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Review Article

Pain and Environmental Stimuli: A Review on Research Methods, Instruments, and Findings

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Abstract

Pain, as a critical health outcome, has been extensively studied across various disciplines. However, the role of environmental stimulation in reducing patients' perceptions of pain in healthcare settings is a relatively emerging area of research. Recent studies have explored the use of environmental stimuli, such as light, nature, music, and virtual reality, as sources of distraction to alleviate pain during medical procedures. This study aims to examine the research objectives, methodologies, and findings of empirical studies in this domain, addressing the following questions: What types of research designs and methods have been employed? What instruments have been used to measure pain? What are the key findings from these studies? A systematic literature search was conducted across four major databases—PsycINFO, PubMed, Wiley Online Library, and Google Scholar—using eight keywords: ‘pain,’ ‘environment,’ ‘light,’ ‘nature,’ ‘sound,’ ‘music,’ ‘virtual reality,’ and ‘video.’ Studies were included if they were empirical, published after 2000, measured pain as a health outcome, and emphasized environmental factors. A total of 53 studies met these criteria. An analytical matrix was developed to categorize studies based on research objectives, design, sample size, methodology, and pain measurement tools. The findings were synthesized into four major themes: environmental interventions, research designs, pain measurement techniques, and outcomes. Environmental contexts included exposure to natural light (two studies), sounds of nature (one study), combined view and sound of nature (one study), music therapy (21 studies), and virtual reality (29 studies). Of the selected studies, 44 employed randomized controlled trials, eight used quasi-experimental designs, and one was descriptive correlational. Pain was measured using a variety of validated instruments, and the study provides a comprehensive list of these tools, detailing their strengths and limitations. This article offers valuable insights for future research by identifying methodological gaps, suggesting research designs that incorporate environmental stimuli, and recommending appropriate pain measurement instruments. Additionally, graphical representations of research processes, pain scale administration guidelines, and pain rating scale comparisons are included to assist researchers in designing rigorous studies. These resources are particularly useful for planning randomized controlled trials or quasi-experiments to investigate the effectiveness of environmental stimulation as a distraction for reducing pain perception in healthcare settings.

Keywords

Pain, Environmental Stimuli, Patient, Healthcare Environment, Virtual Reality, Music Therapy, Visual Analog Scale (VAS)

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1. Introduction

In 1979, the International Association for the Study of Pain (IASP) introduced the most widely used definition of pain [1]. The IASP defined pain as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage.' It has been debated for a long time whether pain is a psychological experience or a biological symptom. Finally, in 2020, the International Association for the Study of Pain (IASP) updated its over 40-year-old definition of pain, officially conceptualizing it as 'an unpleasant sensory and emotional experience associated with, or resembling that associated with actual or potential tissue damage' [2]. Pain management has been influenced by both clinical and nonclinical practices, with distraction playing a significant role. Several theories explain how distraction reduces the perception of pain. In 1965, Melzack and Wall introduced the Gate Control Theory, suggesting that the central nervous system modulates sensory perception [3]. Pain signals must pass through 'nerve gates' before reaching the brain, where factors such as attention, emotion, and experience influence the perception of pain. In 1984, McCaul and Malott expanded on this theory, proposing that human attention has a limited capacity. For pain to be perceived, it must be the focus of attention, meaning that distraction can diminish pain perception [4, 5].

Based on this theory, clinicians often create social environments in healthcare settings to promote adaptive responses to pain. Individuals with greater social support experience less cancer pain, take less pain medication, report less labor pain, and are less likely to use epidural anesthesia during childbirth or suffer from chest pain after coronary artery bypass surgery. Recently, there has been heightened recognition that environmental factors can influence pain. Recent theories of pain highlight the role that sensory stimuli from the environment can play in influencing the pain experience. The patient's auditory stimuli may range from noise generated by the hospital environment to music or sounds of nature. The patient's visual sensory experience is influenced by the treatment settings, including light, view, and positive distractions [6].

Since pain management is challenging in the healthcare process, a recent trend in research has focused on environmental stimuli as a source of distraction to influence patients' pain perception. Several studies focused on music therapy and virtual reality (VR); however, very few studies considered other environmental factors (e.g., view, natural light). These studies attempted to identify the relationship between environmental interventions and health outcomes, particularly pain. The paper aimed to investigate the research objectives and methodological approaches of these studies on pain management.

2. Research Questions

The use of environmental stimulation to reduce pain perception is a new trend, and pain as a health outcome has been measured by several studies from various disciplines and perspectives. This study aimed to investigate the methodological approaches of these empirical studies and considered the following research questions: a) what types of research designs and methods have been used? b) what instruments have been used to measure pain? c) what are the key findings from these studies?

3. Study Methods

This study searched for empirical studies focused on pain management through environmental stimulation, including light, natural scenes, sounds, music, or virtual reality (VR). This search employed several strategies to identify potential studies for review. A keyword search was conducted in four major databases: PsycINFO, PubMed, Wiley Online Library, and Google Scholar. Eight keywords were used: ‘pain,’ ‘environment,’ ‘light,’ ‘nature,’ ‘sound,’ ‘music,’ ‘virtual reality,’ and ‘video.’

3.1. Inclusion and Exclusion Criteria

The criteria for including studies in this review were: (i) interventions involving the health effects (pain management) of environmental stimuli in healthcare settings, compared to other environmental stimuli or no environmental stimuli at all; (ii) clinical trials that were published in peer-reviewed journals after 2000; (iii) patients staying in a healthcare setting for any length of time; and (iv) pain and other health-related outcome measures. For example, clinical outcomes such as length of stay and medication intake were included, as were psychological outcomes such as mood, stress, or satisfaction with care received. Studies that manipulated a single environmental stimulus, as well as those that manipulated multiple stimuli simultaneously, were included. Studies were excluded if the environmental interventions were confounded by non-environmental changes, such as changes in nursing care policy.

3.2. Results

A total of 53 studies were selected [7-59]. In this search, multiple review articles were found on environmental stimuli and pain. Most of these articles focused on VR for pain control, while other reviews addressed pain and the environment. For example, Malenbaum et al. (2008) reviewed environmental studies on pain [6]. Nilsson (2008) reviewed 42 studies on music therapy for reducing pain and anxiety [60]; Sin and Chow (2015) conducted a literature review of 7 articles on the effect of music therapy on postoperative pain management in gynecological patients [61]; Lee (2016) conducted a meta-analysis of 97 articles on the effects of music on pain [62];

Santiváñez-Acosta et al. (2020) conducted a systematic review and meta-analysis of 12 studies on music therapy in pain and anxiety management during labor [63]; and Lin et al. (2020) studied 9 articles in a systematic review aimed at examining the effects of music therapy on pain after orthopedic surgery [64]. A few review articles were found on the utilization of VR for pain control. Mahrer & Gold (2009), Pittara et al. (2020), Goudman et al. (2022), Chuan et al. (2021), Chan et al. (2018), and Huang et al. (2022) reviewed the literature on the clinical and experimental applications of VR for pain control [5, 65-69]. As these reviews are very current, the reference lists of these papers were inspected and cross-checked to include all relevant studies.

4. Data Analysis

This stage involved extracting data from these 53 studies onto a standard template (matrix) [Table A1 in Appendix] for comparison and analysis. Information about the research objective, design, sample size, process, and pain measurement instrument has been provided in Table A1.

4.1. Environmental Context and Intervention

Pain has been studied mainly in four environmental contexts; exposure to natural light, view and sound of nature, presence of music, and access to VR or video. Table 1 presents the four categories of environmental contexts and interventions examined in these 53 studies.

Table 1. *Environmental Context and Intervention.*

Environmental Stimulation	Number of Studies
Exposure to Natural Light	2 study
View and Sound of Nature	1 study
Presence of Music	21 study
Access to VR or Video	29 study
Total Number of Study	53 study

Natural sunlight is an integral part of any building. The presence of sunlight has a positive outcome on patients' mental health [70]. It also affects the duration of patients' hospital stay [71]. Exposure to natural light in the experience of pain is a recent concept. Only one study, conducted by Walch et al. (2005), tested the effects of exposure to sunlight on pain medication usage in 89 patients who had undergone spine surgery. The study found a 22% reduction in medication intake among patients in brighter rooms [7].

Human beings have an inherent bond with the natural world, and that contact with nature could benefit an individual's health [72]. Patients with the view of a natural landscape had shorter stays, took less pain medication, and had fewer negative-toned notes in their hospital charts [73]. Patients exposed to nature images were significantly more likely to switch from strong analgesics to weaker painkillers during their recovery than patients in the other conditions [74]. So, view to nature can influence experience of pain. Only one study found by Diette et al. (2003) tested the effect of combining nature images and sounds to reduce pain in a randomized clinical trial of patients undergoing flexible bronschopies. Patients who were exposed to nature views and sounds reported significantly higher levels of perceived control over pain [8].

Music has been described as a strategy to reduce pain by producing distraction. But, music has more therapeutic use than just a source of distraction. Brown, Chen, and Dworkin (1989) proposed that music may be useful in producing pain relief through two distinct pathways: distraction of attention from pain and altering the affective dimension of pain by influencing mood or emotions [75]. Daveson & Kennelly (2000) found music may allow people to express their feelings, relieving feelings of anxiety and hopelessness and enhancing perception of control [76]. Music may stimulate the brain to reduce stress hormones and exert a positive effect on emotional well-being through other hormonal pathways [77]. Music may stimulate the physiologic relaxation response which has a relation with perceived pain [78-80].

Musical interventions have been used in healthcare settings to reduce patient pain, anxiety, and stress. Various complex theories, hypotheses, and assumptions have been proposed regarding how music works in the healthcare setting. In 1990, Thaut proposed that music stimuli have biological effects on human behavior by engaging specific brain functions involved in memory, learning, and multiple motivational and emotional states. Music acts as a distracter, focusing the patient's attention away from negative stimuli to something pleasant and encouraging [60]. All the twenty-one studies tested the music intervention as a positive destruction to decrease perception of pain during any kind of surgery procedure or postoperative recovery; during biopsy or port placement or removal, recovery from cardiac surgery, hip and knee surgery, or hysterectomy.

Virtual reality (VR) is a relatively new concept and technology in pain management. This multisensory technology has been utilized across various fields and, more recently, has been clinically applied as a distraction method for pain management during medical procedures. VR creates a non-pharmacologic form of analgesia by changing the activity of the body's intricate pain modulation system [5]. Twenty-nine studies explored virtual environments, focusing on the concept of virtual reality (VR) as a distraction intervention to reduce the perception of pain during various medical procedures. This included cancer treatment (six studies), burn wound-care procedure (nine studies), post-surgery (eight studies), dental pain (two studies), Transurethral Microwave Thermotherapy (TUMT) for elderly patients (one study), and considered pediatric patients (ten studies). Most of the studies

found positive outcomes from the intervention.

4.2. Research Design

Among the 53 studies, 44 were randomized controlled trials, 8 were quasi-experimental, and one was descriptive correlational. All the music therapy studies (twenty-one studies) were considered randomized controlled trials. Eleven studies randomized participants into 3 groups [11, 13-16, 19, 21, 34, 44, 50, 52] and thirty-three studies randomized participants into two groups [7, 8, 12, 17, 18, 20, 22-32, 35, 37, 45-49, 51, 54-59].

Among the twenty-nine studies of VR, twenty-one studies considered randomized control trials [31, 32, 34-37, 41, 44-52, 55-59]. Among them only four studies considered three groups or conditions [34, 44, 50, 52]. Six studies considered case studies [33, 38-40, 42, 43]. All case studies are single except the study by Hoffman et al. (2001) 2 which considered 2 patients (aged 51 and 56 years old) [38].

4.3. Sample and Settings

The average sample size of the randomized controlled trials is 64. The music therapy studies included a larger number of participants than the VR studies. The average sample size for music therapy is 98, while that for VR is 21.5. All the studies were conducted in healthcare settings.

4.4. Outcome Measures

According to the selection criteria, all the studies measured pain as a health outcome. Most of the studies measured anxiety, stress, satisfaction, or analgesic medication use. Most of the music therapy studies included physiological measures such as heart rate, systolic and diastolic blood pressure, respiratory rate, and oxygen saturation.

4.5. Instrument and Scale

Pain intensity is commonly measured by scales, questionnaires, and sometimes physiological status. Pain scales are widely used in clinical and experimental settings. These scales are based on self-report, observational (behavioral), or physiological data. Self-report is considered primary and should be obtained if possible. Observational pain scales are also available for neonates, infants, children, adolescents, adults, seniors, and individuals with impaired communication [1]. All the studies considered in this paper used different types of pain measurement scales. Some also included additional questionnaires, and some collected physiological data. Eleven types of scales were used in these studies: ten are self-report scales and one is an observational scale, as discussed below.

4.5.1. Self-Reported Pain Rating Scales

(i). Visual Analogue Scale (VAS)

The VAS consists of a line of specified length (usually 10 cm) that has polar descriptors at its two extremes. The left end of the VAS is signified by the category of no pain and the right end by unbearable pain. The VAS offers a continuous spectrum with which to quantify subjectively the intensity of a pain stimulus. The patient is asked to mark a 100 mm line to indicate pain intensity. The score is measured from the zero anchors to the patient's mark. Using a millimeter scale to measure the patient's score will provide 101 levels of pain intensity [81]. As shown in Figure 1.

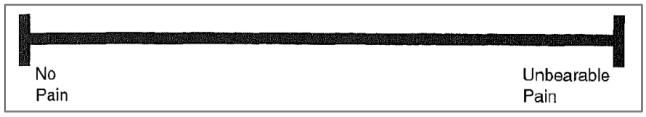

Figure 1. *Visual Analog Scale (VAS).*

(ii). Numerical Rating Scale (NRS)

The NRS is an 11, 21, or 101-point scale where the endpoints are the extremes of no pain and pain as bad as it could be, or worst pain. The NRS can be graphically or verbally delivered. When presented graphically the numbers are often enclosed in boxes and the scale is referred to as an 11 or 21-point box scale depending on the number of levels of discrimination offered to the patient [81]. As shown in Figure 2.

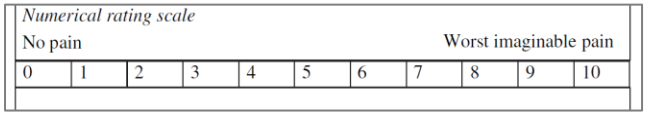

Figure 2. *Numerical Rating Scale (NRS)*

(iii). Verbal Rating Scale (VRS)

The VRS comprises a list of adjectives used to denote increasing pain intensities. The most common words used being: no pain; mild pain; moderate pain; and severe or intense pain. For ease of recording these adjectives are assigned numbers. These rank numbers can lead to the misapprehension that intervals between each descriptor are equal, but this is not the case (Jensen & Karoly 1992) and could be a source of error. The VRS is ordinal. There is no published evidence about the distribution of data obtained from the VRS. In most cases, data collected using a VRS can only be analyzed using non-parametric statistics. As shown in Figure 3.

Verbal ratingscale	
0	No pain
1	Mild pain
2	Moderate pain
3	Severe pain

Figure 3. *Verbal Rating Scale (VRS).*

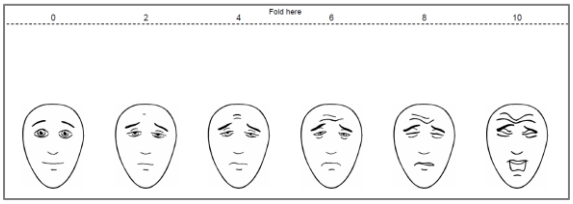

Figure 6. *Faces Pain Scale-Revised (FPS-R).*

(iv). Graphic Rating Scale (GRS)

The GRS is similar to the VAS except that it contains descriptors placed at equal intervals along the base of the scale, The GRS contains, from left to right, categories of descriptors such as no pain, dull ache, slight pain, more slight pain, painful, very painful, and unbearable pain. It has been suggested that these descriptors may lack sufficient sensitivity to measure the pain experience [40]. As shown in Figure 4.

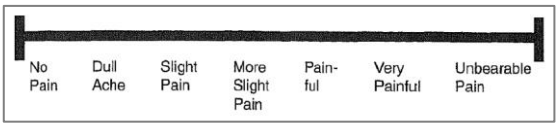

Figure 4. *Graphic Rating Scale (GRS).*

(v). Faces Pain Scale (FPS)

Faces pain scales include a use of cartoon faces with different expressions. These are often useful when used with children. One of the most common pain scales is the Wong-Baker Faces Pain Rating Scale. The Wong-Baker scale goes from 0 to 5. As shown in Figure 5.

Figure 5. *Faces Pain Scale (FPS).*

(vi). Faces Pain Scale-Revised (FPS-R)

The Faces Pain Scale-Revised (FPS-R) is a self-report measure of pain intensity developed for children. It was adapted from the Faces Pain Scale to make it possible to score on the widely accepted 0-to-10 metric. It shows a close linear relationship with VAS across the age range of 4-16 years. It is easy to administer and requires no equipment except for the photocopied faces. The absence of smiles and tears in this scale may be advantageous. It is particularly recommended for use with younger children. Numerical self-rating scales (0-10) can be used with most children over 8 years of age [32], and behavioral observation scales are required for those unable to provide a self-report. As shown in Figure 6.

(vii). Visual Analog Thermometer (VAT)

Pain was measured by the VAT, which was developed to measure pain in burned patients. The VAT is an adapted version of the visual analog scale that consists of a self-report continuous red scale between the extremes, “no pain” and “unbearable pain” with on the backside a 0- to 100-mm scale between the same extremities. The measured pain score (between 0.0 and 10.0) is recorded by the nurse and is not related to the patient. The VAT was developed to address the limitations and disadvantages of the conventional VAS. Its design makes it both suitable for clinical use and effective as an outcome measure in clinical trials [82].

(viii). McGill Pain Questionnaire (MPQ)

The McGill Pain Questionnaire (MPQ) is a scale of rating pain developed at McGill University by Melzack and Torgerson in 1971. It primarily consists of three major classes of word descriptors: sensory, affective, and evaluative. These descriptors are used by patients to articulate their subjective pain experiences. Additionally, it includes an intensity scale and other components designed to assess the characteristics of the pain experience. MPQ was developed to provide quantitative clinical pain measures, enabling statistical analysis [83].

(ix). 5-Point Scale of Pain Control (5P)

The 5-point Pain Control Scale (5P) is a subjective measure used to assess a patient's level of pain management or relief. The scale allows patients to rate their perception of how well their pain is being controlled on a continuum, ranging from poor, fair, good, very good, or excellent [8].

(x). Burn Specific Pain Anxiety Scale (BSPAS)

The Burn Specific Pain Anxiety Scale (BSPAS) is a nine-item self-reported tool designed to evaluate pain-related and anticipatory anxiety in patients with burn injuries. It specifically addresses anticipatory anxiety about procedures such as dressing changes, as well as the pain associated with burn injuries. This tool aids healthcare professionals in understanding the psychological aspects of burn pain, enabling them to implement targeted interventions to manage pain-related anxiety effectively [42, 85].

4.5.2. Observational Pain Rating Scales

Vocalization, facial expression, and body movement are

typically associated with pain. Though inferring pain from behavior is fraught with difficulties, it is useful for infants, young children, or children with cognitive or physical impairments, who are not able to self-report. Only one tool was used among these 53 studies; the Children's Hospital of Eastern Ontario Pain Scale (CHEOPS). CHEOPS is a behavioral scale for evaluating postoperative pain in young children. It can be used to monitor the effectiveness of interventions for reducing pain and discomfort. It rates six behaviors (crying, facial expression, verbal expression, torso position, touch, and leg position). It is mainly intended for ages 0-4 [84].

4.6. Utilization Rate of Pain Scales

Pain rating scales are fundamentally significant in clinical practice. Twenty-five studies used VAS [10, 13, 15, 19, 20, 22-24, 27-30, 33-38, 40, 45-48, 50, 51, 53-55, 57-59]; nine studies used NRS [11, 12, 14, 16-18, 25, 26, 52, 56]; six studies used FPS [27, 31, 32, 35, 43, 49]; three studies used GRS [39, 41, 42]; two studies used VRS [21, 25]; three studies used MPQ [7, 21, 25]; three used CHEOPS [33, 34, 46]; two used FPS-R [35, 49, 59]; and one used VAT [44]; one study used a 5-point scale of Pain control (5P): poor, fair, good, very good, or excellent [8]; and, one study used the Burn Specific Pain Anxiety Scale (BSPAS) [42]. The pie chart represents the use of scales in percentage, as shown in Figure 7.

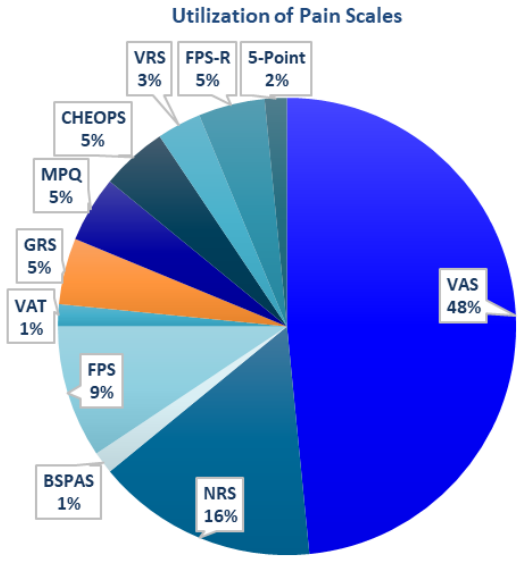

Figure 7. *Utilization rate of pain scales in the selected studies.*

4.7. Data Collection Process

The data collection procedure can be analyzed in two ways; 1) Control Design -group or condition, and 2) Pain Scale Administration - when and how many times.

4.7.1. Types of Randomize Control Design

All the studies tested their interventions using either a control group or a control condition. Seventeen studies employed randomized control groups, with either two or three group designs [7, 8, 13-16, 18-21, 33, 35, 45, 46]. The remaining studies either considered two groups under different conditions, utilizing either a single treatment trial or a cross-over treatment trial. As shown in Figure 8.

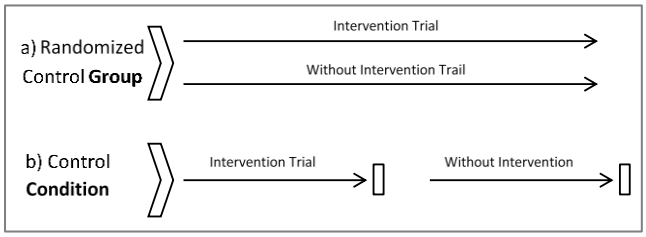

Figure 8. *Two types of randomized control trial process.*

4.7.2. Pain Scale Administration

All the studies administered some form of pain scale to collect data. Some collected data after the intervention trial, others both before and after the trial, while some collected data before and during the trial. Additionally, certain studies gathered data at frequent intervals, such as every hour or every five minutes. However, one study did not specify when or how many times the pain scale was administered [18]. Four primary models were identified in this study, which are described below with graphical presentations.

a) Before & after the trial [7, 11, 17, 19, 21, 35] in Figure 9.

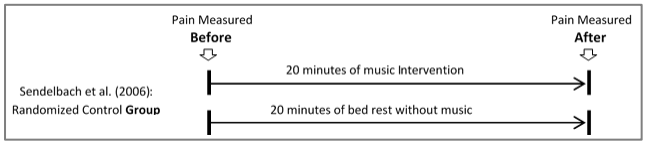

Figure 9. *Pain scale administration - before and after.*

b) Just after the trial in three-group conditions or single conditions [13, 14, 15, 32, 37-41, 42, 44, 45]. As shown in Figures 10 & 11.

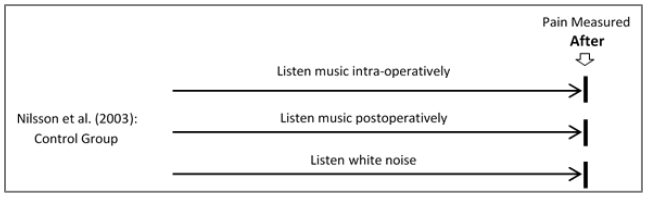

Figure 10. *Pain scale administration - only after the procedure.*

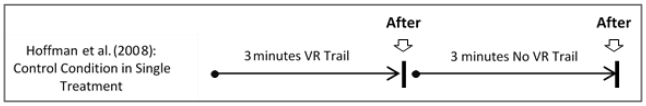

Figure 11. *Pain scale administration - only after the procedure.*

c) Before and during the trial [33, 34, 43, 46] in Figure 12.

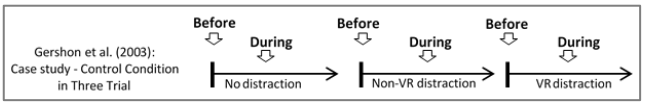

Figure 12. *Pain scale administration - periodically during process.*

d) Frequently or more than two times [10, 31, 13, 14, 20], in Figure 13.

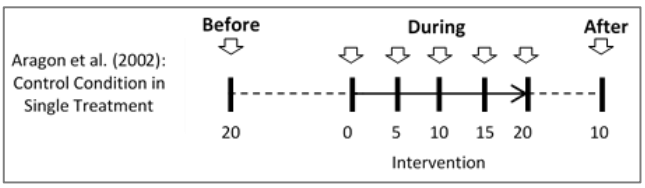

Figure 13. *Pain scale administration - frequently during process.*

5. Discussions

This study found VAS is the most commonly used pain scale in these 53 studies, a total of 31%. The second most is NRS (10%) and the third most is FPS (6%). Only twelve studies among twenty-one of MT used VAS to measure pain [10, 13, 15, 19, 20, 22-24, 27-30]. All the studies except one by Yilmaz et al. (2003) found positive outcomes [20]. VAS was the most commonly used pain measurement tool in (VR) studies. Out of twenty-nine VR studies, nineteen utilized the VAS. As previously discussed, two types of instruments or scales were used in these 53 studies: self-reported and observational. Table 2 presents all the instruments along with their utilization rates expressed as percentages.

Table 2. *Instrument & Scale, and Utilization Rate.*

Type	Scale	%
Self-Reported	1. Visual Analogue Scale (VAS)	31%
	2. Numerical Rating Scale (NRS)	10%
	3. Faces Pain Scale (FPS)	6%
	4. Graphic Rating Scale (GRS)	3%
	5. McGill Pain Questionnaire (MPQ)	3%
	6. Faces Pain Scale-Revised (FPS-R)	3%
	7. Verbal Rating Scale (VRS)	2%
	8. Burn Specific Pain Anxiety Scale (BSPAS)	1%
	9. Visual Analog Thermometer (VAT)	1%
	10. 5-point scale of Pain control (5P)	1%
Observational	Children's Hospital of Eastern Ontario Pain Scale (CHEOPS)	3%

VAS is easy and inexpensive to implement, can be administered quickly, and lends itself to self-completion. Williamson and Hoggart (2004) mentioned that VAS has more practical difficulties than the VRS or the NRS [81]. One of the limitations of the VAS is that it must be administered on paper or electronically. Caution is required when photocopying the scale as this can lead to significant changes in its length. The graphic orientation of the VAS can make a difference in the statistical distribution of the data obtained using it. Ogon et al. (1996) found that data were normally distributed when the VAS was used horizontally, but not when it was used vertically. In a study of Chinese patients (Aun et al. 1986) the vertical scale demonstrated less error than the horizontal scale. A similar study (Scott & Huskisson 1979) exploring the use of the VAS by English language speakers found that there was a 7% failure rate for the VAS when it was presented vertically but less when presented horizontally. This suggests that the graphic orientation of the VAS should be decided according to the normal reading tradition of the population on which it is being used. Torrance et al. (2001) mentioned that cardinal preferences from VAS are prone to biases. The best arrangement is to use a VAS only as an introductory task to familiarize the respondents with the health states and to obtain the ordinal preferences.

NRS was used by eight MT studies [11, 12, 14, 16-18, 25, 26], and only one VR study [52]. All the studies found positive outcomes except one by Kwekkeboom (2003). For general purposes, the NRS has good sensitivity and generates data that can be statistically analyzed for audit purposes. Patients who seek a sensitive pain rating scale would probably choose this one. There is no published information about the distribution or error of data obtained using the NRS. However, the scale is interval level and can provide data for parametric analysis [81].

Of the 53 studies, 44 utilized randomized controlled trials (RCTs), 8 employed quasi-experimental designs, and 1 adopted a descriptive correlational approach. Among the 44 RCTs, the data collection process involved two different models: control groups and control conditions, as shown in Table 3.

Table 3. Types of Randomized Control Design.

Type	Study Design	Intervention Administration
Randomized Controlled Groups	Two Groups	Group A: With Intervention
		Group B: Without Intervention
	Three Groups	Group A: With Intervention
		Group B: Without Intervention
		Group C: With a different or regular Intervention
Randomized Controlled Conditions	One Treatment/linear	Single Group: Without intervention, then with intervention
	Crossover Treatment	Group A: Without intervention, then with intervention
		Group B: With intervention, then without intervention

As previously mentioned, all the studies utilized some type of pain scale to gather data (Table 4). While some studies collected data only after the intervention, others gathered data both before and after the trial, and some recorded data before and during the intervention. Additionally, a few studies measured data at regular intervals, such as every hour or every five minutes.

Table 4. Pain Scale Administration Timing.

Process	Timing
Model-1	Before & After the Trial
Model-2	Only after the Trial
Model-3	Before and During the Trial (not after the trial)
Model-4	Frequently or more than Two Times during the Trial

All the studies on VR found their interventions as a positive distraction for pain reduction. The majority of studies on music therapy found a significant reduction of pain for music or sound intervention. The study on natural light by Walch et al. (2005) found that patients exposed to an increased intensity of sunlight experienced marginally less pain, took 22% less analgesic medication per hour, and had 21% less pain medication costs [7]. Diette et al. (2003) studied distraction therapy with natural sights and sounds and found that older patients and patients with better health status reported significantly less pain [8]. Among the twenty-one studies on music therapy, all found a significant reduction in pain for music or sound intervention. Only two studies (Kwekkeboom, 2003; and Yilmaz et al., 2003) found no significant differences in the reduction of pain for music intervention.

Kwekkeboom (2003) studied the hypothesis that music is greater than simple distraction and both are better at controlling procedural pain and anxiety than treatment as usual. However, the study found results contrary to the initial hypotheses. Outcomes achieved through music interventions did not differ significantly from those achieved through simple distraction. Furthermore, outcomes under standard treatment conditions were not significantly different from those obtained with either music or distraction interventions. Additionally, some patients reported that the interventions were bothersome and expressed a preference to focus on the surgeon's activities and the medical procedure itself [11]. Yilmaz et al. (2003) investigated the effects of music on sedation during extracorporeal shock wave lithotripsy (ESWL) to compare its anxiolytic effects with those of midazolam. The study found a statistically significant decrease in mean arterial pressure at the end of the ESWL procedure in group 2 and a reduction in oxygen saturation from the 10th minute to the end of treatment in group 1. However, the visual analog scale (VAS) did not show statistically significant differences between the experimental and control groups [20].

Aragon et al. (2002) studied a single 20-minute live harp-playing session and found a positive effect on pain (P=.000) and also produced statistically significant differences in physiological measures of systolic blood pressure (P=.046), and oxygen saturation (P=.011) [10]. Although all values over time trended downward, the changes in other variables were not adequate to achieve statistical or clinical significance. McCaffrey & Locsin (2006) studied music on pain and acute confusion in older adults undergoing hip and knee surgery, and all of the patients in the experimental group mentioned music as a positive experience during their recovery [12]. Nilsson et al. (2001) tested music or music in combination with therapeutic suggestions in the intra-operative period under general anesthesia and found music group experienced more effective analgesia the first day after surgery and could be mobilized earlier after the operation [13].

In Nilsson et al. (2003)[1] study, patients exposed to music reported significantly lower pain intensity at 1 and 2 h postoperatively and patients in the postoperative music group required less morphine at 1 h compared to the control group [14]. Nilsson et al. (2003)[2] found that music, with or without therapeutic suggestions, had a beneficial effect on patients' perception of analgesia during the early postoperative period [15]. Nilsson et al. (2005) found that the intraoperative music group reported less pain after 1 h in the post-anesthesia care unit. The postoperative music group had less pain and required less morphine after 1 h. The total requirement of morphine by the music group was significantly lower [16]. Sendelbach et al. (2006) found a significant reduction in pain (P = 0.009) in the music group compared with the control group, but no difference was observed in systolic blood pressure (P = 0.17), diastolic blood pressure (P = 0.11), or heart rate (P = 0.76) [17].

Shertzer & Keck (2001) found a significant reduction in

pain from admission to the PACU until discharge (65% to 74%) in the experimental group. The control group who reported no pain had decreased from 65% to 58% [18]. Zimmerman et al. (2006) found music group had significantly lower pain scores on Day 2 than the rest period control group [21].

All the studies on VR found their interventions as a positive distraction for pain reduction. Chan et al. (2007) tested the effectiveness of VR in reducing pain in wound-care procedures for pediatric burn patients, where nurses observed less behavioral distress in VR conditions. Less pain was noted in the intervention group during and after the dressing change [31]. Das et al. (2005) studied VR games to decrease procedural pain in children with acute burn injuries; and found the average pain score for pharmacological analgesia is 4.1 (SD-2.9), while VR coupled with pharmacological analgesia is 1.3 (SD1.8) [32].

Gershon et al. (2003) investigated VR as a distractor to alleviate pain and anxiety associated with an invasive medical procedure for a pediatric cancer patient. The study found benefits from using VR distraction by lowering pain ratings and pulse rate [33]. Gershon et al. (2004) used VR as a distraction for children with cancer and found lower pulse rates and reports of lower pain by nurses. No significant differences were found for the non-VR condition versus the no distraction condition on pulse rate [34].

Gold et al. (2006) studied VR as a pain distraction for pediatric intravenous (IV) placement for magnetic resonance imaging (MRI) or CT scans. A fourfold increase in affective pain within the control condition; no significant differences were detected within the VR condition. Significant associations between multiple measures provided support for the complex interplay of a multimodal assessment of pain perception. Sufficient amount of evidence supporting the efficacy of Street Luge as a pediatric pain distraction tool during IV placement: an adequate level of presence, no simulator sickness, and significant satisfaction with pain management [35].

Hoffman et al. (2000) investigated VR to distract patients from pain during physical therapy for burn patients. All patients reported less pain when distracted with VR, and the magnitude of pain reduction by VR was statistically significant (e.g., time spent thinking about pain during physical therapy dropped from 60 to 14 mm on a 100-mm scale) [36]. Hoffman et al. (2001)[1] hypothesized that immersive VR continues to reduce pain (via distraction) with repeated use. Pain ratings were statistically lower when patients were in VR. VR does not diminish in analgesic effectiveness with three (and possibly more) uses [37]. Hoffman et al. (2001)[2] studied VR as an effective non-pharmacologic analgesic for dental pain. For patient 1, mean pain ratings were in the severe range while watching a movie (7.2), or no distraction (7.2) but in the mild pain range (1.2) during the VR condition. Patient 2 reported mild to moderate pain with no distraction (mean 4.4), mild pain while watching the movie (3.3), and essentially no pain while in VR (0.6) during his periodontal scaling. Immersive VR merits more attention as a potentially viable adjunctive non-pharmacologic analgesia for procedural dental/periodontal pain [38].

Hoffman et al. (2004) tested water-friendly VR technology with a burn patient undergoing wound care in a hydrotherapy tub. 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). The amount of time spent thinking about his pain during wound care dropped from 10 to 3 [39]. Hoffman et al. (2005) studied VR as an adjunctive pain control during Transurethral Microwave Thermotherapy (TUMT) for elderly patients. The subject experienced improvements in each of the questions related to pain. VR reduced all pain measures. Scores were averaged from the twice-administered questionnaire, both before and during VR. Before the immersion, the subject reported thinking about the pain 30% of the time. During the VR, he spent 15% of the time thinking about the pain [40].

Another study by Hoffman et al. (2008) studies the adjunctive use of water-friendly immersive VR to distract patients from their pain during burn wound debridement in the hydrotherapy tank (hydrotank). Patients reported significantly less pain when distracted with VR. The ‘‘worst pain’’ ratings dropped from ‘‘severe’’ (7.6) to ‘‘moderate’’ (5.1). The 6 patients who reported the strongest illusion of ‘‘going inside’’ the virtual world reported severe pain (7.2) with no VR condition and dropped to mild pain (3.7) with VR [41].

In Patterson et al. (2004) study of a 3-D immersive VR world to control pain & anxiety in a severely burned patient, found the patient’s pain dropped 40% after VR for his Day 41 wound care. Pain dropped to similar levels on Day 42 with an audio-only version of the intervention and then returned to baseline without intervention on Day 43 [42].

Steele et al. (2003) studied VR as a powerful non-pharmacologic analgesic for children following surgery and found patient’s overall pain ratings whilst in the VR condition were 41.2% less than those in the no-VR condition [43]. Van et al. (2007) studied VR and television (TV) during burn wound care sessions and found a significant reduction of pain with VR and TV. The effects of VR were superior, but not statistically significant, to that of television. 13 of 19 patients reported 33% or greater reductions in pain during VR distraction [44].

Wint et al. (2002) studied VR glasses as a feasible, age-appropriate and non-pharmacologic aide in cancer treatment undergoing frequent lumber punctures. Although VAS pain scores were not statistically different between the two groups ($p = 0.77$), VAS scores tended to be lower in the VR group (median VAS of 7.0, range 0-48) than in the control group (median VAS of 9.0, range 0-59). 77% of subjects in the experimental group said the VR glasses helped to distract them from the LP [45].

Wolitzky et al. (2005) tested VR with children receiving treatment for cancer and undergoing a port access procedure.

VR may be a highly effective intervention for children undergoing painful and distressing medical procedures [45].

Due to the space limitations, only the above-mentioned studies are presented in the discussion.

6. Conclusions

This study conducted an exhaustive and systematic literature review to distill the methodological approaches of empirical research studies examining the effects of environmental stimuli on patient pain management in healthcare settings. The methods reviewed encompass a wide range of data collection techniques and processes currently employed in pain research. As these methods transition from research to applied settings, they hold the potential to better personalize pain management, increase access to pain care, and improve the accuracy of clinical trials. However, alongside their promising advantages and strengths, these methods also present considerable concerns, limitations, and critical issues that must be acknowledged and addressed.

The goal of this paper is not only to summarize the processes and techniques of emerging pain measurement methods but also to present various research designs to the broader research community, thereby fostering a deeper understanding of research design. In this context, the analytical matrix and graphical presentations of research design processes can serve as valuable resources for future research. These tools can aid in identifying research gaps, designing methods that account for environmental stimuli, selecting appropriate pain measurement instruments, and planning data collection processes. Additionally, the graphical presentations provide a useful framework for designing randomized controlled trials or quasi-experiments to study environmental stimulation as a distraction to reduce patients' perceptions of pain.

7. Future Research Directions

This study highlights the potential of environmental stimuli, such as light, music, and virtual reality, in pain management, but several areas warrant further research. Future studies should explore additional sensory modalities, such as olfactory and tactile stimuli, as well as the combined effects of multiple interventions (e.g., music and virtual reality). The long-term impact of these interventions on chronic pain and recovery outcomes, beyond their immediate effects, also needs investigation. Expanding research to include diverse populations, such as pediatric, geriatric, and culturally varied groups, along with underserved settings, is critical. Additionally, future research should examine the psychological and neurobiological mechanisms underlying pain reduction through environmental stimulation. Standardizing and validating pain measurement tools will improve comparability across studies, while investigating emerging technologies, such as augmented reality and AI-driven systems, could open new possibilities. Finally, studies should assess the feasibility, cost-effectiveness, and scalability of implementing these interventions in diverse and resource-limited healthcare settings. Addressing these gaps will advance the understanding and application of environmental stimulation in pain management, ultimately improving patient care.

8. Limitations

The literature review has limitations and should be considered an initial effort to investigate the methodological approach of the empirical research studies that focus on examining the effects of environmental stimuli on patient pain management. Because the search process was limited to English-language articles, literature in other languages was not included, which may cause gaps in the literature.

The review was conducted in such a way that it did not consider the conference proceedings relevant to ‘pain management’ or ‘environmental stimuli’ which may contain very meaningful insight to this question. Also, the interpretation was conducted and limited to the solo researcher (Sharmin Kader) who engaged in the code-recode procedure. Further research study is required to understand the validity and outcome of each research design and pain measurement process, specifically the suitability of the pain measuring scales.

Abbreviations

5P	5-Point Scale of Pain Control
BSPAS	Burn Specific Pain Anxiety Scale
CHEOPS	Children’s Hospital of Eastern Ontario Pain Scale
FPS	Faces Pain Scale
FPS-R	Faces Pain Scale-Revised
GRS	Graphical Rating Scale
HADS	Hospital Anxiety and Depression Scale
MT	Music Therapy
MPQ	McGill Pain Questionnaire
NRS	Numerical Rating Scale
VAS	Visual Analog Scales
VAT	Visual Analog Thermometer
VR	Virtual Reality
VRS	Verbal Rating Scale

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Data Availability Statement

The data is available from the corresponding author upon reasonable request. The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Table A1. *Study characteristics for investigating the effects of environmental stimuli on pain management.*

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
Walch et al. (2005) [7]	Natural sunlight to reduce pain	RCT: 2 groups. a) Housed on the "bright" side of the hospital, b) Housed on the "dim" side of the same hospital unit.	89 patients, undergoing elective cervical and lumbar spinal surgery	The intensity of sunlight in each hospital room was measured daily and psychologic questionnaires were administered on the day after surgery and at discharge.	McGill Pain Questionnaire (MPQ)
Diette et al. (2003) [8]	Distraction therapy with nature sights and sounds	RCT: 2 groups. a) Experiment group was exposed to intervention, b) Control group was not offered the nature scene or the sounds.	80 adult patients, undergoing Flexible Bronchoscopy (FB) with conscious sedation.	Baseline information was collected. A natural scene mural was placed at the bedside for the experimental group, accompanied by a tape of nature sounds to be played before, during, and after the procedure. Pain was reported during the procedure, and a follow-up survey was administered on the second-day post-procedure.	A 5-point scale of Pain control: poor, fair, good, very good, or excellent
Bernhofer et al. (2014) [9]	Light exposure to sleep-wake patterns, mood, pain	A descriptive correlational design	23 women and 17 men were admitted to a hospital	Medical inpatients were exposed to light levels that were insufficient for circadian entrainment. Over 72 hours, light exposure and sleep-wake patterns were continuously measured with wrist actigraph/light meters for each participant. Mood was measured daily using the Profile of Mood States BriefTM Form. Subjective pain scores were abstracted from medical records.	Numerical Rating Scale (NRS) of 0-10 with 0 being no pain and 10 being worst pain
Aragon et al. (2002) [10]	A single 20-minute live harp playing session on patient anxiety, pain, and satisfaction	A prospective, quasi-experimental, and repeated measures design was used. A single-treatment study.	17 patients who were postoperative and admitted to a hard-wired-bedside-monitored room of the Vascular Thoracic Unit	The VAS was completed 5 minutes before, immediately after, and 10 minutes following the 20-minute harp-playing session. Patient satisfaction was assessed using a 4-item questionnaire. Physiological measures (heart rate, systolic and diastolic blood pressure, etc.) were recorded from the bedside monitor at baseline (5 minutes before setup), at the start, and at 5, 10, 15, and 20 minutes during the harp session, as well as 5 and 10 minutes	Visual analog scales (VAS) for pain & anxiety. Physiological measures were recorded from the bedside monitor

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
				post-session.	
Kwekkeboom (2003) [11]	a) Music is better than simple distraction; b) both are better than treatment as usual	RCT: 3 groups. a) experimental music intervention, b) experimental distraction intervention c) control group of treatment as usual,	58 people with cancer, Mean age- 53,	Pain intensity ratings were made for three time points: before, during, and post-procedure. Perceived control over pain and anxiety during and after their procedure was measured using a single-item rating created for this study.	Pain intensity by NRS. Severity of pain was rated "right now" from 0 to 10. Perceived controls by NRS (0-10)
McCaffrey & Locsin (2006) [12]	Music on pain & acute confusion in older adults undergoing hip and knee surgery	RCT: 2 groups. a) Control group b) Experimental group	124 patients of age 65 years or older Mean age - 75, Having elective hip or knee surgery	The experimental group had a bedside compact disc (CD) player that would automatically play the compact disc 4 times daily. Nurses' notes, medication records, and the scores for ambulation from the physical therapy - reviewed. Each patient was called 10 days after discharge to determine his or her satisfaction.	NRS (1 to 10). Number of pain medications
Nilsson et al. (2001) [13]	Music or music with therapeutic suggestions (M/TS) could improve recovery of hysterectomy patients.	RCT: 3 groups. a) Music group b) Music combined with therapeutic suggestions (M/TS), c) Control group exposed to operation room sounds.	89 patients, ASA I-II, Mean age 51 years, Having an elective abdominal hysterectomy via a lower abdominal incision	Pain intensity was registered every hour for the first 24 hours and every 3 hours after 24 hours until the patient felt no pain.	Visual Analogue Scale (VAS);
Nilsson et al. (2003)[1] [14]	Music effects on postoperative pain	RCT: 3 groups. a) Listened to music intra-operatively, b) Listened to music post-operatively, c) Listened to 'white noise' or control group.	151 American Society of Anaesthesiologists ASA I-II patients, aged 21-85 years, Having day-case surgery under general anesthesia	Postoperatively, the patient rated pain intensity every ½h for 2 h in the PACU. Pain was also assessed after 1 h in the PACU, at discharge, at home in the evening of the day of surgery, days 1 and 2 after surgery in the morning and in the evening.	Numeric Rating Scale (NRS) from 0 to 10 (0-no pain to 10- maximal possible pain); Amount of morphine.
Nilsson et al. (2003)[2] [15]	Music or music with therapeutic suggestions (M/TS) could improve postoperative recovery in day-surgery.	RCT: 3 groups. a) only music, b) music in combination with therapeutic suggestions, c) Blank tape in the postoperative period.	182 patients having varicose vein or open inguinal hernia repair surgery under general anesthesia	The surgical technique, anesthesia and postoperative analgesia were standardized. Heart rate and oxygen saturation were monitored before the intervention. Vas was measured every half hour until the patient reported < 3 on the scale.	Visual Analogue Scale (VAS); Amount of morphine
Nilsson et al. (2005) [16]	Stress reduction and analgesia in patients exposed to calming music postoperatively	RCT: 3 groups. a) intraoperative music, b) postoperative music, c) silence or control group	75 (ASA) Grade I-II consecutive patients, mean age 56, having surgery of open Lichtenstein inguinal hernia repair under	A 4-month period study. Anesthesia and postoperative analgesia were standardized. Pain, blood pressure, and heart rate were assessed 30 min before anesthesia and 1 hour after admission to the post-anaesthesia care unit (PACU).	NRS (0-10). Physiological Data -Blood Glucose, Blood Pressure, Pulse and amount of morphine.
Sendelbach et al. (2006) [17]	Music therapy - physiological & psychological outcomes for	RCT: 2 groups. a) received 20 minutes of music (N=50), b) 20 minutes of rest in bed	86 patients, Mean age -63.3, Having CABG or heart valve re-	For both groups, measures for pain intensity, HR, and BP were obtained immediately before and after each 20-minute intervention period in a	NRS (0-10) Physiological data - Heart rate, Blood

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
	patients undergoing cardiac surgery	(N=36),	placement.	consistent fashion.	pressure
Shertzer & Keck (2001) [18]	soothing music and lowering noise levels on the pain experience of patients during their PACU stay	RCT: 2 groups. a) Listened to music on a day when staff kept extraneous noise at a minimum in the PACU, b) Experienced the typical PACU day	97 patients, Mean age 59. Undergoing same-day surgery from all surgery services except the open heart.	Pain intensity data were collected at 3 time intervals: on admission to the PACU, 30 minutes after admission, and at discharge. The 30-minute time period was chosen because patients typically remained in the PACU for 1 hour, and 30 minutes would be the midpoint of their stay.	11-point Numerical Rating Scale (NRS), or by a Narrative questionnaire of 0 to 11 points.
Voss et al. (2004) [19]	Sedative music reduces anxiety and pain during chair rest after open-heart surgery	RCT: 3 groups. a) Sedative music (N=19), b) Scheduled rest (N=21), c) Treatment as usual (N=21)	61 adult postoperative open-heart surgery patients who were ordered to chair rest.	30-minute session for all three groups during chair rest. Pain sensation and distress were measured with VAS at the initiation of chair rest and after 30 30-minute sessions. VAS took 30 to 60 seconds to present and complete.	Pain Sensation VAS; Pain Distress VAS;
Yilmaz et al. (2003) [20]	Music on sedation in extracorporeal shock wave lithotripsy (ESWL) treatment to compare its anxiolytic effects with those of midazolam.	RCT: 2 groups. a) 2 mg of midazolam was administered intravenously 5 minutes before ESWL. Had a headset without music. b) music chosen by the patients was listened to with a headset and continued during the treatment.	98 patients, aged 19 to 68 years, With urolithiasis in ASA I-II status and had only one urinary trackstone.	All the physiological status was recorded as baseline information. VAS was measured at 1st minute and every 10 minutes.	VAS, Physiological data - Hemodynamic parameters, Mean arterial pressure, Heart rate, respiration rate, and oxygen saturation.
Zimmerman et al. (2006) [21]	Music & music video intervention on pain and sleep in 2nd & 3rd postoperative day	RCT: 3 groups. a) Music therapy, b) Music video therapy, c) Scheduled rest period or comparison group.	96 patients, Mean Age -67, Having Coronary Artery Bypass Graft (CABG) surgery	MPQ & VRS were administered for baseline information. Each day had two 30-minutes sessions. VRS obtained before and after each session. MPQ was administered before session 1 and after session 4.	Verbal Rating Scale (VRS), McGill Pain Questionnaire (MPQ),
Allred et al. (2017) [22]	Listening to music or having a quiet rest period just before and after the first ambulation can reduce pain and/or anxiety	RCT: 2 groups. a) music intervention group (Listening to music using headphones) b) quiet rest group	56 patients (M-25 & F-31), age range 46 to 84 years, mean age 63.89.	56 patients undergoing total knee arthroplasty were randomly assigned to either a music intervention group or a quiet rest group. The intervention took place on Postoperative Day 1, with patients listening to music for 20 minutes both before and after their first ambulation.	VAS (T1, T2, T3, T4)
Antall and Kresevic (2004) [23]	A guided imagery intervention in the older adult patient who underwent joint replacement surgery.	RCT: 2 groups. a) usual care and a guided imagery audiotape intervention. b) usual care and a music audio tape	13 patients (M-13), mean age 67.85 years, diagnosed with Osteoarthritis.	The experimental group received guided imagery using headphones twice a day for 20 minutes, beginning the evening after surgery and continuing until discharge. The control group received usual care with a music audio tape.	VAS (post operation, day 1)
Chen et al. (2015) [24]	music could lower pain intensity and opioid dosage	RCT: 2 groups. a) music group b) control group	56 patients (M-10 & F-20), age range 45 to 85 years, mean age 68 years.	The experimental group listened to soothing piano music and Chinese violin music at the following times: 1) 30 minutes the night before the oper-	VAS (post operation) and Opioid

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
	during postoperative days.		Patients who underwent total knee replacements	ative day, 2) 30 minutes while waiting for the operation, and 3) 60 minutes in the postoperative recovery (POR).	dosage
Finlay et al. (2016) [25]	To examine the effect of harmony and rhythm on acute, post-operative pain of patients scheduled for knee surgery	RCT: 5 groups. a) four music listening group b) control group	98 patients (M-40 & F-58), mean age 68 years, diagnosed with arthritic pain, radiographic Arthritis.	After surgery using standardized anesthesia, participants undertook a 15-minute intervention per day of in-patient stay. Measures of pain intensity, pain interference, salivary cortisol concentration, and mood were obtained.	VRS, NRS, Short-Form McGill Pain Questionnaire, Brief Pain Inventory.
Gallagher et al. (2018) [26]	MT sessions on post-elective orthopedic surgery patients' pain, mood, nausea, anxiety, use of narcotics and antiemetics, and length of stay.	RCT: 2 groups. a) experimental group - music therapy b) control group - standard medical care	163 patients, (M-92 & F-71), mean age 60.5 years, diagnosed with Osteoarthritis and going through Surgery (Knee 69, hip 88, and shoulder 6)	Patients received music therapy within 24 hours of admission to the unit, as well as every day of their stay. Same-day pre- and post-intervention data were collected 30 minutes apart for both groups, including patient self-reported mood, pain, anxiety, and nausea. Medication use and length of stay were obtained from the electronic medical record.	Numerical Rating Scale (NRS)
Masuda et al. (2005) [27]	To examine the effect of music listening on postoperative pain and/or stress in elderly orthopedic patients.	RCT: 2 groups. a) experimental group - music therapy (M) b) control group - standard medical care (C)	44 (M-18 & F-26), age range 60 to 89 years, mean age 69 years. Diagnosed with spinal disorders: joint disorders (24), musculoskele (16), tal tumors (2), trauma (2)	The patients in Group M were given the option to listen to music for 20 minutes in private rooms. Pain levels were evaluated using the Visual Analog Scale (VAS) and the Wong-Baker Faces Scale (FS). As indicators of stress, systolic and diastolic blood pressure, heart rate, skin temperature, and fingertip blood flow were measured.	Visual Analogue Scale (VAS) Wong/Baker Faces Scale (FS)
Mondanaro et al. (2017) [28]	To examine the effect of music therapy (MT) interventions on the recovery of patients after spine surgery	RCT: 2 groups. a) experimental group - MT plus standard care (medical and nursing care with scheduled pharmacologic pain intervention) b) control group - standard care only	60 patients (M-25 & F-35), age range 40 to 55 years	Measurements for both groups were taken before and after the intervention. MT used patient-preferred live music to promote relaxation through improvisation, singing, rhythmic drumming, or guided visualization. Patients listened to music for 30 minutes postoperatively. The control group received earbuds and standard care.	visual analog scale (VAS) VAS (pre, post operation) Hospital Anxiety and Depression Scale (HADS) Tampa scale
Simcock et al. (2008) [29]	To examine the effect of patient-selected music on reducing perceived pain	RCT: 2 groups. a) experimental group - music therapy 9M) b) control group - standard medical care (C)	30 patients (M-12 & F-18), Mean age 67.3 years, diagnosed with Osteoarthritis (26), traumatic arthritis (2), rheumatic arthritis (1), or lupus (1)	The experimental group wore headphones and MP3 players, listening to music selected by the patient during the surgical procedure. For the control group, a blank file was played during the procedure. VAS was administered preoperatively and at 3, 6, and 24 hours postoperatively.	VAS
Saadatmand et al. (2015)	Natural sounds may help reduce the potentially	RCT: 2 groups. a) Experimental group	60 patients who are receiving mechanical ventilation	All participants wore headphones for 90 minutes. The intervention group heard pleasant natural sounds, while	Visual Analog Scale (VAS)

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
[30]	harmful effects of anxiety and pain in hospitalized patients	(n=30) b) Control group (n=30)	support.	the control group heard nothing. Outcome measures included self-reported VAS for pain at baseline, 30, 60, and 90 minutes into the intervention, and 30 minutes after.	
Chan et al. (2007) [31]	Usability and effectiveness of VR in reducing pain in wound-care procedures for pediatric burn patients	RCT: 2 groups. a) Control b) Experiment. Each patient participated in a single VR trial: once with VR and once without VR.	8 eligible patients: Mean age is 6.54. 7 had been scalded and 1 had been burned.	a) Children reported FPS before, during, and after, b) Interview with nurses, c) Nurses conduct the usability and modified presence questionnaires (PQ), d) A Semi-structured interview for 15 minutes with nurses about their perception of PQ.	Faces Pain Scale (FPS) from 0-100; Usability and modified presence questionnaires (PQ)
Das et al. (2005) [32]	VR game to decrease procedural pain in children (5 - 18 years) with acute burn injuries.	RCT: 2 groups. a) routine pharmacological analgesia, or b) routine pharmacological analgesia with VR	7 Children (5 - 18 years), having burns to more than 3% of their body surface area, & requiring dressing changes	Dressing change has two phases. The subjects were asked to score their average pain experience at the end of each phase of the dressing change procedure. An interview with the child, mother, and the nursing staff.	Self-report FPS 0 (No Hurt) to 10 (Very bad/Worst Hurt)
Gershon et al. (2003) [33]	VR to alleviate pain and anxiety associated with an invasive procedure for a pediatric cancer patient	Single Case Study. Control condition: No distraction (A), non-VR distraction on a computer screen (B), and VR distraction with a headset (C).	An 8-year-old Caucasian male with a diagnosis of acute lymphocytic leukemia, received more than 10 previous port accesses.	A-B-C-A design during four consecutive appointments. The child, parents, and nurse gave VAS pain and anxiety ratings before and after each port access. CHEOPs were recorded during the procedure (5-10 min long procedure). Pulse rate monitored before, during, and after.	VAS (10-cm) line with a slide ruler with facial depictions to help the child. CHEOPS; Pulse rate.
Gershon et al. (2004) [34]	VR as a distraction for children with cancer	RCT: 3 groups a) VR distraction (n=22), b) No distraction control group (n=22), c) Non-VR distraction	59 children, Mean age - 12.7. Having a diagnosis of childhood cancer.	Parents, children, and nurses assessed the child's pain at two intervals; before the port access procedure and after it was completed. Pulse rate was monitored 3 times; before, during, and after. Researched recorded CHEOPS during the procedure.	VAS; CHEOPS; Pulse Rate;
Gold et al. (2006) [35]	VR as a pain distraction for pediatric intravenous (IV) placement for an MRI or CT scans	RCT: 2 groups. a) VR distraction using Street Luge (5DT), presented via a head-mounted display, or (2) standard of care (topical anesthetic) with no distraction.	20 children, Mean age - 10.2, Requiring IV placement for MRI or CT scans that required IV placement.	Following the screening tasks, children and their parents completed baseline measures. Participants completed self-report surveys at 3 separate intervals: approximately 30 min before the IV, immediately before the IV, and following IV placement.	VAS Wong-Baker FACES Pain Rating Scale Faces Pain Scale-Revised to assess affective pain
Hoffman et al. (2000) [36]	VR to distract patients from pain during physical therapy for burn patients.	Quasi-experiment, One-treatment RCT: 2 conditions a) 3 minutes with no distractions, or b) 3 minutes in VR distraction.	12 patients average of 21% of total body surface area burned, mean age - 27.6, Performed range of motion exercises of their injured extremity under an occupational therapist.	Pain was measured after each 3 minutes of experimental treatment during a brief pause in physical therapy. At each pause, patients completed five retrospective subjective pain ratings using 100-mm VASs. With respect to the last 3 minutes of physical therapy, patients rated the variable; Spent thinking about their pain, worst pain, and average pain.	100-mm VAS pain ratings Scale for pain variables.

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
Hoffman et al. (2001)[1] [37]	Immersive VR continues to reduce pain (via distraction) with repeated use.	RCT: 2 groups. a) VR condition b) Control condition.	17 patients average of 23.7% total body surface area burned. Mean age - 21.9; performed range-of-motion exercises under an occu-therapist.	Each 3-day period had two sessions (VR and Control). The mean VR durations were 3.5, 4.9, and 6.4 minutes. Patients completed assess-ments during a brief 2-minute pause after each treatment.	Five VAS -retrospective subjective pain ratings with use 100-mm VAS.
Hoffman et al. (2001)[2] [38]	VR can serve as an effective non-pharmacolo gic analgesic for dental pain	Case study - 2 people. One treatment 3 conditions: a) VR distraction, b) Movie distraction, c) No-distraction	2 patients (aged 51 and 56 years old) Receiving perio-dontal scaling & root planning	Patient 1 spent 2.5 minutes, and Patient 2 spent 5 minutes in each of the 3 treatment conditions. Pain rat-ings were collected after each treat-ment during a 2-minute pause in dental care. After each pause (fol-lowing VR, movie watching, and no distraction), patients completed ret-rospective pain ratings.	VAS pain scores using 0-10 scales;
Hoffman et al. (2004) [39]	Water-friendly VR technology with a burn patient under-going wound care in a hy-drotherapy tub.	Quasi-Experiment Single case study. Two condition: a) Spent 3 minutes of the procedure in VR, b) 3 minutes with no dis-traction.	A 40-year-old male with 19% total body surface area deep flame/flash burns to his legs, neck, back, and buttocks.	The patient was given analgesic medication for procedural pain. Pain and presence ratings were adminis-tered after each treatment condition during a brief pause in wound care, with the patient completing several 10-point scale ratings. After wound care, the patient answered some questions.	Graphical Rat-ing Scale (GRS)
Hoffman et al. (2005) [40]	VR as an ad-junctive pain control during Transurethral Microwave Thermotherapy (TUMT) for elderly patient	Quasi-Experiment - Single case study	A 67-year-old man with BPH, previous bladder stones, and obstruction requir-ing intermittent catheterization presented for TUMT.	Once the mid-intraprostatic temper-ature reached 50 ℃, the patient an-swered pain questions and completed the VAS based on the last 2 minutes. The questionnaire was repeated after 3 minutes and again at 3 and 10 minutes following VR immersion. The total treatment lasted 37.5 minutes.	A validated, standardized pain question-naire consisting of five questions with a 10-point VAS.
Hoffman et al. (2008) [41]	The adjunctive use of wa-ter-friendly immersive VR to distract pa-tients from their pain during burn wound deb-ridement in the hydro tank.	RCT: One treatment 2 conditions study. a) 3 minutes with no dis-traction, b) 3 minutes in VR distrac-tion.	11 hospitalized inpatients, (9 to 40 years) Mean age - 27, had their burn wounds debrided and dressed while par-tially submerged in the hydrotank.	Standard analgesics were given 30 to 45 minutes before the procedure. A 6-minute segment of wound care was conducted under two conditions. During two brief pauses (after each 3 minutes), patients completed three subjective pain ratings for the pre-ceding 3 minutes of wound care.	Three 0 to 10 GRS pain scores (worst pain, time spent thinking about pain, and pain unpleasantness) for each of the 2 treatment con-ditions
Patterson et al. (2004) [42]	A 3-D immer-sive, VR world as a means to control pain & anxiety to a severely burn patient	A quasi-experiment with a single case study involved a two-day treatment under two conditions: Day 1 used hypnotic induction with a 3D VR world, and Day 2 used hypnotic induction without VR, instructing the patient to imagine entering the 3D canyon.	A 37-year-old male, admitted for burns that covered 55% of the patient's total body surface area.	On Day 40, the patient rated baseline pain. On Day 1, the patient began wound care 2 hours after a 90-minute VR hypnotic induction. Pain ratings were administered immediately after by a research assistant. On Day 2, wound care began 1 hour after the intervention, with no psychological intervention during the session. After returning to his room, the patient	GRS; Burn Specific Pain Anxiety Scale (BSPAS);

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
				completed pain and anxiety ratings with the research assistant.	
Steele et al. (2003) [43]	VR may serve as a powerful non-pharmacologic analgesic for children following surgery	Quasi-Experiment with a single Case study. A within-subject design in 2 conditions; a) VR with usual pharmacologic analgesics, b) No VR with usual pharmacologic analgesics.	One 16-year-old boy who had Single Event Multi-Level Surgery	Daily two sessions of physiotherapy from post-operative day 2 to day 6. Patient spent half of the session (approximately 10 min) using VR and half without VR. The patient was asked to rate his pain twice during each physiotherapy session: after the VR and the no-VR conditions.	A self-reported FACES scale was altered to facilitate the use of the scale with the SEMLS population. 1 to 5 scale.
Van et al. (2007) [44]	VR can reduce the procedural pain and anxiety during burn wound care session	RCT: 3 groups. a) standard care (no distraction), b) VR distraction, c) Another self-chosen distraction; television, music, non-medical conversation, and distraction by a childcare worker.	19 inpatients ages 8 to 65 years (mean, 30 years) with a mean TBSA of 7.1% (range, 0.5-21.5%)	Each patient received the standard analgesic regimen. VR was provided during one wound dressing change in the first week, with standard care or alternative distraction on other days. A nurse recorded VAT pain scores the day before VR (no distraction), the day of VR, and the day after VR (no distraction).	Pain - Visual Analog Thermometer (VAT); Anxiety - the state-version of the Spielberger State-Trait Anxiety Inventory.
Wint et al. (2002) [45]	To examine the effects of VR glasses as a non-pharmacologic aid for cancer patients undergoing frequent lumbar punctures.	A Pilot study. RCT: 2 groups. a) Standard intervention during the LP, b) Standard intervention with VR glasses and watching a video (experimental).	30 adolescents with cancer (17 in the VR and 13 in the control group) undergoing frequent Lumbar Punctures (LPs).	After the LP, the nurse assessed sedation using the Sedation Assessment Scale. Both groups marked their pain level on the VAS, and patients were interviewed about their experience.	VAS; Usability Sedation Assessment Scale.
Wolitzky et al. (2005) [46]	VR **i**s a behavioral intervention designed to decrease distress when receiving treatment for cancer and undergoing a port access procedure	RCT: 2 groups. a) VR condition, b) No VR treatment as a control condition.	20 children ages 7 to 14 receiving treatment for cancer and undergoing a port access procedure. 12 male, 55% African-American, 40% White, and 5% Asian.	After the session, the researcher conducted How-I-Feel Questionnaire for the child. The pulse monitor was then connected to the child's finger. The VAS ratings, parents, children, and the nurse all rated the child's pain and anxiety on a 0-100 scale before and during the procedure. A composite measure of distress before and during the procedure.	How-I-Feel questionnaire; Pulse rate; VAS for pain; Children's Hospital of Eastern Ontario Pain Scale (CHEOPS);
Mohammad and Ahmad, (2019) [47]	Immersive Virtual Reality (VR)	RCT: 2 groups. a) VR condition, b) No VR.	80 Female patients with breast cancer, average age of 51.99	For the VR group, assessment was conducted before giving the morphine and after finishing the VR session (VR started exactly at the peak time effect for 15 minutes). For the control group (no VR) assessment was conducted just before giving the morphine and at 15 minutes after the peak time effect.	A visual analog scale (VAS) to measure pain (a 10-cm scale)
Ding et al, (2019) [48]	To examine the effects of Immersive Virtual Reality (VR) in patients who had undergone	RCT: 2 groups. a) VR condition and standard pharmacological analgesic intervention b) No VR, a control condition (standard pharmaco-	182 patients (M-72 & F-110, mean age-45.82. Patients who had undergone hemorrhoidectomy	Pain scores and physiological measurements were collected before, during, and after the first postoperative dressing change. The standard dressing change procedure consisted of removing the dressings, cleaning	The VAS referred to a 10-cm visual scale representing a continuum with the ends

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
	hemorrhoidectomy during the dressing change	logical analgesic intervention).		and sterilizing the wound, wound assessment, and covering the wound with a new dressing.	marked '0 (no pain)' and '10 (unbearable pain)'
Chan et al, (2019) [49]	To assess the efficacy and safety of a VR distraction for needle pain in an emergency department (ED) and an outpatient pathology (ie, outpatient laboratory).	RCT: 2 groups. 2 clinical trials. It randomized undergoing venous needle procedures to virtual reality or the control was standard of care (SOC) practice.	123 patients children aged 4-11 years, mean -8.2 (M-74 & F -55). Populations in whom needle procedures are commonly performed.	In the ED, 64 children were assigned to virtual reality and 59 to SOC. In pathology, 63 children were assigned to virtual reality and 68 to SOC; 2 children withdrew assent in the SOC arm, leaving 66. Pain was measured for baseline pain between virtual reality and SOC on child-rated Faces Pain Scale-Revised.	Child-rated Faces Pain Scale
Dumoulin et al, (2019) [50]	To examine the efficacy of VR as a mode of distraction during a medical procedure compared with two conditions.	RCT: 3 groups. A) VR, B) watching TV with minimal control C) distraction provided by the Child Life gold standard control program	59 children (8-17 years, mean 13.37), Male -38 and Female -21. Children were recruited through the emergency department	A total of 59 children were randomly assigned to one of the three conditions. pain intensity and fear of pain were measured using VAS before and right after the procedure. Patient satisfaction was measured after the intervention.	A visual analog scale (VAS)
Alshatrat et al, (2019) [51]	To identify the effect of immersive VR on pain perception during scaling and root planning procedures (SRP) in dental hygiene clinics.	RCT: 2 groups a) without VR condition, or b) with VR condition.	50 patients, male-22 and female-28, average age of 36.84, who need dental hygiene.	Within-subject/split-mouth design was used in this study. The participants received a full mouth SRP. Pain was measured by VAS. Participants were also asked three questions to assess presence, realism, and nausea.	Visual Analog Scale (VAS): 0-10 scales with cut points on the scale indicating that (0) none, (1-3) mild, (4-6) moderate or (7-10) severe.
Rothgangel et al, (2018) [52]	To compare the effects of traditional mirror therapy (MT), a patient-centered tele-treatment (PACT), and sensomotor exercises without a mirror on phantom limb pain (PLP).	RCT: Three conditions: a) traditional MT followed by a tele-treatment using augmented reality MT, b) traditional MT followed by self-delivered MT, c) sensomotor exercises of the intact limb without a mirror followed by self-delivered exercises.	75 patients (M-52 & F-23, mean -61.12). Adult patients with unilateral lower limb amputation and average PLP intensity of at least 3 on the 0-10 Numeric Rating Scale (NRS).	Subjects randomly received any of the three conditions for four weeks. Intensity, frequency, and duration of PLP and patient-reported outcomes assessing limitations in daily life at baseline, 4 weeks, 10 weeks, and 6 months. Among 75, traditional MT (n = 25), tele-treatment (n = 26) or sensomotor exercises (n = 24).	0-10 Numeric Rating Scale (NRS)
Glennon et al, (2018) [53]	To determine the effects of a VR on pain and anxiety in patients undergoing the procedure.	Quasi-exper. study: a) experiment (use of VR goggles) b) control group (standard treatment).	97 patients, mean age- 51.40; undergoing a bone marrow aspiration & biopsy procedure.	Vital signs, pain, and anxiety were measured before and after the procedure.	VAS
Piskorz and Czub, (2018)	VR technology is an effective	Quasi-experimental study: 2 groups - a) with VR, b) no	38 patients (M-20 & F-18, mean -	Participants in the treatment group received the venipuncture procedure	Visual analog scales (VAS) on

Study	Env. Stimuli	Research Design	Sample	Process	Instrument /Scale
[54]	tool in the treatment of acute pain in children with dysfunctional kidneys.	VR	11.32), children staying in hospital with dysfunctional kidneys	with VR distraction. Participants rated their pain and stress intensity.	a scale of 0 to 100. A short questionnaire.
Gold and Mahrer, (2018) [55]	To evaluate the feasibility and efficacy of VR compared with SOC for reducing pain, and anxiety, and improving satisfaction associated with blood draw in children ages 10-21 years.	RCT: 2 groups. a) virtual reality (VR), b) standard of care (SOC) 143 triads were randomized to receive either VR or SOC when undergoing routine blood draws.	143 triads (patients, their caregivers, and the phlebotomist). Male-72 and female-71, average age of 15.43. Patients with procedural pain	Patients and caregivers completed pre- and post-procedural measures of pain, anxiety, and satisfaction, while phlebotomists reported on the patient's experience during the procedure. Patients and caregivers used the VAS, CAS, and Faces Pain Scale to measure affective pain before and after the procedure, and assessed their anxiety with the VAS for anxiety and the Facial Affective Scale.	VAS, Colored Analogue Scale (CAS) ranging from 0 to 10 indicating to report on pain intensity pre-procedure and post-procedure. FPS-Revised
JahaniShoorab et al, (2015) [56]	Virtual reality is an effective complementary non-pharmacological method to reduce pain during episiotomy repair.	RCT: 2 groups. a) usual treatment with VR and local infiltration (5 ml solution of lidocaine 2%) B) control group only received local infiltration	30 primiparous parturient women having labor, average age of 24.11	Pain was measured using the NPR Scale before, during, and after the episiotomy repair. In total there are four stages of repair. Parturient satisfaction was recorded before and after episiotomy repair.	Numeric Pain Rating Scale (0-100)
Kim et al, (2014) [57]	To determine the effects of a VR-based yoga program on middle-aged female low back pain patients.	RCT: 2 groups. a) a physical therapy program, b) a VR-based yoga program.	30 middle-aged female patients with chronic low back pain. (M-0 & F-30, mean age-44.33),	Patients were distributed into two programs for four weeks. A 30-minute VR-based Wii Fit yoga program or trunk stabilizing exercise was performed thrice weekly. Pain was measured using VAS before & after intervention.	VAS - A 10-cm scale marked with 1-cm increments: 0 to 10
Guo et al, (2015) [58]	To assess the effect of VR distraction on pain among patients with a hand injury undergoing a dressing change.	RCT: 2 groups. a) experiment (49 cases), and b) control (49 cases)	98 patients, Male-85 and Female -13. Hand injury (including cuts nail bed damage or skin avulsion)	Pain levels were compared between the two groups before and after the dressing change using a visual analog scale (vas).	VAS
Brown et al, (2014) [59]	Investigate the effect of the Ditto™ intervention on re-epithelialization rates in acute pediatric burns.	RCT: 2 groups. a) Ditto™ Group, b) Control Group (standard)	N=75 (M-60 & F-39) children (4-12 years, mean -8.33) with an acute burn.	Burn re-epithelialization, pain intensity, anxiety and stress measures were obtained at every dressing change until complete wound re-epithelialization.	FPS-R, FLACC, VAS-A

References

[1] International Association for the Study of Pain, IASP. (1995) Pain Measurement in Children. *Pain Clinical Updates*, 3(2).

[2] International Association for the Study of Pain, IASP. (2020). *Definition of pain*. In: Terminology. Available online at: https://www.iasp-pain.org/resources/terminology/

[3] Melzack R, Wall PD. (1965). Pain mechanisms: a new theory. *Science*, 150: 971-979. https://doi.org/10.1126/science.150.3699.971

[4] McCaul KD, Malott JM (1984). Distraction and coping with pain. *Psychol Bull*, 95: 516-533. https://doi.org/10.1037/0033-2909.95.3.516

[5] Mahrer, NE. and Gold, JI. (2009). The Use of Virtual Reality for Pain Control: A Review. *Current Pain and Headache Reports, 13*: 100-109. https://doi.org/10.1007/s11916-009-0019-8

[6] Malenbaum, S., Keefe, FJ., Williams, ACdeC, Ulrich, R. and Somers, TJ. (2008). Pain in its environmental context: Implications for designing environments to enhance pain control. *Pain*, 134(3): 241-244. https://doi.org/10.1016/j.pain.2007.12.002

[7] Walch JM, Rabin BS, Day R, Williams JN, Choi K, Kang JD. (2005). The effect of sunlight on postoperative analgesic medication use: a prospective study of patients undergoing spinal surgery. *Psychosom Med*, 67: 156-63. https://doi.org/10.1097/01.psy.0000155676.42473.d3

[8] Diette GB, Lechtzin N, Haponik E, Devrotes A, Rubin HR. (2003). Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: a complementary approach to routine analgesia. *Chest*, 123: 941-8. https://doi.org/10.1378/chest.123.3.941

[9] Bernhofer, E. I., Higgins, P. A., Daly, B. J., Burant, C. J., & Hornick, T. R. (2014). Hospital lighting and its association with sleep, mood and pain in medical inpatients. *Journal of Advanced Nursing*, 70(5), 1164-1173. https://doi.org/10.1111/jan.12282

[10] Aragon D., Farris C. and Byers J. F. (2002). The effects of harp music in vascular and thoracic surgical patients. *Alternative Therapies in Health and Medicine*, 8(5): 52.

[11] Kwekkeboom KL. (2003). Music versus distraction for procedural pain and anxiety in patients with cancer. *Oncol Nurs Forum*, 30(3): 433-440. https://doi.org/10.1188/03.ONF.433-440

[12] McCaffrey R, Locsin R. (2006). The effect of music on pain and acute confusion in older adults undergoing hip and knee surgery. *Holist Nurs Pract.* 20(5): 218-226. https://doi.org/10.1097/00004650-200609000-00006

[13] Nilsson U, Rawal N, Unestål LE, Zetterberg C, Unosson M. (2001). Improved recovery after music and therapeutic suggestions during general anaesthesia: a double-blind randomised controlled trial. *Acta Anaesthesiol Scand.* 45(7): 812-817. https://doi.org/10.1034/j.1399-6576.2001.450705.x

[14] Nilsson U, Rawal N, Unosson M. (2003). A comparison of intra-operative or postoperative exposure to music- a controlled trial of the effects on postoperative pain. *Anaesthesia.* 58(7): 699-703. https://doi.org/10.1046/j.1365-2044.2003.03181.x

[15] Nilsson U, Rawal N, Enqvist B, Unosson M. (2003). Analgesia following music and therapeutic suggestions in the PACU in ambulatory surgery; a randomized controlled trial. *Acta Anaesthesiol Scand*, 47(3): 278-283. https://doi.org/10.1034/j.1399-6576.2003.00064.x

[16] Nilsson U, Unosson M, Rawal N. (2005). Stress reduction and analgesia in patients exposed to calming music postoperatively: a randomized controlled trial. *Eur J Anaesthesiol.* 22(2): 96-102. https://doi.org/10.1017/S0265021505000189

[17] Sendelbach SE, Halm MA, Doran KA, Miller EH, Gaillard P. Effects of music therapy on physiological and psychological outcomes for patients undergoing cardiac surgery. *J Cardiovasc Nurs*. 2006; 21(3): 194-200. https://doi.org/10.1097/00005082-200605000-00011

[18] Shertzer KE, Keck JF. (2001). Music and the PACU environment. *J Perianesth Nurs.* 16(21): 90-102. https://doi.org/10.1053/jpan.2001.22060

[19] Voss, J. A., Good, M., Yates, B., Baun, M. M., Thompson, A., & Hertzog, M. (2004). Sedative music reduces anxiety and pain during chair rest after open-heart surgery. *Pain*, *112*(1-2), 197-203. https://doi.org/10.1016/j.pain.2004.08.020

[20] Yilmaz E, Ozcan S, Basar M, Basar H, Batislam E, Ferhat M. (2003). Music decreases anxiety and provides sedation in extracorporeal shock wave lithotripsy. *Urology.* 61(2): 282-286. https://doi.org/10.1016/S0090-4295(02)02158-1

[21] Zimmerman L, Nieveen J, Barnason S, Schmaderer M. (1996) The effects of music interventions on postoperative pain and sleep in coronary artery bypass graft (CABG) patients. *Sch Inq Nurs Pract, Summer; 10(2):* 153-70.

[22] Allred, K. D., Byers, J. F., & Sole, M. L. (2010). The effect of music on postoperative pain and anxiety. *Pain Management Nursing*, 11(1), 15-25. https://doi.org/10.1016/j.pmn.2008.12.002

[23] Antall, G. F., & Kresevic, D. (2004). The use of guided imagery to manage pain in an elderly orthopaedic population. *Orthopaedic Nursing*, *23(5)*, 335-340. https://doi.org/10.1097/00006416-200409000-00010

[24] Chen, H. J., Chen, T. Y., Huang, C. Y., Hsieh, Y. M., & Lai, H. L. (2015). Effects of music on psychophysiological responses and opioid dosage in patients undergoing total knee replacement surgery. *Japan J. of Nursing Science*, 12(4), 309-319. https://doi.org/10.1111/jjns.12070

[25] Finlay, K. A., Wilson, J. A., Gaston, P., Al-Dujaili, E. A., & Power, I. (2016). Post-operative pain management through audio-analgesia: Investigating musical constructs. *Psychology of Music, 44(3)*, 493-513. https://doi.org/10.1177/0305735615577247

[26] Gallagher, L. M., Gardner, V., Bates, D., Mason, S., Nemecek, J., DiFiore, J. B.,. & Bethoux, F. (2018). Impact of music therapy on hospitalized patients post-elective orthopaedic surgery: a randomized controlled trial. *Orthopaedic Nursing, 37(2),* 124-133. https://doi.org/10.1097/NOR.0000000000000434

[27] Masuda, T., Miyamoto, K., & Shimizu, K. (2005). Effects of music listening on elderly orthopaedic patients during postoperative bed rest. *Nordic Journal of Music Therapy, 14(1),* 4-14. https://doi.org/10.1080/08098130509478122

[28] Mondanaro JF, Homel P, Lonner B, Shepp J, Lichtensztein M, Loewy JV. (2017). Music Therapy Increases Comfort and Reduces Pain in Patients Recovering From Spine Surgery. *Am J Orthop (Belle Mead NJ). Jan/Feb; 46(1)*: E13-E22.

[29] Simcock, X. C., Yoon, R. S., Chalmers, P., Geller, J. A., Kiernan, H. A., & Macaulay, W. (2008). Intraoperative music reduces perceived pain after total knee arthroplasty-A blinded, prospective, randomized, placebo-controlled clinical trial. The journal of knee surgery, 21(04), 275-278. https://doi.org/10.1055/s-0031-1297718

[30] Saadatmand, V., Rejeh, N., Heravi-Karimooi, M., Tadrisi, S. D., Vaismoradi, M., & Jordan, S. (2015). Effects of natural sounds on pain: A randomized controlled trial with patients receiving mechanical ventilation support. Pain Management Nursing, 16(4), 483-492. https://doi.org/10.1016/j.pmn.2014.09.008

[31] Chan EA, Chung JW, Wong TK, et al. (2007). Application of a virtual reality prototype for pain relief of pediatric burn in Taiwan. J Clin Nurs, 16: 786-793. https://doi.org/10.1111/j.1365-2702.2006.01866.x

[32] Das DA, Grimmer KA, Sparon AL, et al. (2005). The efficacy of playing a virtual reality game in modulating pain for children with acute burn injuries: a randomized controlled trial. *BMC Pediatr, 5*: 1-10. https://doi.org/10.1186/1471-2431-5-1

[33] Gershon J, Zimand E, Lemos R, et al. (2003). Use of virtual reality as a distracter for painful procedures in a patient with pediatric cancer: a case study. *Cyberpsychol Behav, 6:* 657-662. https://doi.org/10.1089/109493103322725450

[34] Gershon J, Zimand E, Pickering M, et al. (2004). A pilot and feasibility study of virtual reality as a distraction for children with cancer. *J Am Acad Child Adolesc Psychiatry*, 43: 1243-49. https://doi.org/10.1097/01.chi.0000135621.23145.05

[35] Gold J, Kim S, Kant A, et al. (2005). Effectiveness of virtual reality for pediatric pain distraction during IV placement. *Cyberpsychol Behav, 9*: 207-212. https://doi.org/10.1089/cpb.2006.9.207

[36] Hoffman HG, Patterson DR, Carrougher CJ (2000). Use of virtual reality for adjunctive treatment of adult burn pain during physical therapy: A control study. *Clin J Pain, 16*: 244-250. https://doi.org/10.1097/00002508-200009000-00010

[37] Hoffman HG, Garcia-Palacios A, Patterson DR, et al. (2001). The effectiveness of virtual reality for dental pain control: a case study. *Cyberpsychol Behav, 4*: 527-535. https://doi.org/10.1089/109493101750527088

[38] Hoffman HG, Patterson DR, Carrougher CJ, Sharar SR (2001). Effectiveness of virtual reality-based pain control with multiple treatments. *Clin J Pain, 17*: 229-235. https://doi.org/10.1097/00002508-200109000-00006

[39] Hoffman HG, Patterson DR, Magula J, et al. (2004). Water-friendly virtual reality pain control during wound care. *J Clin Psychol, 60*: 189-195. https://doi.org/10.1002/jclp.10244

[40] Hoffman, HG. and Wright, JL. (2005). Virtual reality as an adjunctive pain control during transurethral microwave thermotherapy. *Urology, 66(6):* 1320e1-1320e3. https://doi.org/10.1016/j.urology.2005.07.013

[41] Hoffman HG, Patterson DR, Seibel E, et al. (2008). Virtual reality pain control during burn wound debridement in the hydrotank. *Clin J Pain, 24*: 299-304. https://doi.org/10.1097/AJP.0b013e318164d2cc

[42] Patterson DR, Tininenko JR, Schmidt AE, Sharar SR. (2004). Virtual reality hypnosis: a case report. *Int J Clin Exp Hypn, 52:* 27-38. https://doi.org/10.1076/iceh.52.1.27.23923

[43] Steele E, Grimmer K, Thomas B, et al. (2003). Virtual reality as a pediatric pain modulation technique: a case study. *Cberpsychol Behav, 6*: 633-638. https://doi.org/10.1089/109493103322725379

[44] van Twillert B, Bremer M, Faber AW (2007). Computer-generated virtual reality to control pain and anxiety in pediatric and adult burn patients during wound dressing changes. *J Burn Care Res, 28*: 694-702. https://doi.org/10.1097/BCR.0b013e318093e3e4

[45] Wint S, Eshelman D, Steele J, Guzetta CE (2002). Effects of distraction using virtual reality glasses during lumbar punctures in adolescents with cancer. *Oncol Nurs Forum, 29:* 8-15.

[46] Wolitzky, K., Fivush, R., Zimand, E., Hodges, L., Rothbaum, B. O. (2005). Effectiveness of virtual reality distraction during a painful medical procedure in pediatric oncology patients. *Psychology and Health, 6:* 817-24. https://doi.org/10.1080/14768320500143339

[47] Mohammad, E. B., & Ahmad, M. (2019). Virtual reality as a distraction technique for pain and anxiety among patients with breast cancer: a randomized control trial. *Palliative & supportive care, 17(1),* 29-34. https://doi.org/10.1017/S1478951518000244

[48] Ding, J., He, Y., Chen, L., Zhu, B., Cai, Q., Chen, K., & Liu, G. (2019). Virtual reality distraction decreases pain during daily dressing changes following haemorrhoid surgery. *Journal of International Medical Research,* 47*(9),* 4380-4388. https://doi.org/10.1177/0300060519864703

[49] Chan, E., Hovenden, M., Ramage, E., Ling, N., Pham, J. H., Rahim, A.,. & Leong, P. (2019). Virtual reality for pediatric needle procedural pain: two randomized clinical trials. *The Journal of pediatrics, 209,* 160-167. https://doi.org/10.1016/j.jpeds.2019.01.024

[50] Dumoulin, S., Bouchard, S., Ellis, J., Lavoie, K. L., V ézina, M. P., Charbonneau, P.,. & Hajjar, A. (2019). A randomized controlled trial on the use of virtual reality for needle-related procedures in children and adolescents in the emergency department. *Games for Health Journal*, *8(4)*, 285-293. https://doi.org/10.1089/g4h.2018.0128

[51] Alshatrat, S. M., Alotaibi, R., Sirois, M., & Malkawi, Z. (2019). The use of immersive virtual reality for pain control during periodontal scaling and root planing procedures in dental hygiene clinic. *International Journal of Dental Hygiene*, 17*(1)*, 71-76. https://doi.org/10.1111/idh.12351

[52] Rothgangel, A., Braun, S., Winkens, B., Beurskens, A., & Smeets, R. (2018). Traditional and augmented reality mirror therapy for patients with chronic phantom limb pain: results of a three-group, multicentre single-blind randomized controlled trial. *Clinical Rehabilitation*, *32*(12), 1591-1608. https://doi.org/10.1177/0269215518786663

[53] Glennon, C., McElroy, S. F., Connelly, L. M., Lawson, L. M., Bretches, A. M., Gard, A. R., & Newcomer, L. R. (2018). Use of virtual reality to distract from pain and anxiety. In *Oncology Nursing Forum*, *45*(4). https://doi.org/10.1188/18.ONF.545-552

[54] Piskorz, J., & Czub, M. (2018). Effectiveness of a virtual reality intervention to minimize pediatric stress and pain intensity during venipuncture. *Journal for Specialists in Pediatric Nursing*, *23*(1), e12201. https://doi.org/10.1111/jspn.12201

[55] Gold, J. I., & Mahrer, N. E. (2018). Is virtual reality ready for prime time in the medical space? A randomized control trial of pediatric virtual reality for acute procedural pain management. *Journal of Pediatric Psychology*, *43*(3), 266-275. https://doi.org/10.1093/jpepsy/jsx129

[56] JahaniShoorab, N., Zagami, S. E., Nahvi, A., Mazluom, S. R., Golmakani, N., Talebi, M., & Pabarja, F. (2015). The effect of virtual reality on pain in primiparity women during episiotomy repair: a randomize clinical trial. *Iranian journal of medical sciences*, *40*(3), 219.

[57] Kim, S. S., Min, W. K., Kim, J. H., & Lee, B. H. (2014). The effects of VR-based Wii fit yoga on physical function in middle-aged female LBP patients. *Journal of Physical Therapy Science*, *26*(4), 549-552. https://doi.org/10.1589/jpts.26.549

[58] Guo, C., Deng, H., & Yang, J. (2015). Effect of virtual reality distraction on pain among patients with hand injury undergoing dressing change. *Journal of Clinical Nursing*, *24*(1-2), 115-120. https://doi.org/10.1111/jocn.12626

[59] Brown, N. J., Kimble, R. M., Rodger, S., Ware, R. S., & Cuttle, L. (2014). Play and heal: randomized controlled trial of Ditto™ intervention efficacy on improving re-epithelialization in pediatric burns. *Burns*, *40*(2), 204-213. https://doi.org/10.1016/j.burns. 2013.10.010

[60] Nilsson, U. (2008). The anxiety-and pain-reducing effects of music interventions: a systematic review. *AORN Journal*, *87*(4), 780-807. https://doi.org/10.1016/j.aorn.2007.09.013

[61] Sin, W. M., & Chow, K. M. (2015). Effect of music therapy on postoperative pain management in gynecological patients: a literature review. *Pain Management Nursing*, *16*(6), 978-987. https://doi.org/10.1016/j.pmn.2015.07.002

[62] Lee, J. H. (2016). The effects of music on pain: a meta-analysis. *The Journal of Music Therapy*, *53*(4), 430-477. https://doi.org/10.1093/jmt/thw012

[63] Santiv áñez-Acosta, R., Tapia-L ópez, E. D. L. N., & Santero, M. (2020). Music therapy in pain and anxiety management during labor: a systematic review and meta-analysis. *Medicina*, *56*(10), 526. https://doi.org/10.3390/medicina56100526

[64] Lin, C. L., Hwang, S. L., Jiang, P., & Hsiung, N. H. (2020). Effect of music therapy on pain after orthopedic surgery—a systematic review and meta‐analysis. *Pain Practice*, *20*(4), 422-436. https://doi.org/10.1111/papr.12872

[65] Pittara, M., Matsangidou, M., Stylianides, K., Petkov, N., & Pattichis, C. S. (2020). Virtual reality for pain management in cancer: a comprehensive review. *IEEE Access*, *8*, 225475-225489. https://doi.org/10.1109/ACCESS.2020.3044084

[66] Goudman, L., Jansen, J., Billot, M., Vets, N., De Smedt, A., Roulaud, M.,. & Moens, M. (2022). Virtual reality applications in chronic pain management: systematic review and meta-analysis. *JMIR Serious Games*, *10*(2), e34402. https://doi.org/10.2196/34402

[67] Chuan, A., Zhou, J. J., Hou, R. M., Stevens, C. J., & Bogdanovych, A. (2021). Virtual reality for acute and chronic pain management in adult patients: a narrative review. *Anaesthesia*, *76*(5), 695-704. https://doi.org/10.1111/anae.15202

[68] Chan, E., Foster, S., Sambell, R., & Leong, P. (2018). Clinical efficacy of virtual reality for acute procedural pain management: A systematic review and meta-analysis. *PloS one*, *13*(7), e0200987. https://doi.org/10.1371/journal.pone.0200987

[69] Huang, Q., Lin, J., Han, R., Peng, C., & Huang, A. (2022). Using virtual reality exposure therapy in pain management: a systematic review and meta-analysis of randomized controlled trials. *Value in Health*, *25*(2), 288-301. https://doi.org/10.1016/j.jval.2021.08.014

[70] Martiny, K. (2004). Adjunctive Bright Light in Non-Seasonal Major Depression. *Acta Psychiatr Scand*, *110*: 7-28. https://doi.org/10.1111/j.1600-0447.2004.00307.x

[71] Beauchemin, K. M., Hays, P. (1996). Sunny hospital rooms expedite recovery from severe and refractory depressions. *J Affect Disord*, *40*: 49-51. https://doi.org/10.1016/0165-0327(96)00040-7

[72] Wilson, E. O. (1984). Biophilia. Harvard University Press, Cambridge, Massachusetts.

[73] Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, *224*(4647), 420-421. https://doi.org/10.1126/science.6143402

[74] Ulrich, R. S., Lundén, O., & Eltinge, J. L. (1993). Effects of exposure to nature and abstract pictures on patients recovering from heart surgery. Paper presented at the Thirty-Third Meetings of the Society for Psychophysiological Research, Rottach-Egern, Germany. Abstract published in *Psychophysiology 30*(Suppl. 1), 7.

[75] Brown, C. J., Chen, A. C. N., & Dworkin, S. F. (1989). Music in the control of human pain. *Music Therapy*, *8*(1), 47-60.

[76] Daveson, B. A., & Kennelly, J. (2000). Music therapy in palliative care for hospitalized children and adolescents. *Journal of Palliative Care*, *16*, 35-38.

[77] Weber, S., Nuessler, V., & Wilmanns, W. (1997). A pilot study on the influence of receptive music listening on cancer patients during hemotherapy. *International Journal of Arts Medicine*, *5*(2), 27-35.

[78] Beck, S. L. (1991). The therapeutic use of music for cancer-related pain. *Oncology Nursing Forum*, *18:* 1327-1337.

[79] Magill-Levreault, L. (1993). Music therapy in pain and symptom management. *Journal of Palliative Care*, *9*, 42-48.

[80] O'Callaghan, C. C. (1996). Pain, music creativity, and music therapy in palliative care. *Complementary Medicine International*, *3*(2), 43-48.

[81] Williamson, A., & Hoggart, B. (2005). Pain: a review of three commonly used pain rating scales. *Journal of clinical nursing*, *14*(7), 798-804. https://doi.org/10.1111/j.1365-2702.2005.01121.x

[82] Choinière, M. and Amsel, R. (1996). A visual analogue thermometer for measuring pain intensity. Journal of Pain and Symptom Management, 11(5): 299-311. https://doi.org/10.1016/0885-3924(96)00072-0

[83] Melzack, R. (1975). The McGill Pain Questionnaire: Major properties and scoring methods. *Pain*, *1*(3): 277-299. https://doi.org/10.1016/0304-3959(75)90044-5

[84] McGrath, P. J., Johnson, G., Goodman, J. T., Schillinger, J., Dunn, J., & Chapman, J. (2003). Children's Hospital of Eastern Ontario Pain Scale. *Assessing Children's Well-Being: A Handbook of Measures*, *28*(3), 38.

[85] Taal, L. A., & Faber, A. W. (1997). The burn specific pain anxiety scale: introduction of a reliable and valid measure. *Burns*, *23*(2), 147-150. https://doi.org/10.1016/S0305-4179(96)00091-3

Biography

Sharmin Kader, Ph.D., is an assistant professor at Ball State University. She is an architectural designer and researcher. Sharmin received her doctoral degree in architecture from the University of Kansas in 2016 and her master's degree in construction management from Texas A&M University. She worked as a postdoctoral research scholar at Kent State University in the healthcare design program. She has received numerous awards and has been published in many venues. She also served as a journal article reviewer, a reviewer of conference proposals, a juror of international awards, and an editor of books or proceedings. She served as the Chair of the Board of the Environmental Design Research Association (EDRA) in 2020-22. She was the Chair of the education committee of the Nursing Institute for Health Design in 2023. Currently, she is serving as a co-chair of the sub-committee of the Academy of Architecture for Health (AIA-AAH).

Research Field

Sharmin Kader: healthcare facility design, post-occupancy evaluation, hospice care environment, environmental gerontology, and environment for higher education.