimuli. Recent advances in software and hardware besides cost reductions made VR promising for managing pain and other emotional problems related to cancer [87]. Another direction of research for VR distraction that may produce more analgesic effects is integrating VR distraction with Cognitive behavioral therapy. To our knowledge, few studies investigated the effect of integration [27], [88]. So, future research studies may consider this direction that that may increase the impact of VR distraction.

Our findings are consistent with previous reviews, which have shown that VR is effective in managing different types of pain. In sum, VR has emerged as a powerful non-pharmacological treatment intervention. According to the presented studies, effective VR distraction can be achieved using several resources and different settings. So, today VR is being used in numerous medical applications to help treat many psychological disorders and control pain. Despite the promising results indicated from the literature, we found that there is no study focused on investigating the impact of different visual parameters on human perception in VR. It is highly demanded to conduct further research to determine the visual effects that perceive most of the patient's attention and in turn provide more distraction and more pain tolerance. Finally, to ensure the effectiveness of the used VR application, more research is needed to determine how VR works to reduce the experienced pain and what is the best form of VR that provides a much analgesic effect.

VIII. Conclusion

Nowadays non-pharmacological analgesics including VR have great potential in managing pain related to different health care problems. This survey showed that VR technology is quickly gaining attention as a promising alternative for distracting patients during painful medical procedures. All studies presented in this survey have investigated the impact of using VR in controlling pain (acute, chronic, or cancer) experienced by adults or children. Findings from the presented studies showed that using any type of distraction is better than no distraction. In addition, interactive distraction is more effective than passive distraction. With VR distraction interventions, results indicated that high technology equipment provides much more immersion and presence than low technology, so pain intensity significantly decreased. So, the more quality of the VR system, the more analgesic effect occurs.

TABLE 4. VR HARDWARE AND SOFTWARE EQUIPMENT FOR PSYCHOLOGICAL TREATMENT

References	VR Software Equipment	VR Hardware Equipment
	Acrophobia	
Rothbaum et al. [20]	Special designed environments (footbridges, balconies, and elevator)	HMD
Emmelkamp et al. [21]	Special designed environments (a mall, a fire escape, and a roof garden)	HMD
Krijn et al. [22]	Special designed environments (a mall, a fire escape, a roof garden,and a building site)	HMD & CAVE
Suyanto et al. [23]	A special designed game (Acrophobia simulator)	HMD
Freeman et al. [24]	A special designed application (Now I can do heights)	HMD
Donker et al. [25]	A special designed application (ZeroPhobia)	HMD
	Aerophobia	
Rothbaum et al. [26]	A special designed virtual airplane	HMD
Muhlberger et al. [27]	A special designed simulated flights	HMD
Rothbaum et al. [28]	A special designed virtual airplane	HMD
Tortella-Feliu et al. [29]	A special designed virtual flight software	5D Technologies HMD
	Social phobia	
Klinger et al. [30]	Four special designed environments	HMD
North et al. [31]	A special designed software to generate a fearful public speaking situations	HMD
Kampmann et al. [32]	A special designed virtual social environments (one-to-one and group situations)	HMD

TABLE 5. VR HARDWARE AND SOFTWARE EQUIPMENT FOR PHYSICAL PAIN REDUCTION

References	VR Software Equipment	VR Hardware Equipment
	Burn Pain	
Hoffman et al. [40],Jeffs et al. [42] Hoffman et al. [44],Hoffman et al. [47]	SnowWorld VR system	A special designed VR system (VR helmet mounted to articulated arm)
Kipping et al. [41]	Chicken Little™ and Need for Speed™ games	A special designed VR system (off-the-shelf VR system)
Brown et al. [43]	Ditto™ intervention	An immersive hand-held device (Ditto)
Ford et al. [45]	Eight special designed environments	Sunny peak VR headset
Khadra et al. [46]	A special designed Bubbles video game	A special designed VR system (a projector-based VR system)
	Routine Procedures	
Hoffman et al. [51]	SnowWorld VR system	i-glasses HMD
Furman et al. [52],Aminabadi et al. [53] Tanja-Dijkstra et al.[54]	A special designed VR environment	i-glasses HMD
Gold et al. [48],Gold et al. [49] Piskorz and Czub [50]	A special designed VR environment	HMD
	Chronic Pain	
Sato et al. [62]	A special designed virtual environment	Non-immersive computer-based VR system
Wiederhold et al. [63]	A special designed virtual environment	HMD
Jones et al. [64],Jones et al.[65]	VR application called COOL	Oculus Rift DK2
	Cancer Pain	
Schneider et al. [67], [68], [70], [72]	A special designed VR environments	i-glasses HMD
Gershon et al. [69],Birnie et al. [73]		HMD
Nilsson et al. [71]		Non-immersive computer-based VR system
Sharifpour et. al [74]	VR movie	Samsung Gear VR

Moreover, few studies have identified that the VR analgesic effect did not diminish during repeated use. Besides, patients reported a shorter time perception during the treatment when using VR distraction. One study has suggested that longer VR sessions have a much more analgesic effect than shorter sessions. In conclusion, VR emerges as a valuable distraction tool with unique characteristics suitable for reducing pain associated with different painful medical procedures. Also, this survey demonstrated that VR interventions were effectively used for treating different psychological problems such as phobias. Finally, with advances in using VR in many health care applications, patients may need fewer opioids during painful procedures and also may need a fewer number of treatment sessions.

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