Pain and Anxiety Distraction for Children with Burns During Wound Care Using Virtual Reality

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Taima Ahmad Alrimy

A thesis submitted for the requirements of the degree of Master of Science in Computer Science

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بسم الله الرحمن الرحيم

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Dedication

I dedicate this work to all who suffer from burn injuries.

Acknowledgments

First and foremost, I thank Allah Almighty for giving me the strength, knowledge, ability, and opportunity to undertake this research and to preserve and complete it satisfactorily. Without his blessings, this achievement would not have been possible.

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Abstract

Children's burn injury is one of the most traumatic childhood injuries as children encounter both physical pain and emotional anxiety. Virtual Reality (VR) distraction techniques have indicated significant results in burn patients' pain reduction during medical procedures, but an effective distraction for young children (aged < 6 years) has not been extensively studied. Hence, this research evaluates the effectiveness of a Virtual Environment (VE) used in pain and anxiety distraction for young children with burns during wound care. The VE was designed based on the needs and requirements of the targeted people, and it was tested on healthy volunteers. The VE significantly reduces the "just noticeable" pain sensitivity of children in the testing phase. 10 children with wound care were recruited for the VR clinical study in the hospital. All children received a wound care session with VR and another session with a traditional treatment randomly on different days. The results reported a significant reduction in the pain by 38.7% during the VR treatment based on the observational scale, while anxiety was reduced by 32.2%. As for the parents' observations, there was 36.8% pain reduction and 40% anxiety reduction during VR treatment. In addition, the children's enjoyment during the VR treatment was increased by 89.5% compared to the traditional treatment. These results indicate that our designed VE was efficient for children's pain and anxiety distraction.

Key Word:*Virtual Reality, Burns, Children, Pain Distraction, Anxiety Distraction*

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Chapter 1

Introduction

This chapter introduces the main problem, the importance of research, objectives, research questions, methodology, and thesis organization.

1.1 Problem Overview

Young children are at a high risk of undergoing burn injuries, which involve some of the most painful medical procedures than other injuries in medicine [1], [2]. Most children are injured by scald burns, as they sometimes move around and unexpectedly reach out for hot liquids [3], [4]. In addition, burn is one of the most traumatic injuries of childhood as children encounter both physical pain and emotional anxiety due to the experienced pain, hospitalization, and medical procedures [5].

Burn wounds care sessions are fundamental as patients need to remove their bandages and clean their wounds daily to prevent infection. Then, the caregivers open

the wounds, remove the dead tissues, and apply antiseptic ointments. These wound care sessions and dressing changes can take weeks or months until wounds are healed [6]. In some cases, a surgeon's intervention may be needed to surgically remove injured skin and transfer fresh skin from other parts of the body, like the patient's own unburned hands or thighs [7]. After the surgery, the staples or adhesive devices that temporarily hold the transferred skin in place must be removed [7].

Children remarkably exhibit their pain and anxiety during wound care sessions and describe them as the most painful procedure of the treatment (The International Association in [8] defined pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage."). Children below six years exhibit more pain and anxiety than older children, which may correlate with their cognitive development level. As these children cannot express their feelings verbally, they intend to show more significant pain and anxiety levels [9]. Due to their anxiety, they become uncooperative during wound care sessions, resulting in medical care disruption, extended hospitalization, and perhaps increased infection risk.

Adequate pain management has been recognized as a vital factor in effective long-term burn treatments. Burn patients go under pharmacological medication during wound care sessions, but the repetition of opioids over time gradually decreases analgesic effects. Furthermore, increasing the opioid doses does not control the pain, yet it has side effects like depression, nausea, cognitive dysfunction, and other concerns [10]. In addition, pharmacological analgesia used with young children has often failed to meet the child's needs; therefore, there is a growing interest in non-pharmacological methods to reduce the pain [5].

Non-pharmacological methods for anxiety and pain distraction for children include toys, music, videos, and video games. The main idea behind distraction is to grab the child's attention from the painful procedure to an attractive element or scene. Thus, immersive and interactive distraction techniques, such as virtual reality (VR), are interesting for procedural pain and anxiety distraction [11].

Virtual reality is a technology that allows users to view themselves in an alternative world, and more precisely, it is a distraction technique that enables users in the real world to interact with computer-simulated entities via multisensory stimulation like vision, hearing, and touch [11]. The logic behind how VR works is as follows: people have limited attention capacity, and pain needs attention. So, when interacting with the virtual reality world, patients use some amount of their limited attentional capacity. Therefore, VR makes the patient pay less attention to the real world (during medical care), resulting in a significant pain reduction compared to the other distraction like toys and music [10].

Interactive VR-based distraction showed promising results for pain reduction in the past two decades. Hoffman *et al*. in [7] reviewed evidence from laboratory and clinical research studies exploring VR as analgesia for burn patients. The researchers presented a study that showed 35–50% pain reductions reported by burn patients while in a distracting immersive treatment (VR + standard medications) compared with treatment as usual (no VR + standard medications only). While in another study, burn patients had received VR in a hydrotherapy tank during burn wound sessions to investigate whether VR may reduce intense pain or not. The study was the first to examine VR analgesia in a subgroup of burn patients experiencing severe pain

intensity. After the experiment, patients completed subjective pain ratings scaled from 0 to 10 labeled Graphic Rating Scales (GRS), and ratings were designed to measure the amount of time spent thinking about pain, the unpleasantness, and the worst pain. The experiment results indicated that immersive VR is an effective pain reduction technique for burn patients experiencing severe pain in a hydrotherapy tank. Moreover, after reviewing several studies, Hoffman *et al.* [7] described the relationship between the analgesic effectiveness and immersiveness of the VR System; the more increased interactivity and immersiveness of the VR system, the more increased the analgesic effectiveness.

Regardless of the promising results, most studies targeted adolescents and older patients. However, even when the study included children, the average sample age was six years, and it was not clear how many children aged less than five years. Hence, to our knowledge, VR for pain and anxiety distraction in young children (aged < 6 years) has not been extensively studied.

Few studies examined distraction in young children (aged < 6 years) like Miller *et al.* [5], who developed a handheld interactive device called multi-modal distraction (MMD) to distract burned children during dressing changes and to tell them about the procedure they will experience. The main objective of their research was to explore whether MMD distraction (MMD-D) or MMD procedural preparation (MMD-PP) can reduce the pain of the children compared to the traditional distraction by handheld video games (VG) and other toys. MMD varies from VR systems because it does not require a headset, and it is specially developed to fit children's physical and psychosocial needs. Also, Khadra *et al.* [11] conducted the pain

distraction technique during a medical procedure on fifteen young children with burn injuries aged two months to ten years using a projector-based VR tool that does not require a headset. Moreover, Sil and Dahlquist [12] conducted a case study on a four-year-old female patient with second-and third-degree burns to her shoulders, neck, and left thigh. The experiment was designed to compare the effects of interactive (Nintendo Wii) versus passive audio-video videogame in distress distraction. The study concluded that the interactive videogame distraction seems an effective and feasible distress reduction technique for young children with severe burns undergoing repeated medical procedures.

Furthermore, Sullivan *et al.* [13] and Asl Aminabadi *et al.* [14] studied the impact of VR distraction on dental pain for children, resulting in less pain during VR treatment. In addition, VR pain distraction had been experimented with oncological therapy like chemotherapy, as the researchers performed in [15], [16], and [17] with cancer patients. Again, the outcomes were promising, as the pain was less observed during VR chemotherapy treatments. Many other researchers applied the VR technology as a pharmacological distraction in general medical procedures, like researchers in [18] who performed the study during IV placement for magnetic resonance imaging and authors in [19], [20], and [21] who investigated VR effectiveness during blood draw.

1.2 Problem Statement

Children's pain and anxiety have been long observed, but an effective distraction for young children (aged < 6 years) has not been extensively studied. Pharmacological analgesia used with children has often failed to meet the child's needs and VR distraction techniques have indicated significant results in burn patients' pain reduction during medical procedures (wounds care, physical therapy). Still, mainly, the experiments were designed for patients aged above six years due in part to limitations of traditional head mounted VR displays (i.e., VR helmets not designed for children under 6 years old). This is an especially unfortunately gap in the scientific literature, since most pediatric scald burns occur in children under six, and because enfants and toddlers burn more quickly and at lower temperatures than older children and adults [12]. Since the current VR tools do not match young children's physical and psychosocial needs, this research evaluates the effectiveness of designing a VR environment used in pain and anxiety distraction for young children (aged < 6 years) with burns during wound care.

1.3 Importance of the Study

The research will help develop the artificial intelligence fields as it exposes those young children who suffer pain to the virtual reality world that work as a non-pharmacological distraction to overcome the effort and time spent in the treatment when children become uncooperative during medical care. Easing the children's pain and helping them use recent and effective technologies is one of the kingdom's

goals that leads to achieving the 2030 vision. The research addresses more than one goal of the Saudi vision 2030: quality of life, and the second one is digital transformation as we can see the system introduces the AI and VR systems to help children who suffer from pain. The system works as a pain control system to replace the pharmaceutical approach.

1.4 Research Objectives

The main objectives of this study are:

1. To find the design consideration that contributes to the distraction of children.
2. To design a VR environment that distracts pain for children based on their requirements.
3. To evaluate the effectiveness of the designed VE by measuring pain and anxiety during wound care sessions.
4. To help manage pain and anxiety for children during wound care sessions
5. To find the most suitable VR tool for children younger than six years old
6. To help achieve two goals of the Saudi vision 2030: digital transformation and quality of life by applying VR in medical care.

1.5 Research Questions

After doing preliminary research on the topic, we seek answers to the following question:

1. What are the design considerations that contribute to the distraction of children?
2. To what extent does the designed VR environment provide pain and anxiety distraction for young children with burns during wound care sessions?
3. What is the most suitable VR tool for children younger than six years old?

1.6 Methodology

The main steps to achieve the goal of this research were as follows: First, a questionnaire to gather the needs and requirements of the children, second questionnaire analysis and findings, third designing the VR environment, then test the effectiveness of the design by distributing another questionnaire about the design and by having children volunteers to experience the VR while exposed to uncomfortable sensation using the pressure pain stimulation system to see how much the VR system provides pain distraction. Lastly, the design is evaluated during hospital wound care sessions by measuring the pain and anxiety distraction. The methodology steps can be summarized in Figure 1.1.

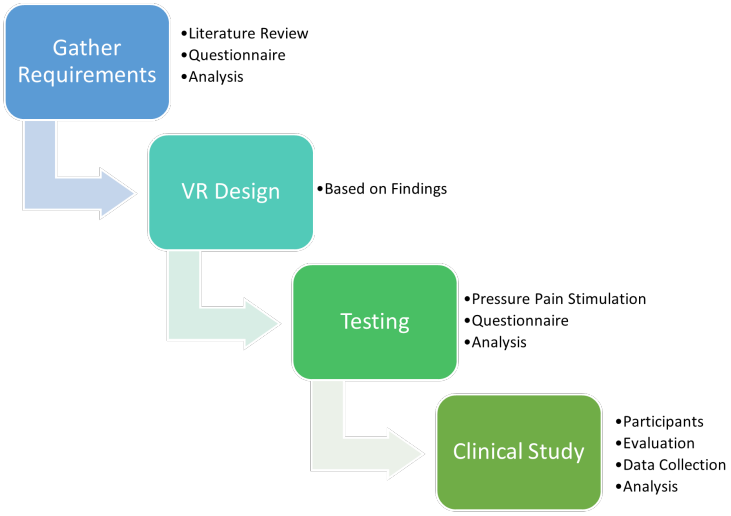

Figure 1.1: Methodology Process

1.7 Thesis Organization

This thesis is divided into five chapters; Chapter 1 presents an overview of the main problem, the objectives, and the importance of this thesis. Additionally, the research questions were listed. Chapter 2 chapter helps to understand the topic by going through the problem background and how the burn treatment has evolved using technology and reviews recent related studies. Chapter 3 highlights the research methodology and the steps taken in the VR design requirement and process. Also, it demonstrates the details of the experiment, the involved participants, and the data collection and analysis methods applied in this study. Chapter 4 represents and discusses the results and analysis of the thesis, while chapter 5 concludes the thesis and illustrates the future research directions.

Chapter 2

Literature Review

Children's pain can be challenging to control as children can show severe pain accompanied by anxiety and other concerns during their wound care session treatment [5]. Burn is one of the most traumatic injuries of childhood, and the prevalence of its associated pain is recognized, but it remains overlooked [22]. Pharmacological pain control, such as opioids, is the traditional management method. Yet, recently there has been a growing interest in non-pharmacological approaches such as toys and devices and their effectiveness in managing the pain. This chapter helps to understand the topic by going through the problem background and how the burn treatment has evolved using technology and reviews some related studies.

2.1 Traditional Management of Pain

Burns are extremely painful and frightening, especially for children. Burn pain remains undertreated even though burn injuries are common in children and it causes severe pain. Simultaneously, increasing evidence is accumulating that undertreated pain has substantial long-term medical and mental implications, which can be alleviated with better pain management [22]. Pain control is essential to assure an effective long-time treatment as it helps make the patients cooperative during the treatment and heal fast without increasing the infection risk. Pharmacological Management is the traditional pain control for patients in hospitals, and it is mainly focused on pain medication. To achieve profound sedation, studies of analgesia and sedation have mostly focused on varied combinations of propofol, ketamine, morphine, and remifentanil. There must be some general rules to govern medication use [23]: First, the patient is genuinely suffering if they say that they are feeling pain. Secondly, the analgesics must be taken regularly rather than "when needed" to be most effective. The third rule is to avoid giving medication as an intramuscular injection because they result in pain and anxiety. Lastly, the doses should be continuously reassessed to ensure the pain is managed and that the patient is not undergoing any side effects. Doses and drug selection differ according to each clinical situation since pain is not a single entity. Some of the well-known medications used for burn pain, such as opioids and morphine, are summarized in Table 2.1.

Table 2.1: Pain Medication

Medication	**Note** [23]
OPIOIDS	- The main and most popular analgesics of burn pain control. - Its use is limited due to its side effects, including pruritus, constipation, and depression of respiration.
MORPHINE	- The gold standard and first option in several burn units for treating burn pain. - A condition called Opioid-induced hyperalgesia (OIH) is encountered by some patients in which their pain increases with larger doses of morphine.
KETAMINE	- A potent analgesic with many features makes it ideal for treating burn victims. - It causes an increase in cerebral blood flow that may increase intracranial pressure in addition to tachycardia and hypertension.
REMIFENTANIL	- Remifentanil is an extremely short-acting opioid. - Hyperalgesia was associated with the sudden recovery from remifentanil analgesia.
PROPOFOL	- It is most widely used for general anesthesia induction. - It involves a fast onset of action and a rapid emergence after prolonged infusion with little cumulative effect, but it is painful when delivered through a peripheral vein.
NITROUS OXIDE	- The only nonhalogenated anesthetic gas currently in clinical use. - Severe hematopoietic and neurologic toxicity may result from repetitive exposure to higher concentrations.
BENZODIAZEPINES	- The most used anxiolytic agent for burns has three main drugs, Midazolam, lorazepam, and diazepam. - Midazolam is widely used in burn clinics since it is a fast-acting agent appropriate for short procedures or infusions.
ANTICONVULSANTS	- Anticonvulsants drugs such as Gabapentin and pregabalin have proved beneficial in pain control. - This type of drug is usually used as a multi-modal pain management protocol.

2.2 Alternative Management of Pain

Burns procedures and conditions can be painful and result in a massive anxiety situation, especially for young patients. Therefore, it has been a need to find the best way to reduce these children's pain and anxiety or help distract them. Unfortunately, pharmacological analgesia used with young children has often failed to meet their needs in reducing their pain and anxiety [5]. Researchers have shown an increasing interest in non-pharmacological methods such as toys, games, music, phones, and virtual reality for burn patients' anxiety and pain distraction and designed many different techniques and tools in the past two decades that have shown significant results in distracting and fun techniques.

Fratianne *et al.* [24] tested the effectiveness of music-based imagery and alternate musical engagement during debridement treatment in managing patients' pain and anxiety. The experiment included Twenty-five people aged seven years and above. The results showed that music therapy effectively reduced pain compared to the traditional treatment without music ($P < .03$).

In another study, Ullán *et al.* [25] believe that play is necessary for children patients to replace the negative psychosocial effect of the hospitalization. The study was performed on postsurgical pain in pediatric patients in which they were divided into two groups. The control group received traditional treatment while the other group played with toys. The results found that children who played had lower pain scores than the children from the control group.

2.3 VR Management of Pain

Virtual reality is a technology that allows users to view themselves in an alternative world, and more precisely, it is a distraction technique that enables users in the real world to interact with computer-simulated entities via multisensory stimulation like vision, hearing, and touch [11], [26]. VR tools are classified into levels of immersion ranging from fully-immersive to non-immersive [27], [28]. An immersive VR tool example is the head-mounted display (HMD), in which the patient becomes visually isolated from the hospital environment. Also, by using headphones, the sounds and hospital noise are blocked and replaced by the sounds of the alternative VR world. Another immersive tool is CAVE (Cave Automatic Virtual Environment), in which the walls, floors, and ceilings are projection screens. Giving such an illusion to the patients that they are present in the VR world allows them to perceptually escape from the painful procedure, which can reduce their pain. Non-immersive VR is referred to the screen that displays 3D without any interaction or input device. One of the most used examples of non-immersive VR is the computer monitor. Although the screen gives a low level of immersion and presence, it can provide user comfort and graphic quality with a low cost. In addition, if the screen display has an interaction and tracking devices is it considered to be semi-immersive VR because users feel more presence.

VR has been used as a distraction in many contexts. The logic behind how VR works is as follows: people have limited attention capacity, and pain needs attention. So, when interacting with the virtual reality world, patients use some amount of their limited attentional capacity. Therefore, VR makes the patient pay less attention to

the real world [29] (during medical care), resulting in a significant pain reduction compared to the other traditional distraction like toys and music [10].

2.4 VR Distraction for Pain and Anxiety

There is growing evidence that immersive virtual reality can be a powerful non-drug pain reduction technique that helps patients cope with uncomfortable medical treatments. Clinical researchers suggest that more distracting virtual reality versions be used for painful medical procedures, such as burn wound sessions [30].

2.4.1 Fully-immersive VR Distraction

Hoffman and Patterson designed *SnowWorld* [31], the first immersive VR software for burn pain and anxiety distraction. Users can interact with snowmen, penguins, flying fish, and igloos in the virtual environment by throwing snowballs at them. *SnowWorld* environment is widely used in pain distraction for burn patients as Hoffman *et al*., Van Twillert, Bremer, and Faber [6], [10], [32], [33] used it in their studies.

Hoffman *et al*. [33] explored whether immersive VR with repeated use continues to distract/reduce pain. The study was conducted on seven patients aged 9–32 years with a range of 3–60% total body surface area burned that performed physical therapy sessions on three separate days at least. Patients spent an equivalent amount of time in the control condition for each session without distraction and VR. In

addition, Van Twillert, Bremer, and Faber [32] studied if immersive VR can reduce pain and anxiety during a complete wound care session. Nineteen burn patients ages 8 to 65 years participated in the study for a one-week treatment of wound dressing changes with usual care (no VR) and with distraction care (VR). Thirteen participants reported clinically significant pain reduction (33% or higher), while no significant decrease in VR distraction treatment for anxiety.

Furthermore, Hoffman *et al.* [6] conducted the first experiment on eleven burn-injured patients ages 9 to 40 years to distract them from their pain during burn wound debridement in the hydrotherapy tank (Hydro tank) using VR. Each patient spent three minutes without distraction and three other minutes using VR during a wound care session. The researchers concluded that the results illustrated that from a controlled study, this was the first available evidence that immersive VR can be an effective nonpharmacologic pain reduction method for burn patients with severe pain to excruciating pain during wound care.

Also, Das *et al.* [34] designed a new VR game named *Quake* and explored whether the game can reduce procedural pain in children aged 5–18 years with severe burn injuries. The results indicated strong evidence that VR-based games help minimize pain and proved their reusability and versatility. Additionally, Kipping *et al.* [35] examined the effectiveness of VR distraction for teenagers with burns using a VR environment called *Chicken Little*™. Forthy-one patients aged 11-17 years were enrolled in the randomized control trial. The results showed A significant reduction in pain scores during dressing changes was reported by the nurses.

Moreover, Chan *et al.* in [36] investigated the effect of the VR prototype in reducing

the pain of burn children patients in Taiwan. The researchers implemented a VR environment suitable for the children's age group and cognitive ability. The VE is about an ice-cream factory that provides a cold sensation similar to the snow world game by Hoffman *et al.* [33]. The idea of the game is to shoot the fox with ice cream to scare him from breaking the orderliness. The experiment was performed on eight children with an average age of 6.54 in a local hospital in Taiwan. The results showed a significant pain reduction reported by children in VR treatment compared to traditional treatment. The researcher also noted that children have different responses to pain with VR due to their different natures.

In addition, Schmitt *et al.* [37] studied the effectiveness of VR as a distraction way for burn patients during physical therapy. The study included Fifty-four patients aged 6–19 years old assigned for physical therapy treatments to do range-of-motion exercises for 1–5 days. All patients spent time in VR therapy sessions and the traditional sessions equally. Graphic ratings were used to assess pain by patients; the results showed significant pain reduction by 27-44% in VR sessions compared to the traditional session. Additionally, the fun scale was measured and was increased during VR treatment.

Furthermore, Hua *et al.* [38] examined the effectiveness of VR distraction on children with burns in their lower limbs. The study included sixty-five children aged 4-16 years. The results reported significant pain reduction during the dressing time with VR compared to traditional.

Additionally, Hoffman *et al.* [39] investigated the effect of VR distraction on Latin-American children with severe burns during wound care. Forty-eight children

were enrolled, aged 6-to 17 years, and all children experienced VR treatment and traditional treatment. The results reported significant pain reduction during VR treatment and continued to show lower pain levels after multiple sessions. All the studies mentioned above used VR with headsets (VR glasses) as a tool to display the environments.

2.4.2 Semi-immersive VR Distraction

To assess the acceptability and feasibility of using VR for young children's procedural pain management, Khadra *et al*. [11] conducted the pain distraction technique during a medical procedure on fifteen children with severe burn injuries aged two months – to 10 years, and they displayed Bubbles® environment that enables children to generate bubbles on the screen. Each child experienced the usual treatment (medication + no VR) and projector-based VR treatment (medication + VR). The children were mainly calm and cooperative. Therefore, it was evident that the projector-based VR was a feasible and acceptable tool to manage pain in young children with severe burn injuries. The projector-based VR was then used for a randomized crossover trial by Khadra *et al*. [40] to examine its effects on pain in children with burns during hydrotherapy wound care. The study included 38 children aged six months to -7 years old, and the results showed that VR significantly reduced pain and increased patients' comfort levels compared to No VR treatment.

On the other hand, Miller *et al*. [5] developed a handheld interactive device called multi-modal distraction (MMD) to distract burned children during dressing changing and tell them about the procedure they will experience. The main objective of the

research was to explore whether MMD distraction (MMD-D) or MMD procedural preparation (MMD-PP) can reduce the pain of the children compared to the traditional distraction by handheld video games (VG) and other toys. Another objective is to understand the effectiveness of MMD-PP and MMD-D on the procedures by measuring the time of treatments between groups. MMD varies from VR systems because it does not require a headset, and it is specially developed to fit children's physical and psychosocial needs. The displayed scene was Bobby got a Burn Story for the MMD-PP, while in MM-D, they used a story named touch and find. The experiment studied eighty burned children aged 3-10 years during their first three dressing changes. The results of MMD-D and MMD-PP showed significant pain reduction ($p \leq 0.05$), and the length of the dressing changes was decreased ($p \leq 0.05$) compared to the traditional distraction.

Besides, Dahlquist *et al.* [41] examined whether an HMD improves children's videogame distraction effect during cold pressor pain. Forty-one children aged 6-14 years were enrolled in which each child played the same videogame with and without the HMD in the same order cold pressor trials. The results reported that with and without HMD, distraction enhanced pain tolerance relative to baseline. It was also noted that older children (11-14) reported more reduction from using the helmet, whereas younger children (6-10) appeared to benefit equally. The study concluded that using fully immersive VR can improve distraction for older children, while younger ones can have the same results using semi-immersive VR [42].

Moreover, Patterson *et al.* [43] studied the feasibility of using a water-friendly VR during debridement for adult burn patients. The study investigated whether

interactive VR would have more pain reduction than natural stimuli viewed in the same VR tool. The experiment included forty-eight patients (children and adults) with severe burn injuries in which they spent equivalent time in each condition (VR and traditional). The results indicated that pain was significantly reduced in VR treatment compared to traditional treatment. At the same time, results showed that interactive VR did not decrease pain compared to the natural stimuli as predicted.

Furthermore, Armstrong *et al*. [44] examined the effectiveness and feasibility of mobile phone VR for children with burns in home dressing changes. The researchers developed a "Virtual Reality Pain Alleviation Tool (VR-PAT)" tool used by thirty-five patients aged 5-17 years. Children were assigned into two groups of treatment: the VR-PAT and traditional treatment. According to the pain scores assessed by patients and caregivers, the VR group reported less pain during dressing changes and more fun compared to the other group.

2.4.3 Non-immersive VR Distraction

Non-immersive VR distraction is the use of passive distractions (with no interactivity) like videos or movies. This type of distraction was used in some studies to compare interactive VR and passive distractions. For example, Jeffs *et al*. [45] compared the effectiveness of VR distraction vs. passive distraction for teenagers aged 10 – 17 years. The study included 28 adolescents with burns, and patients were assigned randomly to three conditions: VR distraction without HMD, passive distraction, and traditional treatment. The results indicated that the VR group reported less pain than other treatments. This study added to the existing knowledge

that VR could effectively reduce pain without wearing the HMD.

Also, Furness *et al*. [13] performed a small-scale qualitative study to explore the impact and usability of active and passive VR on burn patients during painful dressing changes. The study included five patients; each had three observed dressing change sessions, one with an active VR method, one with a passive VR method, and one with no VR. The results indicated that active VR was acceptable and helped patients manage their pain.

Besides, Sil and Dahlquist [12] conducted a case study on a four-year-old female patient with second-and third-degree burns to her shoulders, neck, and left thigh. The experiment was designed to compare the effects of interactive versus passive videogame on distress distraction. The patient experienced three baselines and ten videogame distraction sessions (five passive and five interactive). In conclusion, the interactive videogame distraction seems an effective and feasible distress reduction technique for young children with severe burns undergoing repeated medical procedures.

In addition, Xiang *et al*. [46] examined the efficiency of a mobile phone VR in pain distraction for burned children during dressing. Ninety children aged 6 to 17 were enrolled and divided into three groups of treatment: active VR, passive VR, and traditional care. The pain was significantly reduced in the VR conditions (active and passive) compared to traditional conditions. The active VR group also showed more pain reduction than the passive group. This experiment showed that mobile phone VR efficiently reduces pain for burned children.

2.5 Pain and Anxiety Assessments

Valid and reliable assessments are important for effective pain and anxiety management. How do we measure pain and anxiety when patients get distracted during medical procedures? Pain and anxiety can be measured using observational, self-reporting, interviews, and physiological measures.

- **Self-Reporting**

  The visual analog scale (VAS) is one of the most well-known scales that allows patients to assess their pain by feeling its intensity [47]. Researchers like Miller *et al*. [5], Hoffman *et al*. [33], Kipping *et al*. [35], Hua *et al*. [38], and [32] used it in their studies. Also, Hoffman et al. [6] and Schmitt et al. [37] used patients' ratings as severe to excruciating during the experiment using three 0 to 10 graphic rating scale pain scores (time spent thinking about pain, pain unpleasantness, and worst pain).

  Moreover, Wong-Baker Faces (FACES) is a self-report scale for children used by Miller *et al*. [5], Das *et al*.[34], Chan *et al*. [36] and Hua *et al*. [38] in their experiments. FACES shows a series of faces ranging from a happy face at 0, or "no hurt," to a crying face at 10, representing "hurts like the worst pain imaginable." Children's Self-reporting is usually accepted as a standard way of pain reporting, and the outcome can be significant if given age-appropriate tools [48]. As for the anxiety, the state-version of the Spielberger State-Trait Anxiety Inventory was used by Jeffs *et al*. [45], [32] and [41], a 40-item self-administered questionnaire that aims to assess anxiety with 20 items each.

Additionally, The Revised Children's Manifest Anxiety Scale is a 37-item self-report measure used to assess anxiety in children and teenagers used by [41].

- **Observations**

  The observational Faces, Legs, Activity, Cry, and Consolability scale (FLACC) is a behavioral/observational pain scale from 0 to 10 (0=relaxed and comfortable, 7–10=severe discomfort/pain) for children from 0 to 18 years old [49][50]. It was used by Miller *et al*. [5], Kipping *et al*. [35], and Khadra *et al*. [11] [40] in addition to NRS-obs (Numerical Rating Scale-obs) in their studies.

  Besides, Khadra *et al*. [11] used the following observational scales for anxiety and sedation: Procedure Behavior Check List, which comprises eight behaviors based on occurrence and intensity for a possible total score ranging from 0 to 40 [51]. Also Modified Smith Scale, an observational scale with four levels ranging from 0 (no anxiety) to 3 (most anxious), and OCCEB-BECCO [behavioral observational scale of comfort level for child burn victims], which is a new scale with scores ranging from 0 to 10 developed by [52].

  Moreover, Sil and Dahlquist [12] measured the distress level using the Observation Scale of Behavioral Distress (OSBD), which is a scale by [53] that consists of verbal, vocal, and motor behaviors indicative of distress in children coded in 15-s continuous intervals.

- **Interviews**

  Researchers like Furness *et al*. [9], Sil and Dahlquist [12], and Das *et al*.[34]

used interviews and qualitative post-intervention interviews with nurses and parents to evaluate the patient's pain and cooperative behavior.

- **Physiological Measures**

  Miller *et al*. [5] and Hua *et al*. [38] recorded the physiological measures of oxygen saturations (O2) and pulse rate (PR), which are accepted as pain indicators. While Hoffman *et al*. [54] and Lewis *et al*. [55] used fMRI pain-related brain activity to measure pain.

An overview of the related work is summarized in Table 2.2 below.

Table 2.2: Summary of Related Studies

#	Source	Experimental Conditions	Number of Patients	Patients Ages	VR Tool	Environment Design	Pain Measurement Tool	Results
1	[6]	During wound care	11 Burn patients	9 to 40 years	HMD	Snow World game	Graphic Rating Scales (GRS)	41% Pain reduction
2	[32]	Wound care session	19 burn patients	8 to 65 years	HMD	Snow World game	VAS and the state-version of the Spielberger State-Trait Anxiety Inventory.	33% or more significant pain reduction
3	[54]	During medical procedures	8 Burn patients	18 to 43 years	HMD	Snow World game	fMRI pain-related brain activity	All five brain regions of interest confirmed significant pain-related brain activity reduction.
4	[37]	Physical therapy	54 burn patients	6-19 years	HMD	Snow World game	Graphic Rating Scales (GRS)	The results showed significant pain reduction by 27-44% in VR sessions compared to the traditional session
5	[39]	Wound care	48 patients	6-17 years	HMD	Snow world game	Graphic Rating Scales (GRS)	The results reported significant pain reduction during VR treatment and continued to show lower pain levels after multiple sessions.
6	[33]	Physical therapy sessions	7 Burn patients	9 to 32 years	HMD	Spider World & Snow World games	The visual analog scale of 0 to 10 (VAS)	VR does not reduce analgesic effectiveness with three (and possibly more) uses.

7	[34]	Changing dressings	9 Burn patients	5 to 18 years	HMD	Quake game	Self-report Faces Scale and interviews with parents and nurses.	The results showed the significant effect of VR in reducing pain during burn dressing changes.
8	[9]	Wound Dressing	5 Burn patients	19 to 68 years	HMD	Basket and Flocker & Oculus video application	Interview	VR was feasible and acceptable to all patients when used during dressing changes.
9	[35]	Burn wound care	41 Burn patients	11 to17 years	HMD	Chicken Little™	VAS and FLACC	A significant reduction in pain scores during dressing changes was reported by the nursed
10	[38]	Dressing change	65 patients	4-16 years	HMD	Ice age game	FACES, VAS, and physiological measure	The results reported significant pain reduction during the dressing time with VR compared to traditional.
11	[36]	Burn wound care	8 burn patients	Mean age 6.54	HMD	Ice-factory Game	self-reported faces pain scale	showed a significant pain reduction reported by children in VR treatment compared to traditional treatment
12	[41]	cold pressor pain	41 children	6-14 years	HMD videogame and no HMD videogame	Free dive	Revised Children's Manifest Anxiety Scale and State-Trait Anxiety Inventory	The results reported that older children (11-14) reported more reduction from using the helmet, whereas younger children (6-10) appeared to benefit equally.
13	[43]	debridement	48 patients	4 children and 44 adults	VR goggles	Nature stimuli and snow world	Graphic Rating Scales (GRS)	The results indicated that pain was significantly reduced in VR treatment compared to traditional treatment. However, at the same time, results showed that interactive VR did not decrease pain compared to the natural stimuli as predicted.
14	[5]	Dressing changes	80 Burn patients	Three to 10 years	MMD-D + MMD-PP	Bobby got a Burn & touch and find story	FACES, VAS, FLACC, physiological measure	MMD significantly reduced pain and time for dressings ($p \leq 0.05$) compared to SD and VG.
15	[12]	Burn Dressing Changes	One patient	Four years old	The Nintendo Wii	Go, Diego, Go! Safari Rescue	Observation Scale of Behavioral Distress (OSBD) and Post-Intervention Interview	Distress scores were decreased from 5.30 during the experiment phase to 2.92

16	[11]	Burn wound care procedures	15 Burn patients	Two months to 10 years	Projector-based VR	Bubbles®	FLACC scale, Modified Smith Scale, Procedure Behavior Check List, OCCEB-BECCO, and (Ramsay Sedation Scale).	The mean pain score and the discomfort level were decreased.
17	[40]	hydrotherapy sessions	38 children	6 months – 7 years	Projector-based hybrid VR	Bubbles®	FLACC 0-10 NRS-obs (Numerical Rating Scale-obs)	significantly pain reduction in pain by FLACC (p=0.026) pain rated by the nurses using the NRS-obs were non-significant (p=0.135)..
18	[45]	Wound care	28 patients	10-17 years	Interactive VR	Snow world game	Spielberger's State-Trait Anxiety Inventory for Children and Pre/post-Procedure	The results indicated that the VR group reported less pain than other treatments. This study added to the existing knowledge that VR could effectively reduce pain without wearing the HMD.
19	[46]	Dressing change	90 patients	6-17 years	VR-PAT	The Virtual River Cruise game	VAS and FLACC	The pain was significantly reduced in the VR conditions (active and passive) compared to traditional conditions. The active VR group also showed more pain reduction than the passive group.
20	[44]	Home dressing change	35 patients	5-17 years	VR-PAT	The Virtual River Cruise game	Pain ratings 1-10 scale from patients and caregivers	The VR group reported less pain during dressing changes and more fun than the other group.

2.6 Children and Technology

There is a lack of knowledge about how children use technology; thus, the researchers in [56] examined how apps for children aged (0-5) encourage play and creativity. The study was developed in collaboration between many universities and organizations. The Importance of this study is that play in the digital world is increasing, and many technology companies' products aim for the 0-5 age group, so the products must fit their needs. In addition, there was a constant demand for this research into

technology and media use in this age group. The study was conducted in the UK. Its main objectives are to collect information about how children aged (0-5 years) use apps at home, find the most popular used tablet app, and investigate the effect of tablet apps on play and creativity. Researchers distributed an online survey of caregivers and conducted in-depth case studies of children's app use in six families to achieve the study's goals. Also, they performed interviews and observations for children and, finally, the analysis phase. Based on data analysis and observations, researchers listed the successful features of apps for each age group summarized in Table 2.3. The study result was beneficial for the design phase of this research as successful game features for the age group were considered alongside understanding children's use of technology in Saudi Arabia by using some survey questions in our study.

Table 2.3: Successful Features of Apps

Age group	**Features** [23]
0-1 year	- Sound, vision, and touch are the primary features of this age group. - Large shapes, distinct patterns, and the use of contrasting colors. - Audio support visual and animated elements. - Cause and effect (actions should be consistent throughout the app, with a large margin for error). - Naming objects.

1-2 years	- Simple, repeating actions. - Children voice-overs. - Recall/ recap (embedded where appropriate). - Interaction. - Nursery rhymes. - Competencies (swiping, tracing, tapping).
2-3 years	- Text-to-speech, animation, sounds, and visual effects. - Co-operation and turn-taking. - Exploration of all dimensions of music (rhythm, pitch, timbre, speed, volume, texture. - Drawing. - Early engagement with numbers and letters (upper and lower) in a playful context. - Use of popular characters. - Complex competencies (dragging, pinching). - Autosaving.

3-4 years	- Some features outlined above are relevant for this age group. - Independent use of device features (taking photographs). - Offline to online play (building models) - Extended games (number of levels of a challenge). - Pause and resume the app - Drawing apps with an undo function. - Sense of wonder. - Building of worlds. - Role-playing.
4-5 years	- Some features outlined above are relevant for this age group. - Solving real-world problems (early mathematical skills). - Drill and skill. - Writing and spelling games with creative engagement with letters and words through meaningful tasks. - Story apps by highlighting words as the narrator say them. - Regular opportunities for feedback. - Online social interaction with others.

2.7 Children and VR

Virtual Reality technology is becoming widely popular nowadays and has many users of all ages, including children. Yet, the is a lack of effects of VR on children and many concerns about safety issues, so there is an interest in developing best practices around VR and children. A study was conducted with collaboration between companies specializing in digital TV and VR content alongside emerging communicative technologies for young children called "Children and Virtual Reality" [57]. The study examined the effect of VR on children aged 8-12 years old and explored VR use for children younger than eight years old. Some hardware manufacturers limit VR use over 13 years old without a rationale justification for the age limit. Therefore, the study investigated any safety issues or harmful effects of using VR under the age of 13 and added recommendations for that age group. The study aimed to understand awareness of VR to children and its usability for children aged 8-12 years old and study the effect of short-term VR use on vision and balance. In addition, to find the best practices in the design and production of VR for children with guidelines for caregivers to support safe and helpful use. The researcher conducted an online questionnaire on VR awareness in the USA and UK, observed children's engagement with VR, tested their vision and balance and analyzed the collected data. The result showed that VR is being expanded into children's lives in education, training, entertainment, health, and other fields. As for health concerns, researchers found no risk in short-term play for children regarding vision and balance. The outcomes of this study helped understand the best VR practices for children to ensure safe and healthy usage of the technology.

Nevertheless, some of the study questions were used in our research to acknowledge VR awareness and preferences in Saudi Arabia.

Moreover, VR effectiveness was evidenced in pain distraction for adult patients. The question "Is VR an effective tool in reducing pain and anxiety when used by children undergoing medical procedures?" has been an interesting question that has led to many clinical trial studies and research. Eijlers *et al*. [58] have collected and searched for studies that applied VR as a distracting technique for children and adolescents. They found seventeen studies that used VR for children's patients as a pain and anxiety distraction technique, and six of the studies included burn patients. They also noticed that distraction is the main focus of research when applying VR to children. Their main finding is that VR is very effective as a pain and anxiety distracting technique for children in clinical studies.

2.8 Summary and Limitations

Children's pain and anxiety have been long observed, but most studies targeted adolescents and older patients. However, even when the study included children, the average sample age was six years, and it was not clear how many children aged less than five years. Hence, to our knowledge, VR for pain and anxiety distraction in young children (aged < 6 years) has not been extensively studied. Also, it was noted that the presented studies, which included children (aged <6 years), used low immersive VR such as 2D video games, Wii, and handheld devices [59]. Furthermore, even when using VR, some of them used projector-based or smartphone VR

because, to their knowledge, the currently available VR glasses are heavy and do not fit the children's physical needs. There are several reasons for this gap in the VR analgesia literature regarding whether VR analgesia is effective in children under 6 years old. For example, the commercially available VR glasses are not designed to be worn by such young children because the interocular distance between the eyepieces is too far apart for infants and young children. Additionally, recent research shows a notable gap in research on design considerations for creating VR environments, even if there is significant evidence of VR effectiveness in decreasing pain and anxiety [60]. Therefore, the VR environment should be designed to fulfill the requirement of the intervention purpose and the targeted users to achieve the best results.

Chapter 3

Research Methodology

This chapter highlights the research methodology and the steps taken in the VR design requirement and process. Also, it demonstrates the details of the experiment, the involved participants, and the data collection and analysis methods applied in this study.

3.1 Pre-Design Questionnaire

An online questionnaire has been created using Google Forms, a tool used in online surveys. It provides clear interfaces and graphics and is easy to make and use. It also represents the responses into different kinds of charts with precise analysis to improve understanding of the data. The questionnaire was distributed on social media -such as WhatsApp, Twitter, and Telegram- targeting parents or guardians of children between 0 and 5 years old. The main goal of the questionnaire is to

illustrate the relationship between these children and technology, and how much they are exposed to the technology (what type of devices they use, and how/when they use them). Also, to find out how familiar parents and children are with VR and what type of VR experiences children prefer. Figure 3.1 illustrates the four-level questionnaire map: basic background information, children and technology, VR, and VR in the medical field.

Figure 3.1: Questionnaire Map

The total number of responses reached 20054, but respondents with no relation with kids or have kids aged above five years were excluded leaving 1240 complete responses. The questionnaire has helped to understand the design requirements for the targeted age group (0-5 years) and their needs, and the VR game was designed based on that. This section illustrates the descriptive analysis of the survey, but the statistical analysis is discussed in Chapter 4. Appendix A describes the questionnaire.

3.1.1 Part 1: Basic Background Information

This part shows the basic information about the respondents and their relationship with kids. Also, the questionnaire was answered on behalf of children, so the age

and gender of the child were asked. Table 3.1 illustrates the background information of the respondents. As seen, the majority (73.3%) of the respondents were parents, 13.7% were aunts/uncles, some were siblings (5.8%), while 3.5% were teachers and 2.4% grandparents, and few children's specialists participated (1.3%). Moreover, the respondents were mainly females (95%), and a few were males (5%). Also, Half of the respondents were aged between 25 and 35 years, while some were aged between 35-45 (21%) and 16-25 (14.4%). Few were between 45 and 55 years and younger than 16 years (5.5%). Significantly few respondents were older than 55 years (3.7%).

Table 3.1: Background information of Respondents

Relationship	***frequency***	***percent***
Parent	909	73.3
Aunt or Uncle	170	13.7
Sibling	72	5.8
Teacher	43	3.5
Grandparent	30	2.4
Children's specialist	16	1.3
Gender	*frequency*	*percent*
Female	1173	94.6
Male	67	5.4
Age Group	*frequency*	*percent*
16	57	4.6
16-25	177	14.4

26-35	625	50.8
36-45	258	21.0
46-55	68	5.5
55	46	3.7

Table 3.2 shows that the gender of respondents' children was 50.3% female and 49.7% male, and the age of the children is defined as follows: 23.1% aged five years, 25.7% aged four years, 20.3% aged three years, 15.9% aged two years, 8.1% age one year, while 6.8% aged less than one year.

Table 3.2: Background information of Respondent's Children

Gender	*frequency*	*percent*
Female	624	50.3
Male	616	49.7
Age Group	*frequency*	*percent*
5 Years	287	23.1
4 Years	319	25.7
3 Years	252	20.3
2 Years	197	15.9
1 Year	101	8.1
Younger than one	84	6.8

3.1.2 Part 2: Children and Technology

This part maps the relationship between children and technology. The questions were taken from the study in [56], which is explained in section 2.6. It illustrates how children use technology and when they use it. As seen in Figure 3.2, the most used device for children is the TV 33%, after that phone 30%, then Tablet 25%, very few use the game console 2%, and 10% of the children don't use any device.

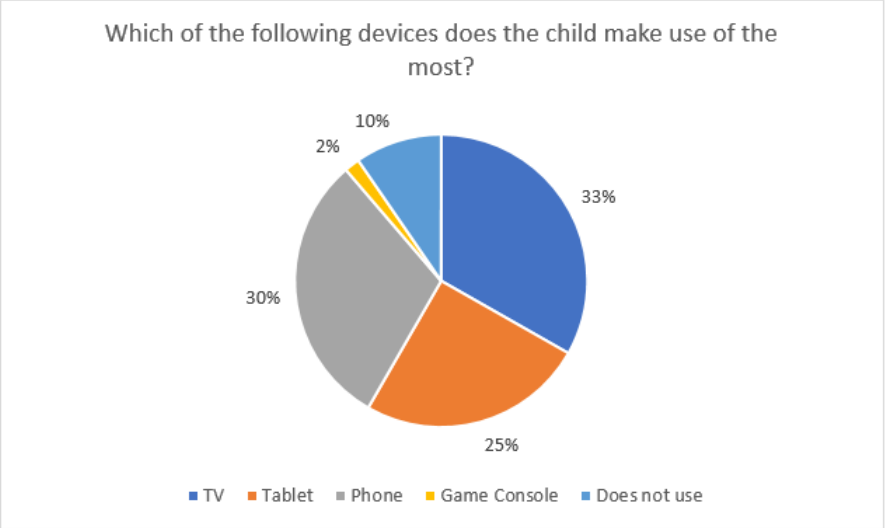

Figure 3.2: Most used Devices by Children

Children use the devices for many activities; Figure 3.3 illustrates the most used activities: watching videos, videos made by other children, cartoons, music videos, and listening to music.

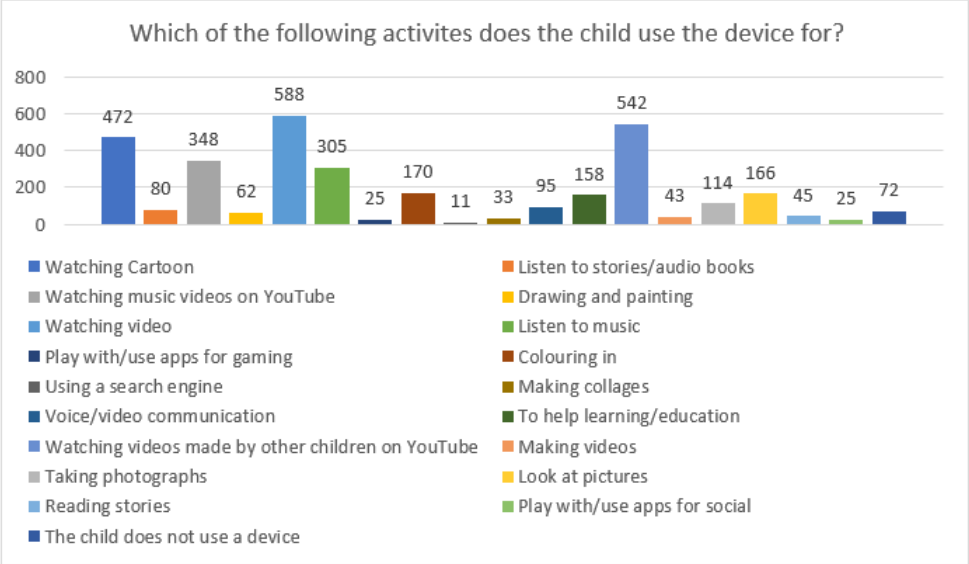

Figure 3.3: Activities children use the device for

Most of the children use the device with their parents, 40%, as Figure 3.4 shows. However, 24% of them can use the device independently, and few don't use any device 2%. The rest use the device with an adult or family members.

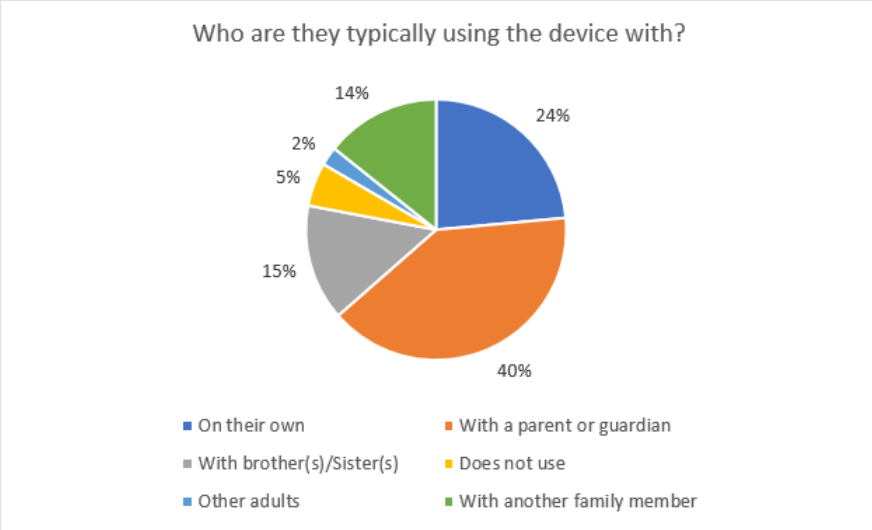

Figure 3.4: Children Device usage

Figure 3.5 indicates that most people allow children to use the device for a distraction or educational purposes.

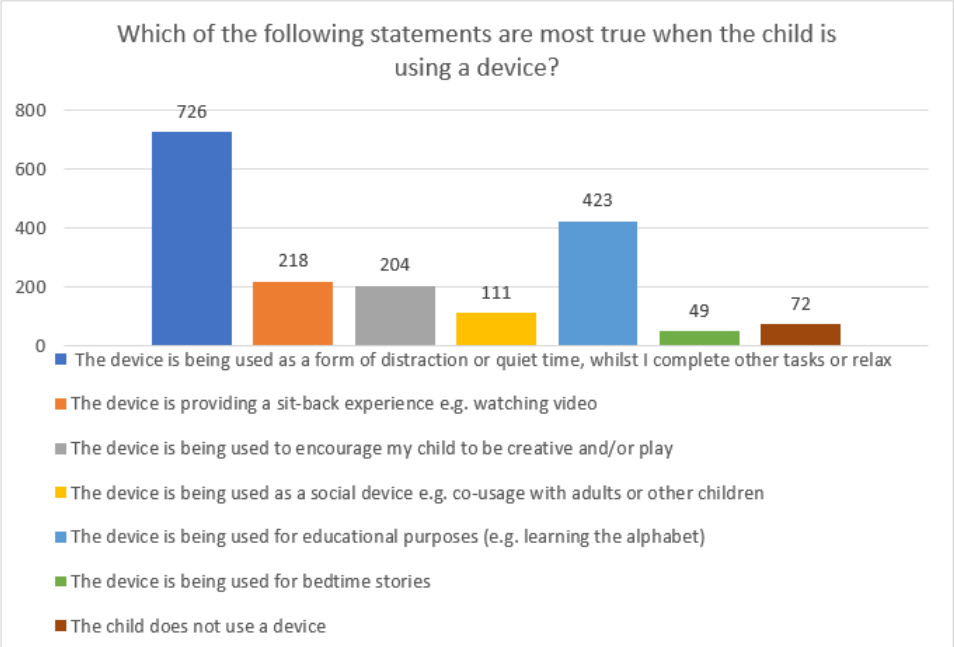

Figure 3.5: True statements when child is using a device

3.1.3 Part 3: Virtual Reality

This part investigates VR awareness and familiarity in Saudi Arabia, and questions were taken from this study [57], as mentioned in Section 2.7. As shown in Table 3.3 that 37% of people know about the technology, 14.6% used it, and 34.6% heard of it. Nevertheless, 13.8% are not aware of it. In addition, Table 3.3 points out how parents expect their children to be interested in VR. 16.2% reported that children would be highly interested, and 29.2% anticipated that they would be fairly interested. However, 15% assumed that children would feel neutral about it, 7.4%

that they wouldn't be very interested, and 3.1% that they would not be interested at all. Furthermore, 29.1% reported that their children would be unaware of the technology. Moreover, the most pleasant experiences for children are playing with cartoons and animals, and go to a virtual park, as shown in Figure 3.6.

Table 3.3: VR Familiarity and Interest

VR familiarity	*frequency*	*percent*
I know exactly what this is	459	37.0
I have used this I'm familiar with it	181	14.6
I've definitely heard of it	429	34.6
Unaware	171	13.8
VR interest	*frequency*	*percent*
Extremely interested	201	16.2
Fairly interested	362	29.2
Neither interested nor not interested	186	15.0
Not very interested	92	7.4
Not interested at all	38	3.1
Unaware	361	29.1

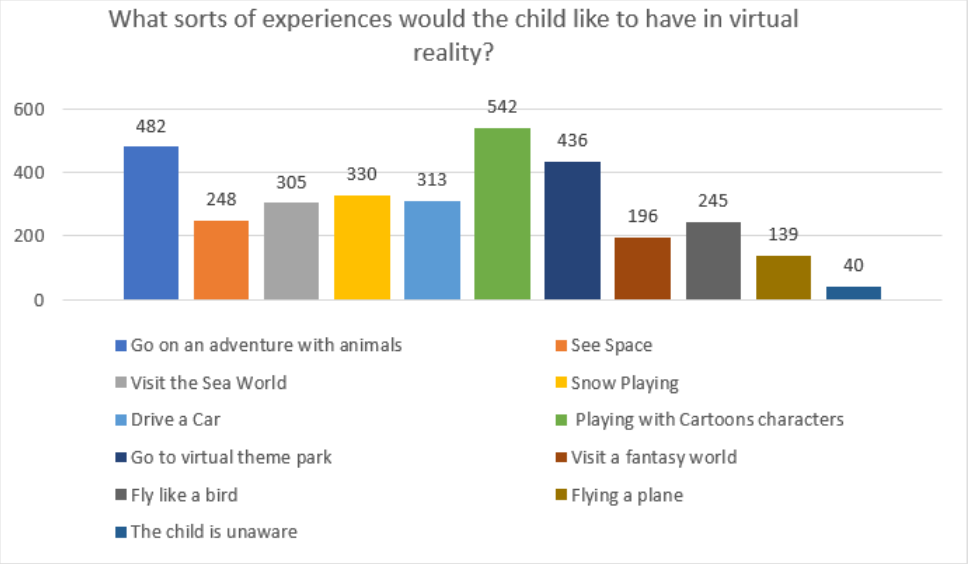

Figure 3.6: VR Experiences

3.1.4 Part 4: Virtual Reality in Medical Field

Table 3.4 shows that if people anticipate that children would still be interested in VR while feeling pain.

The percentage dropped from 16.2% to 12.7% of extremely interested children and 29.1% to 25.1% of unaware children. In contrast, the percentage increased a bit from 29.2% to 29.8% of fairly interested children, 15% to 18% for neutral feeling, 7.4% to 9.8% of not very interested, and lastly, 3.1% to 4.7% of not interested at all. Moreover, 47.9% of people believe that VR technology is a helpful method for pain distraction, and 30.8% strongly believe that, while 14.8% don't know. However, 6.5% disbelieve that. In addition, Table 3.4 illustrates that 68.5% of people preferred VR screens for their children, while 29.8% preferred VR glasses. Few would rather

none 1.7%.

Table 3.4: VR in Medical Field

VR interest in medical centers	*frequency*	*percent*
Extremely interested	157	12.7
Fairly interested	369	29.8
Neither interested nor not interested	223	18.0
Not very interested	122	9.8
Not interested at all	58	4.7
Unaware	311	25.1
VR is helpful in medical centers	*frequency*	*percent*
I strongly believe	382	30.8
Yes, I believe	594	47.9
I don't know	183	14.8
I disbelieve	67	5.4
I strongly disbelieve	14	1.1
VR Preference	*frequency*	*percent*
VR screen	849	68.5
VR glasses	370	29.8
Unaware	21	1.7

3.2 The Development of the Proposed VR Design

After the questionnaire analysis and requirements gathering, the virtual environment (VE) was designed. The design considered children's familiarity with TV screens and their love for cartoons, animals, and sounds. Also, their age group and cognitive development ability were considered as the game objects are large, simple, and easy to interact with. More importantly, the purpose of the design, distraction, is taken into account, so the game is attractive in colors and sounds with a sense of wonder and adventure.

3.2.1 The Design

The VE design is a forest with animals trapped in big bubbles floating in the scene, as displayed in Figure 3.7. The Player has to rescue the animals from falling on their land by busting the bubbles, so the game is called Animal Rescue. The player movement is automated in the path of floating bubbles. Each bubble has inside it an animated animal with simple gesture movement. The Player also can interact with a saved animal on the ground; if pressed, the animal plays its sound and glows. The mixture of animal sounds and movements creates a sense of presence and immersion in the game. The Player can speed up/down along the path, and when all bubbles are burst, the game terminates. The bubble and interactivity scores are calculated to measure the player interaction. Design considerations are mapped with Animal Rescue as shown in Table3.5 .

Figure 3.7: The Proposed VR Design

Table 3.5: Design Considerations

Design Consideration	**Animal Rescue**
Perception of safety by using familiar elements	Using animals objects
Perception of control	Interacting with environment
Perception of empathy	Saving animals (toggling gravity)
Purpose of the design ”Distraction”	Automated player movement (Minimum patient motion)
Visuals	Large and simple
Movements	Animated Animals
Attractive colours	Scene colors and glowing animals
Interactivity: patterns and repeated action	Bursting bubbles and glowing animals
Audio	Animals sounds, nursery rhythms

3.2.2 Software and Materials

The VE was designed using Unity® game engine and visual studios for coding in the object-oriented c# programming language. In addition, the game shaders use Universal Render Pipeline (URP), which provides optimized graphics prebuilt by Unity®. The design runs on a Windows® 10 HP gaming laptop powered by a 2.80 GHz Intel® Core (TM) i7-7700HQ CPU, 16GB of RAM, and an NVIDIA® GeForce® GTX 1050 Ti GPU with up to 8GB of dedicated video memory graphics for endless gaming. Finally, the VE is displayed on three tools: an HTC® VIVE HMD device, containing a resolution of 1080 x 1200 pixels per eye with a refresh rate of 90 Hz, presenting a dual AMOLED 3.6" diagonal and 110 degrees field of view, and a TV device for screen-based 2D VR with an input device with a mouse acting for interacting with the environment. Additionally, the design is also displayed on a touch-screen laptop in which children could use their fingers to interact. All used VR tools are shown in Figure 3.8.

Figure 3.8: Different VR tools

3.2.3 The VE Flowchart

The flow of the VE is presented in Figure 3.9: the game starts with an automated move, and each press on the scene is counted as interactivity. If a bubble is hit, the bubble burst with a sound and the animal inside falls to the ground, and a score is calculated. If an animal is hit, the animal glows with its sound. The game keeps running until all bubbles are burst (score=80) or if it was quitted or paused.

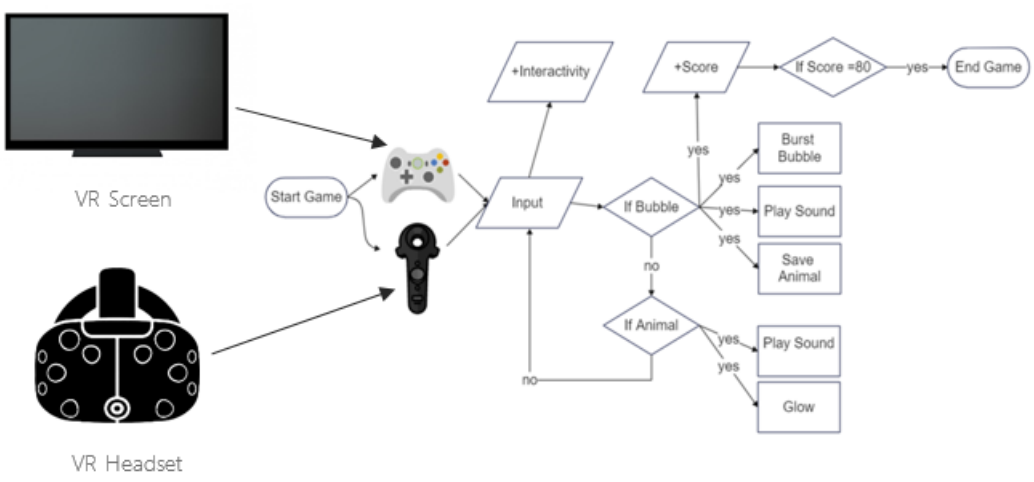

Figure 3.9: The VE Flowchart

3.2.4 The System Architecture

The VE is used for distraction purposes, as mentioned before. Patients interact with the VE during their treatment session while pain and anxiety are measured and stored in a database, as presented in Figure 3.10.

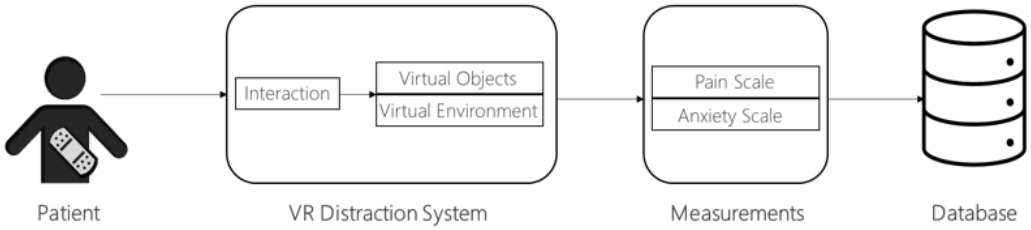

Figure 3.10: The System Architecture

3.3 System Testing

Testing to check the system's feasibility was done in two steps: a questionnaire to gather opinions and a test on children volunteers with pressure pain simulation.

3.3.1 Post-Design Questionnaire

A questionnaire was conducted and disturbed about the VE to determine what people with children think about the final design described in Appendix B. A video of the design was inserted with questions and 5-point Likert scale answers. The questions explored if respondents believe that the VE is suitable for the children's age group and if they anticipate their children would be interested in experiencing the game with/without feeling pain.

3.3.2 Pressure Pain Simulation

A hand-held pressure pain simulation in Figure 3.11 was used to generate pain sensation. The pressure algometer has a linear response to force application with a 1-cm2 round rubber tip. The rubber tip is placed on the volunteer's body (random

parts) and pressed on the skin, as a pressure score is displayed while applying force. Volunteers are exposed to a discomfort sensation using the pressure pain stimulation system while interacting with the VR system to see how much the VR system provides a distraction. The volunteers were told to tell immediately when the pressure turns into a discomfort sensation. If so, the pressure is stopped, and the score is taken. Measurements were taken three times (P1, P2, P3). First, P1 was taken while interacting with the VR system to see how much the VR design can provide pain distraction. Then, P2 was taken when children sat in a normal relaxed position with no VR. Finally, P3 was taken when children were playing a verbal game called (Colors game) in which they chose a color, and the other person started naming different colors, and when they heard their selected color, they had to call it out loud. Each child experinces the three conditions (P1, P2, P3) in a randomized order.

Figure 3.11: Pressure Pain Simulation System *Wagner FDX-25 device (Wagner Instruments, Greenwich, CT)

3.4 The Clinical Study

This research involves an clinical study in hospitals, so ethical approval is taken from the Institutional Review Board (IRB), as displayed in Appendix D. This section explains all steps and methods used to implement the experiment to achieve the objectives.

3.4.1 Participants

Children with burns admitted to the burn unit in the hospital can participate. Parents' written approval of child participation is taken, including their permission to take photos of their child during the experiment and use them in publication. Children are excluded from the study if they do not meet the following criteria:

1. Suffers from burn injury.
2. Not diagnosed with a disability that prevents them from interacting with the distracting environment.
3. Not allergic to any analgesics or opioids used in the experiment.
4. Negative Covid-19 test

3.4.2 Measurements

The pain and anxiety are measured using the following measurement tools that the doctors, nurses, and parents assess:

⋆ Anxiety is measured by Procedure Behavior CheckList (PBCL) scale, which comprises eight behaviors based on occurrence and intensity for a possible total score ranging from 0 to 40, as seen in Table 3.6 [51].

Table 3.6: PBCL Scale

Behavioral Category	***Definition***
Muscle Tension	Displays any of the following behaviors: eyes shut tight, clenched jaw, body stiffness, clenched fists, or gritted teeth.
Screaming	Raises voice or yells with sound or words
Crying	Displays tears or sobs
Restraint Used	Has to be held down by someone or have heavy tape placed across their legs
Pain Verbalized	Says “ow,” “ouch,” or comments about hurting (e.g., “you are hurting me”)
Anxiety Verbalized	Says “I’m scared” or “I’m afraid.”
Verbal Stalling	Expresses verbal delay (stop, I’m not ready, I want to tell you something)
Physical Resistance	Moves around, will not stay in position or tries to climb off the table

⋆ Pain is measured using the Faces, Legs, Activity, Cry, and Consolability scale (FLACC), a behavioral/observational pain scale from 0 to 10 (0=relaxed and comfortable, 7–10=severe discomfort/pain) for children from 0 to 18 years old, as shown in Table 3.7 [50].

Table 3.7: FLACC Scale

Criteria	***Score 0***	***Score 1***	***Score 2***
Face	No particular expression or smile	Occasional grimace or frown, withdrawn, uninterested	Frequent to constant quivering chin, clenched jaw
Legs	Normal position or relaxed	Uneasy, restless, tense	Kicking or legs drawn up
Activity	Lying quietly, normal position moves easily	Squirming, shifting, back and forth, tense	Arched, rigid, or jerking
Cry	No cry (awake or asleep)	Moans or whimpers; occasional complaint	Crying steadily, screams or sobs, frequent complaints
Consolability	Content, relaxed	Reassured by occasional touching, hugging, or being talked to, distractible	Difficult to console or comfort

⋆ Self-Reporting: Children who are old enough will rate their pain using Wong-Baker Faces Pain Rating Scale, which shows a series of faces ranging from a happy face at 0, or "no hurt," to a crying face at 10, which represents "hurts like the worst pain imaginable" as seen in Figure 3.12. Also, they will rate their anxiety by a series of faces ranging from 0=relaxed to 4=angry, as shown in Figure 3.13.

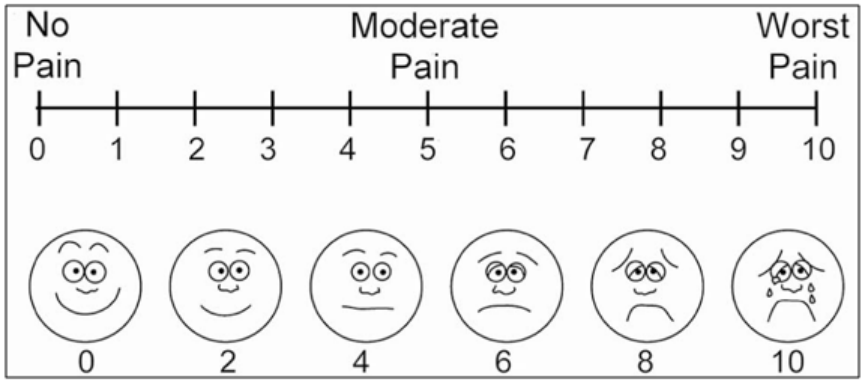

Figure 3.12: Wong-Baker Scale

Figure 3.13: Subjective Anxiety Scale

★ Joy Scale: children and parents also rate the enjoyment during the VR and Traditional sessions using the joy faces scale ranging from 0=no joy to 5= Ecstatic, as displayed in Figure 3.14.

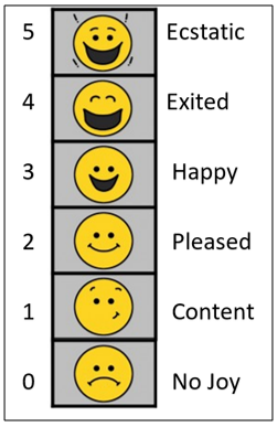

Figure 3.14: Joy Scale

- ⋆ Parents Rating: parents will rate their child's pain, anxiety, and satisfaction using a scale from 1= not pain/anxiety to 5=severe pain/anxiety.
- ⋆ Feasibility and Acceptability: A survey is distributed to doctors, nurses, and parents to assess the feasibility and acceptability of the intervention.
- ⋆ The treatment time is essential to measure in both sessions to compare the effectiveness of the VR in a matter of time.

3.4.3 Data Collection

The effectiveness of the designed VR system is evaluated during the wound care session in the hospital. The study goes through these steps:

1. Each child experiences a VR treatment session and another traditional (no VR) treatment session in a randomized order (on different days).
2. Choice of VR tool depends on the patient's condition and preference/acceptance.
3. Measurements are taken before starting the session.
4. Measurements are taken during the VR/Traditional session.
5. Measurements are taken immediately after the session is completed.
6. A comparison is performed between the VR and traditional sessions.
7. Sessions are assigned randomly, meaning some children start with VR sessions and some start with traditional sessions.

3.4.4 System Testing

A continuous assessment of the VR system is performed during the experimental study steps for a possible system improvement or modification.

3.5 Data Analysis and Evaluation

All collected data from the experiment is analyzed using the statistical analysis methods (SPSS) to evaluate the effectiveness of the VR system in pain and anxiety distraction.

Chapter 4

Results and Discussion

This chapter represents and discusses the research results and their analysis. The data analysis was carried out using the statistical software package SPSS version 25.0. Descriptive statistics were used, and chi-square, independent-sample t-test, and Mann-Whitney test were used to find the differences between variables. Cronbach's Alpha was measured to estimate the reliability of the questionnaire dimensions, and Person correlation coefficients were calculated to assess the internal consistency. The repeated measure was used to find the differences between the means of three experience measures and the LSD post hoc test to find the difference between the variables group. All reported p-values are two-tailed, with $p < 0.05$ being considered significant.

4.1 Pre-Design Questionnaire Analysis

This section presents the analysis of the questionnaire mentioned in Section 3.1. The main goal of the analysis is to highlight the differences between respondents' answers due to the child's age and gender.

4.1.1 Children and Technology

- ⋆ **Which of the following devices does the child make use of the most due to children's age (0-2 y, 3-5 y)?**

Table 4.1 shows a statistical difference (p-value < 0.05) in most used devices due to children's ages. It's clear that 78.2% of the nonusers are aged 0-2 years, while 3-5 years children use TV, mobile phone, tablet, and game console.

Table 4.1: The result of chi-square of the most used devices due to age

Q.	categorize	age			chi-square	p-value
		0-2y	3-5y	Total		
		N (%)	N (%)	N (%)		
Which of the following devices does the child make use of the most?	None	93 (78.2%)	26 (21.8%)	119 (9.6%)	23.900	.000**
	TV	156 (37.9%)	256 (62.1%)	412 (33.2%)		
	Mobile Phone	98 (26.0%)	279 (74.0%)	377 (30.4%)		
	Tablet (iPad, galaxy tab, etc.)	35 (11.3%)	276 (88.7%)	311 (25.1%)		
	Game Console	0 (0.0%)	21 (100.0%)	21 (1.7%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Which of the following devices does the child make use of the most due to children's gender (Male, Female)?**

Table 4.2 shows a statistical difference (p-value < 0.05) in most used devices by children due to their gender. For example, male children use TV and Game Consoles more, while Female children use mobile phones and tablets more.

Table 4.2: The result of chi-square of the most used devices by due to gender

Q.	categorize	gender			chi-square	p-value
		Male	Female	Total		
		N (%)	N (%)	N (%)		
Which of the following devices does the child make use of the most?	None	63 (52.9%)	56 (47.1%)	119 (9.6%)	23.900	.000**
	TV	218 (52.9%)	194 (47.1%)	412 (33.2%)		
	Mobile Phone	171 (45.4%)	206 (54.6%)	377 (30.4%)		
	Tablet (iPad, galaxy tab, etc.)	144 (46.3%)	167 (53.7%)	311 (25.1%)		
	Game Console	20 (95.2%)	1 (4.8%)	21 (1.7%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Which of the following activities does the child use the device for due to children's age (0-2 y, 3-5 y)?**

There is a statistical difference (p-value < 0.05) as shown in Table 4.3 in children's activities while using the device due to their age. These activities are (Coloring in, Listen to music, Watching Cartoon, Watching videos made by other children on YouTube, Making collages, Making videos, Watching videos, Taking photographs, Play with/use apps for gaming, To help learning/education, Watching music videos on YouTube, Reading stories, Drawing and painting), which means that children aged 3-5 years do these activities while children aged 0-2 years don't. At the same

time, other activities like (Look at pictures/photos, Listen to stories/audiobooks, Voice/video communication, e.g., Facetime /Skype, Play with/use apps for social, using a search engine) has no statistical differences (p-value > 0.05) which mean children aged 0-5 years can do these activities.

Table 4.3: The result of chi-square of activities children use due to age

Q.	answer	categorize	age			chi-square	p-value
			0-2 years	3-5 years	Total		
			N (%)	N (%)	N (%)		
Which of the following activities does the child use the device for?	Coloring in	Yes	12 (7.1%)	158 (92.9%)	170 (13.7%)	52.03	.000**
		No	370 (34.6%)	700 (65.4%)	1070 (86.3%)		
	Listen to music	Yes	122 (40.0%)	183 (60.0%)	305 (24.5%)	16.09	.000**
		No	260 (27.8%)	675 (72.2%)	935 (75.5%)		
	Watching Cartoon	Yes	120 (25.4%)	352 (74.6%)	472 (38.1%)	10.85	.001**
		No	264 (34.1%)	506 (65.9%)	768 (62.1%)		
	Watching videos made by other children on YouTube	Yes	117 (21.6%)	425 (78.4%)	542 (43.7%)	39.24	.000**
		No	265 (38.0%)	433 (62.0%)	698 (56.3%)		
	Look at pictures/photo	Yes	48 (28.9%)	118 (71.1%)	166 (13.4%)	0.32	0.575\\
		No	334 (31.1%)	740 (68.9%)	1074 (86.6%)		
	Making collages	Yes	2 (6.1%)	31 (93.9%)	33 (2.7%)	9.73	.002**
		No	380 (31.5%)	827 (68.5%)	1207 (97.3%)		
	Making videos	Yes	5 (11.6%)	38 (88.4%)	43 (3.5%)	7.67	.006**
		No	377 (31.5%)	820 (68.5%)	1197 (96.5%)		

Watching video	Yes	163 (27.7%)	425 (72.3%)	588 (47.2%)	5.31	.021*
	No	219 (33.6%)	433 (66.4%)	652 (52.8%)		
Taking photographs	Yes	23 (20.2%)	91 (79.8%)	114 (9.2%)	6.63	.010*
	No	359 (31.9%)	767 (68.1%)	1126 (90.8%)		
Play with/use apps for gaming	Yes	33 (8.1%)	373 (91.9%)	406 (32.6%)	145.23	.000**
	No	349 (41.8%)	485 (58.2%)	834 (67.4%)		
To help learning/education	Yes	16 (10.1%)	142 (89.9%)	158 (12.7%)	36.26	.000**
	No	366 (33.8%)	716 (66.2%)	1082 (87.3%)		
Watching music videos on YouTube	Yes	142 (40.8%)	206 (59.2%)	348 (27.9%)	21.89	.000**
	No	240 (26.9%)	652 (73.1%)	892 (72.1%)		
Reading stories	Yes	5 (11.1%)	40 (88.9%)	45 (3.6%)	8.48	.004**
	No	377 (31.5%)	818 (68.5%)	1195 (96.4%)		
Listen to stories/audio books	Yes	17 (21.3%)	63 (78.8%)	80 (6.4%))	3.65	0.056\\
	No	365 (31.5%)	795 (68.5%)	1160 (93.6%)		
Voice/video communication, e.g. FaceTime /Skype	Yes	23 (24.2%)	72 (75.8%)	95 (7.5%)	3.18	0.075\\
	No	359 (31.4%)	786 (68.6%)	1145 (92.5%)		
Play with/use apps for social	Yes	4 (16.0%)	21 (84.0%)	25 (2.0%)	2.62	0.105\\
	No	378 (31.1%)	837 (68.9%)	1215 (98.0%)		
Drawing and painting	Yes	7 (11.3%)	55 (88.7%)	62 (5.0%)	11.64	.001**
	No	376 (31.8%)	803 (68.2%)	1178 (95.0%)		

	Using a search engine (e.g. typing key words into Google and searching)	Yes	1 (9.1%)	10 (90.9%)	11 (0.9%)	2.45	.117\\
		No	381 (31.0%)	848 (69.0%)	1229(99.1%)		
	None	Yes	60 (83.3%)	12 (16.7%)	72 (5.8%)	99.02	.000**
		No	322 (27.6%)	846 (72.4%)	1168 (94.2%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

⋆ Which of the following activities does the child use the device for due to children's gender (Male, Female)?

Table 4.4 shows a statistical difference (p-value < 0.05) in activities children use the device for due to their gender. Female children do activities like (Coloring in, Listen to music, Watching videos made by other children on YouTube, Making videos, Taking photographs, Drawing, and painting) more than male children. There are no statistical differences (p-value > 0.05) in other activities (Watching Cartoon, Making collages, Watching video, Look at pictures/photo, Play with/use apps for gaming, To help learning/education, Watching music videos on YouTube, Reading stories, Listen to stories/audiobooks, Voice/video communication, Play with/use apps for social, using a search engine, None) due to gender.

Table 4.4: The result of chi-square of activities children use due to gender

Q.	answer	categorize	Gender			chi-square	p-value
			Male	Female	Total		
			N (%)	N (%)	N (%)		
Which of the following activities does the child use the device for?	Coloring in	Yes	58 (34.1%)	112 (65.9%)	170 (13.7%)	19.08	.000**
		No	558 (52.1%)	512 (47.9%)	1070 (86.3%)		
	Listen to music	Yes	131 (43.0%)	174 (57.0%)	305 (24.5%)	7.32	.007**
		No	485 (51.9%)	450 (48.1%)	935 (75.5%)		
	Watching Cartoon	Yes	232 (49.2%)	240 (50.8%)	472 (38.1%)	0.08	0.772\\
		No	No 384 (50.0%)	384 (50.0%)	768 (62.1%)		
	Watching videos made by other children on YouTube	Yes	251 (46.3%)	291 (53.7%)	542 (43.7%)	4.37	.037*
		No	365 (52.3%)	333 (47.7%)	698 (56.3%)		
	Look at pictures/photo	Yes	75 (45.2%)	91 (54.8%)	166 (13.4%)	1.55	0.213\\
		No	541 (50.4%)	533 (49.6%)	1074 (86.6%)		
	Making collages	Yes	14 (42.4%)	19 (57.6%)	33 (2.7%)	0.71	0.398\\
		No	602 (49.9%)	605 (50.1%)	1207 (97.3%)		
	Making videos	Yes	13 (30.2%)	30 (69.8%)	43 (3.5%)	6.74	.009**
		No	603 (50.4%)	594 (49.6%)	1197 (96.5%)		
	Watching video	Yes	277 (47.1%)	311 (52.9%)	588 (47.2%)	2.95	0.086\\
		No	339 (52.0%)	313 (48.0%)	652 (52.8%)		
	Taking photographs	Yes	43 (37.7%)	71 (62.3%)	114 (9.2%)	7.18	.007**

	No	573 (50.9%)	553 (49.1%)	1126 (90.8%)		
Play with/use apps for gaming	Yes	201 (49.5%)	205 (50.5%)	406 (32.6%)	0.01	0.933\\
	No	415 (49.8%)	419 (50.2%)	834 (67.4%)		
To help learning/education	Yes	70 (44.3%)	88 (55.7%)	158 (12.7%)	2.09	0.148\\
	No	546 (50.5%)	536 (49.5%)	1082 (87.3%)		
Watching music videos on YouTube	Yes	169 (48.6%)	179 (51.4%)	348 (27.9%)	0.24	0.624\\
	No	447 (50.1%)	445 (49.9%)	892 (72.1%)		
Reading stories	Yes	16 (35.6%)	29 (64.4%)	45 (3.6%)	3.73	0.054\\
	No	600 (50.2%)	595 (49.8%)	1195 (96.4%)		
Listen to stories/audio books	Yes	35 (43.8%)	45 (56.3%)	80 (6.4%)	1.20	0.273\\
	No	581 (50.1%)	579 (49.9%)	1160 (93.6%)		
Voice/video communication, e.g. FaceTime /Skype	Yes	40 (42.1%)	55 (57.9%)	95 (7.5%)	2.36	0.125\\
	No	576 (50.3%)	569 (49.7%)	1145 (92.5%)		
Play with/use apps for social	Yes	14 (56.0%)	11 (44.0%)	25 (2.0%)	0.41	0.523\\
	No	602 (49.5%)	613 (50.5%)	1215 (98.0%)		
Drawing and painting	Yes	18 (29.0%)	44 (71.0%)	62 (5.0%)	11.13	.001**
	No	598 (50.8%)	580 (49.2%)	1178 (95.0%)		
Using a search engine (e.g. typing key words into Google and searching)	Yes	3 (27.3%)	8 (72.7%)	11 (0.9%)	2.23	0.135\\
	No	613 (49.9%)	616 (50.1%)	1229(99.1%)		

	None	Yes	38 (52.8%)	34 (47.2%)	72 (5.8%)	0.29	0.588\\
		No	578 (49.5%)	590 (50.5%)	1168 (94.2%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

⋆ Who are they typically using the device with due to children's age (0-2 y, 3-5 y)?

There is a statistical difference (p-value< 0.05) in "who are children typically use the device with" due to children's age, as seen in Table 4.5. Notably, 89.6% of non-device users are aged 0-2 years, while other children mostly use the device with a parent or guardian.

Table 4.5: The result of chi-square of using the device with whom due to age

Q.	**categorize**	**age**			**chi-square**	**p-value**
		0-2y	**3-5y**	**Total**		
		N (%)	**N (%)**	**N (%)**		
Who are they typically using the device with?	None	60 (89.6%)	7 (10.4%)	67 (5.4%)	200.326	.000**
	On their own	31 (10.6%)	261 (89.4%)	292 (23.5%)		
	With me or another parent or guardian	193 (38.9%)	303 (61.1%)	496 (40.0%)		
	With brother(s)/ Sister(s)	30 (16.8%)	149 (83.2%)	179 (14.4%)		

	With another family member	54 (30.5%)	123 (69.5%)	177 (14.3%)		
	Other adult, e.g. Nursery worker, child minder, school teacher	14 (48.3%)	15 (51.7%)	29 (2.3%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

- ⋆ **Who are they typically using the device with due to children's gender (Male, Female)?**

Table 4.6 shows that there is no statistical difference (p-value > 0.05) in "who are children typically use the device with" due to children's gender.

Table 4.6: The result of chi-square of using the device with whom due to gender

Q.	**categorize**	**gender**			**chi-square**	**p-value**
		Male	**Female**	**Total**		
		N (%)	**N (%)**	**N (%)**		
Who are they typically using the device with?	None	36 (53.7%)	31 (46.3%)	67 (5.4%)	0.70	0.983\\
	On their own	146 (50.0%)	146 (50.0%)	292 (23.5%)		
	With me or another parent or guardian	242 (48.8%)	254 (51.2%)	496 (40.0%)		
	With brother(s)/ Sister(s)	90 (50.3%)	89 (49.7%)	179 (14.4%)		
	With another family member	87 (49.2%)	90 (50.8%)	177 (14.3%)		
	Other adult, e.g. Nursery worker, child minder, school teacher	15 (51.7%)	14 (48.3%)	29 (2.3%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

⋆ **Which of the following statements are most true when the child is using a device due to children's age (0-2 y, 3-5 y)?**

There is a statistical difference (p-value < 0.05) in the choices of true statements when children use a device due to their ages. For example, as shown in Table 4.7, children aged 3-5 years use the devices more in the following conditions: (The device is being used for educational purposes, The device is being used to encourage my child to be creative and/or play, The device is providing a sit-back experience, e.g., watching a video). Additionally, most of the "none" choice is chosen for children aged 0-2 years. On the other hand, there are no statistical differences (p-value $>$ 0.05) in these statements (The device is being used as a social device, e.g., co-usage with adults or other children, The device is being used for bedtime stories, The device is being used as a form of distraction or quiet time, whilst I complete other tasks or relax) due to their age, which means that children with different ages can use the device as a social device, bedtime stories, a form of distraction or quiet time.

Table 4.7: The result of chi-square of true statements due to age

Q.	answer	categorize	age			chi-square	p-value
			0-2y	3-5y	Total		
			N (%)	N (%)	N (%)		
Which of the following statements are most true when the child is using a device?	The device is being used as a social device, e.g., co-usage with adults or other children	Yes	33 (29.7%)	78 (70.3%)	111 (9.0%)	0.07	0.797\\
		No	349(30.9%)	780(69.1%)	1129(91.0%)		
	The device is being used for bedtime stories	Yes	10 (20.4%)	39 (79.6%)	49 (4.0%)	2.59	0.108\\
		No	372 (31.2%)	819 (68.8%)	1191 (96.0%)		
	The device is being used for educational purposes (e.g. learning the alphabet)	Yes	112 (26.5%)	311 (73.5%)	423 (34.1%)	5.64	.018*
		No	270 (33.0%)	547 (67.0%)	817 (65.9%)		
	The device is being used to encourage my child to be creative and/or play	Yes	36 (17.6%)	168 (82.4%)	204 (16.5%)	19.84	.000**
		No	346(33.4%)	690(66.6%)	1036(83.5%)		
	The device is providing a sit-back experience e.g. watching video	Yes	47 (21.6%)	171 (78.4%)	218 (17.6%)	10.61	.001**
		No	335(32.8%)	687(67.2%)	1022(82.4%)		
	The device is being used as a form of distraction or quiet time, whilst I complete other tasks or relax	Yes	223 (30.7%)	503 (69.3%)	726 (58.5%)	0.01	0.935\\
		No	159 (30.9%)	355 (69.1%)	514 (41.5%)		

	None	Yes	62 (86.1%)	10 (13.9%)	72 (5.8%)	109.68	.000**
		No	320 (27.4%)	848 (72.6%)	1168 (94.2%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\not significant**

⋆ Which of the following statements are most true when the child is using a device due to children's gender (Male, Female)?

Table 4.8 shows no statistical differences (p-value > 0.05) in the choices of true statements when children use a device due to their gender, which means male and female children do the same things when using a device.

Table 4.8: The result of chi-square of true statements due to gender

Q.	answer	categorize	Gender			chi-square	p-value
			Male	Female	Total		
			N (%)	N (%)	N (%)		
Which of the following statements are most true when the child is using a device?	The device is being used as a social device, e.g., co-usage with adults or other children	Yes	54 (48.6%)	57 (51.4%)	111 (9.0%)	0.05	0.820\\
		No	562 (49.8%)	567 (50.2%)	1129(91.0%)		
	The device is being used for bedtime stories	Yes	25 (51.0%)	24 (49.0%)	49 (4.0%)	0.04	0.848\\
		No	591 (49.6%)	600 (50.4%)	1191 (96.0%)		
	The device is being used for educational purposes (e.g. learning the alphabet)	Yes	203 (48.0%)	220 (52.0%)	423 (34.1%)	0.73	0.393\\
		No	413 (50.6%)	404 (49.4%)	817 (65.9%)		

	The device is being used to encourage my child to be creative and/or play	Yes	92 (45.1%)	112 (54.9%)	204 (16.5%)	2.05	0.152\\
		No	524 (50.6%)	512 (49.4%)	1036(83.5%)		
	The device is providing a sit-back experience e.g. watching video	Yes	110 (50.5%)	108 (49.5%)	218 (17.6%)	0.06	0.799\\
		No	506 (49.5%)	516 (50.5%)	1022(82.4%)		
	The device is being used as a form of distraction or quiet time, whilst I complete other tasks or relax	Yes	364 (50.1%)	362 (49.9%)	726 (58.5%)	0.15	0.700\\
		No	252 (49.0%)	262 (51.0%)	514 (41.5%)		
	None	Yes	40 (55.6%)	32 (44.4%)	72 (5.8%)	1.06	0.304\\
		No	576 (49.3%)	592 (50.7%)	1168 (94.2%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\not significant**

4.1.2 Virtual Reality

⋆ **How familiar is the respondent or the child with the term VR due to children's age (0-2 y, 3-5 y)?**

There are no statistical differences (p-value>0.05) in How familiar is the respondent or the child with the term VR due to the children's age, as seen in Table 4.9.

Table 4.9: The result of chi-square of VR familiarty due to age

Q.	categorize	age			chi-square	p-value
		0-2y	3-5y	Total		
		N (%)	N (%)	N (%)		
Who are they typically using the device with?	Unaware	65 (38.0%)	106 (62.0%)	171 (13.8%)	7.220	.065\\
	I've definitely heard of it	130 (30.3%)	299 (69.7%)	429 (34.6%)		
	know exactly what this is	142 (30.9%)	317 (69.1%)	459 (37.0%)		
	have used this I'm familiar with it	45 (24.9%)	136 (75.1%)	181 (14.6%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

⋆ **How familiar is the respondent or the child with the term VR due to children's gender (Male, Female)?**

There are no statistical differences (p-value>0.05) in How familiar is the respondent or the child with the term VR due to children's gender, as seen in Table 4.10.

Table 4.10: The result of chi-square of VR familiarty due to gender

Q.	categorize	gender			chi-square	p-value
		Male	Female	Total		
		N (%)	N (%)	N (%)		
Who are they typically using the device with?	Unaware	79 (46.2%)	92 (53.8%)	171 (13.8%)	1.19	0.756\\
	I've definitely heard of it	219 (51.0%)	210 (49.0%)	429 (34.6%)		
	know exactly what this is	227 (49.5%)	232 (50.5%)	459 (37.0%)		
	have used this I'm familiar with it	91 (50.3%)	90 (49.7%)	181 (14.6%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

★ **How familiar is the respondent or the child with the term VR due to the respondents' age?**

Table 4.11 shows statistical differences (p-value < 0.05) in how familiar is the respondent or the child with the term VR due to the respondent's age. It shows that respondents aged 26-45 years are more familiar with VR than other age groups.

Table 4.11: The result of chi-square of VR familiarty due to the respondent's age

Q	Answer	How familiar are you or the child with the term VR?				chi-square	p-value
		Unaware	I've definitely heard of it	know exactly what this is	have used this I'm familiar with it		
		N (%)	N (%)	N (%)	N (%)		
Respondent's age	< 16	8 (4.8%)	24 (5.7%)	14 (3.1%)	11 (6.1%)	51.94	.000*
	16-25	15 (8.9%)	51 (12.1%)	81 (17.6%)	30 (16.6%)		
	26-35	63 (37.5%)	215 (50.8%)	256 (55.8%)	91 (50.3%)		
	36-45	55 (32.7%)	97 (22.9%)	69 (15.0%)	37 (20.4%)		
	46-50	15 (8.9%)	22 (5.2%)	23 (5.0%)	8 (4.4%)		
	> 50	12 (7.1%)	14 (3.3%)	16 (3.5%)	4 (2.2%)		
Total		168 (13.6%)	423 (34.4%)	459 (37.3%)	181 (14.7%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

★ **Do you expect that the child is interested in experiencing Virtual Reality due to children's age (0-2 y, 3-5 y)?**

There is a statistical difference (p-value< 0.05) in children interested in experiencing Virtual Reality due to their age. Table 4.12 shows that children aged 3-5 years are fairly and extremely interested more than children aged 0-2 years.

Table 4.12: The result of chi-square of children interest in VR due to age

Q.	categorize	age			chi-square	p-value
		0-2y	3-5y	Total		
		N (%)	N (%)	N (%)		
Do you expect that the child is interested in experiencing Virtual Reality?	Unaware	173 (47.9%)	188 (52.1%)	361 (29.1%)	76.704	.000**
	Not interested at all	5 (13.2%)	33 (86.8%)	38 (3.1%)		
	Not very interested	20 (21.7%)	72 (78.3%)	92 (7.4%)		
	Neither interested nor not interested	57 (30.6%)	129 (69.4%)	186 (15.0%)		
	Fairly interested	81 (22.4%)	281 (77.6%)	362 (29.2%)		
	Extremely interested	46 (22.9%)	155 (77.1%)	201 (16.2%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Do you expect that the child is interested in experiencing Virtual Reality due to the children's gender (Male, Female)?**

Table 4.13 shows no statistical difference (p-value > 0.05) in children interested in experiencing Virtual Reality due to gender.

Table 4.13: The result of chi-square of children interest in VR due to gender

Q.	categorize	gender			chi-square	p-value
		Male	**Female**	**Total**		
		N (%)	**N (%)**	**N (%)**		
Do you expect that the child is interested in experiencing Virtual Reality?	Unaware	167 (46.3%)	194 (53.7%)	361 (29.1%)	4.53	0.476\\
	Not interested at all	18 (47.4%)	20 (52.6%)	38 (3.1%)		
	Not very interested	48 (52.2%)	44 (47.8%)	92 (7.4%)		
	Neither interested nor not interested	91 (48.9%)	95 (51.1%)	186 (15.0%)		
	Fairly interested	181 (50.0%)	181 (50.0%)	362 (29.2%)		
	Extremely interested	111 (55.2%)	90 (44.8%)	201 (16.2%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **What sorts of experiences would the child like to have in virtual reality due to children's age (0-2 y, 3-5 y)?**

Table 4.14 shows that there are statistical differences (p-value < 0.05) in the sorts of experiences the child would like to have in virtual reality due to their ages, these experiences are (Flying a plane, Go to virtual theme park, Snow Playing, Playing with Cartoons characters, Drive a Car, Visit the Sea World, See space). Children

aged 3-5 years are more likely to prefer those experiences over children aged 0-2 years.

Furthermore, there are no statistical differences (p-value> 0.05) in (Fly like a bird, Go on an adventure with animals, Visit a fantasy world) due to their age, which means that children of different ages prefer those experiences.

Table 4.14: The result of chi-square of Preferred VR experiences due to age

Q.	Answer	categorize	age			chi-square	p-value
			0-2y	3-5y	Total		
			N (%)	N (%)	N (%)		
Which of the following activities does the child use the device for?	Fly like a bird	Yes	65 (26.5%)	180 (73.5%)	245 (19.8%)	2.62	0.106\\
		No	317 (31.9%)	678 (68.1%)	995 (80.2%)		
	Flying a plane	Yes	22 (15.8%)	117 (84.2%)	139 (11.2%)	16.48	.000**
		No	360 (32.7%)	741 (67.3%)	1101 (88.8%)		
	Go on an adventure with animals	Yes	154 (32.0%)	328 (68.0%)	482 (38.9%)	0.48	0.487\\
		No	228 (30.1%)	530 (69.9%)	758 (61.1%)		
	Go to virtual theme park	Yes	113 (25.9%)	323 (74.1%)	436 (35.2%)	7.54	.006*
		No	269 (33.5%)	535 (66.5%)	804 (64.8%)		
	Visit a fantasy world	Yes	52 (26.5%)	144 (73.5%)	196 (15.8%)	2.00	0.158\\

		No	330 (31.6%)	714 (68.4%)	1044 (84.2%)		
	Snow Playing	Yes	68 (20.6%)	262 (79.4%)	330 (26.6%)	21.95	.000**
		No	314 (34.5%)	596 (65.5%)	910 (73.4%)		
	Playing with Cartoons characters	Yes	149 (27.5%)	393 (72.5%)	542 (43.7%)	4.97	.026*
		No	233 (33.4%)	465 (66.6%)	698 (56.3%)		
	Drive a Car	Yes	70 (22.4%)	243 (77.6%)	313 (25.2%)	14.00	.000**
		No	312 (33.7%)	615 (66.3%)	927 (74.8%)		
	Visit the Sea World	Yes	75 (24.6%)	230 (75.4%)	305 (24.6%)	7.33	.007**
		No	307 (32.8%)	628 (67.2%)	935 (75.4%)		
	See space	Yes	56 (22.6%)	192 (77.4%)	248 (20.0%)	9.84	.002**
		No	326 (32.9%)	666 (67.1%)	992 (80.0%)		
	Unaware	Yes	31 (77.5%)	9 (22.5%)	40 (3.2%)	42.27	0.001**
		No	351 (29.3%)	849 (70.8%)	1200 (96.8%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

⋆ **What sorts of experiences would the child like to have in virtual reality due to children's gender (Male, Female)?**

There are statistical differences (p-value < 0.05) in the experiences the child would like to have in virtual reality due to their gender, as seen in Table 4.15. The results show that male children prefer the following experiences: (Flying a plane, Drive a Car) and female children prefer (Go to virtual theme park, Playing with Cartoons characters). Otherwise, there are no statistical differences (p-value > 0.05) in the rest of the experiences: (Fly like a bird, Go on an adventure with animals, Snow Playing, Visit the Sea World, See space, Visit a fantasy world,) due to their gender, which means that male and female children prefer them the same.

Table 4.15: The result of chi-square of Preferred VR experiences due to gender

Q.	**Answer**	**categorize**	**Age**			**chi-square**	**p-value**
			0-2y	**3-5y**	**Total**		
			N (%)	**N (%)**	**N (%)**		
	Fly like a bird	Yes	121 (49.4%)	124 (50.6%)	245 (19.8%)	0.01	0.919\\
		No	495 (49.7%)	500 (50.3%)	995 (80.2%)		
	Flying a plane	Yes	83 (59.7%)	56 (40.3%)	139 (11.2%)	6.31	.012*
		No	533 (48.4%)	568 (51.6%)	1101 (88.8%)		
	Go on an adventure with animals	Yes	250 (51.9%)	232 (48.1%)	482 (38.9%)	1.51	0.219\\

Which of the following activities does the child use the device for?		No	366 (48.3%)	392 (51.7%)	758 (61.1%)		
	Go to virtual theme park	Yes	179 (41.1%)	257 (58.9%)	436 (35.2%)	20.00	.000**
		No	437 (54.4%)	367 (45.6%)	804 (64.8%)		
	Visit a fantasy world	Yes	94 (48.0%)	102 (52.0%)	196 (15.8%)	0.27	0.600\\
		No	522 (50.0%)	522 (50.0%)	1044 (84.2%)		
	Snow Playing	Yes	156 (47.3%)	174 (52.7%)	330 (26.6%)	1.04	0.308\\
		No	460 (50.5%)	450 (49.5%)	910 (73.4%)		
	Playing with Cartoons characters	Yes	243 (44.8%)	299 (55.2%)	542 (43.7%)	9.04	.003**
		No	373 (53.4%)	325 (46.6%)	698 (56.3%)		
	Drive a Car	Yes	242 (77.3%)	71 (22.7%)	313 (25.2%)	127.94	.000**
		No	374 (40.3%)	553 (59.7%)	927 (74.8%)		
	Visit the Sea World	Yes	160 52.5%	145 (47.5%)	305 (24.6%)	1.25	0.263\\
		No	456 (48.8%)	479 (51.2%)	935 (75.4%)		
	See space	Yes	133 (53.6%)	115 (46.4%)	248 (20.0%)	1.94	0.164\\

		No	483 (48.7%)	509 (51.3%)	992 (80.0%)		
	Unaware	Yes	22 (55.0%)	18 (45.0%)	40 (3.2%)	0.47	0.494\\
		No	594 (49.5%)	606 (50.5%)	1200 (96.8%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

★ **Which VR tool do you think is more comfortable and suitable for your child due to children's age (0-2 y, 3-5 y)?**

There is a statistical difference (p-value < 0.05) in the suitable VR tool for your child due to their age, as shown in Table 4.16. It's clear that most of the respondents who chose "none" have children aged 0-2 years, while the rest prefer VR screens more than VR glasses.

Table 4.16: The result of chi-square of suitable VR tool due to age

Q.	**categorize**	**age**			**chi-square**	**p-value**
		0-2y	**3-5y**	**Total**		
		N (%)	**N (%)**	**N (%)**		
Which VR tool do you think is more comfortable and suitable for your child?	Unaware	13 (61.9%)	8 (38.1%)	21 (1.7%)	21.07	.000**
	VR glasses	87 (23.5%)	283 (76.5%)	370 (29.8%)		
	VR screen	282 (33.2%)	567 (66.8%)	849 (68.5%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

⋆ **Which VR tool do you think is more comfortable and suitable for your child due to children's gender (Male, Female)?**

Table 4.17 shows no statistical differences (p-value > 0.05) in which VR tool you think is more comfortable and suitable for your child due to their gender, Which means that males and females children prefer the same VR tool.

Table 4.17: The result of chi-square of suitable VR tool due to gender

Q.	categorize	gender			chi-square	p-value
		Male	Female	Total		
		N (%)	N (%)	N (%)		
Which VR tool do you think is more comfortable and suitable for your child?	Unaware	11 (52.4%)	10 (47.6%)	21 (1.7%)	.905	.636\\
	VR glasses	191 (51.6%)	179 (48.4%)	370 (29.8%)		
	VR screen	414 (48.8%)	435 (51.2%)	849 (68.5%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

4.1.3 Virtual Reality in Medical Field

⋆ **Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain due to children's age (0-2 y, 3-5 y)?**

There are statistical differences (p-value < 0.05) in children interested in experiencing Virtual Reality in medical centers when he/she is in pain due to their age,

As seen in Table 4.18. The results show that children aged 0-2 years are mostly unaware, while children aged 3-5 years are more fairly interested, neither interested nor not interested, and extremely interested.

Table 4.18: The result of chi-square of children interest in VR in medical centers due to age

Q.	**categorize**	**age**			**chi-square**	**p-value**
		0-2y	**3-5y**	**Total**		
		N (%)	**N (%)**	**N (%)**		
Do you expect that the child is interested in experiencing Virtual Reality in medical centers when they are in pain?	Unaware	145 (46.6%)	166 (53.4%)	311 (25.1%)	51.96	.000**
	Not interested at all	10 (17.2%)	48 (82.8%)	58 (4.7%)		
	Not very interested	28 (23.0%)	94 (77.0%)	122 (9.8%)		
	Neither interested nor not interested	59 (26.5%)	164 (73.5%)	223 (18.0%)		
	Fairly interested	102 (27.6%)	267 (72.4%)	369 (29.8%)		
	Extremely interested	38 (24.2%)	119 (75.8%)	157 (12.7%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain due to children's gender?**

There is no statistical difference (p-value > 0.05) in children interested in experiencing Virtual Reality in medical centers when he/she is in pain due to their gender, as seen in Table 4.19.

Table 4.19: The result of chi-square of children interest in VR in medical centers due to gender

Q.	**categorize**	**age**			**chi-square**	**p-value**
		0-2y	**3-5y**	**Total**		
		N (%)	**N (%)**	**N (%)**		
Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain?	Unaware	142 (45.7%)	169 (54.3%)	311 (25.1%)	3.45	0.632\\
	Not interested at all	27 (46.6%)	31 (53.4%)	58 (4.7%)		
	Not very interested	61 (50.0%)	61 (50.0%)	122 (9.8%)		
	Neither interested nor not interested	117 (52.5%)	106 (47.5%)	223 (18.0%)		
	Fairly interested	190 (51.5%)	179 (48.5%)	369 (29.8%)		
	Extremely interested	79 (50.3%)	78 (49.7%)	157 (12.7%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain due to children's interest in experiencing Virtual Reality?**

There are statistical differences (p-value < 0.05) in children interested in experiencing Virtual Reality due to VR in medical centers when they are in pain, as shown in Table 4.20. The results show that the child who is Neither interested nor not interested, Fairly interested, and Extremely interested in experiencing Virtual Reality becomes Fairly interested in experiencing Virtual Reality in medical centers when he/she is in pain.

Table 4.20: The result of chi-square of children interested in VR vs VR in medical centers

Q.	categorize	Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain?						chi-square	p-value
		Unaware	Not interested at all	Not very interested	Neither interested nor not interested	Fairly interested	Extremely interested		
		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)		
Do you expect that the child is interested in experiencing Virtual Reality?	Unaware	214 (59.3%)	14 (3.9%)	23 (6.4%)	39 (10.8%)	53 (14.7%)	18 (5.0%)	608.395	0.001**
	Not interested at all	6 (15.8%)	14 (36.8%)	6 (15.8%)	4 (10.5%)	5 (13.2%)	3 (7.9%)		
	Not very interested	11 (12.0%)	10 (10.9%)	33 (35.9%)	10 (10.9%)	22 (23.9%)	6 (6.5%)		
	Neither interested nor not interested	21 (11.3%)	4 (2.2%)	21 (11.3%)	66 (35.5%)	58 (31.2%)	16 (8.6%)		
	Fairly interested	47 (13.0%)	11 (3.0%)	28 (7.7%)	77 (21.3%)	151 (41.7%)	48 (13.3%)		
	Extremely interested	12 (6.0%)	5 (2.5%)	11 (5.5%)	27 (13.4%)	80 (39.8%)	66 (32.8%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety due to the children's age (0-2 y, 3-5 y)?**

There is no statistical difference (p-value > 0.05) in "Do you believe that having VR

technology in medical centers and hospitals will help distract the children from pain and anxiety" due to children's age, as shown in Table 4.21.

Table 4.21: The result of chi-square of VR technology in medical centers due to age

Q.	categorize	age			chi-square	p-value
		0-2y	3-5y	Total		
		N (%)	N (%)	N (%)		
Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety?	I don't know	49 (26.8%)	134 (73.2%)	183 (14.8%)	6.07	0.194\\
	I strongly disbelieve	8 (57.1%)	6 (42.9%)	14 (1.1%)		
	I disbelieve	20 (29.9%)	47 (70.1%)	67 (5.4%)		
	Yes I believe	186 (31.3%)	408 (68.7%)	594 (47.9%)		
	I Strongly believe	119 (31.2%)	263 (68.8%)	382 (30.8%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

- ⋆ **Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety due to the children's gender (Male, Female)?**

There is no statistical difference (p-value > 0.05) in "Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety" due to children's gender, as shown in Table 4.22.

Table 4.22: The result of chi-square of VR technology in medical centers due to gender

Q.	categorize	gender			chi-square	p-value
		Male	Female	Total		
		N (%)	N (%)	N (%)		
Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety?	I don't know	83 (45.4%)	100 (54.6%)	183 (14.8%)	4.26	0.372\\
	I strongly disbelieve	9 (64.3%)	5 (35.7%)	14 (1.1%)		
	I disbelieve	31 (46.3%)	36 (53.7%)	67 (5.4%)		
	Yes I believe	292 (49.2%)	302 (50.8%)	594 (47.9%)		
	I Strongly believe	201 (52.6%)	181 (47.4%)	382 (30.8%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

★ **Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety due to the respondent's age?**

Table 4.23 shows statistical differences (p-value < 0.05) in whether VR technology in medical centers and hospitals will help distract the children from pain and anxiety due to the respondent's age. However, the results show that respondents in all age-group believe having VR technology in medical centers and hospitals will help distract the children from pain and anxiety.

Table 4.23: The result of chi-square of VR technology in medical centers due to respondent's age

Q	Answer	Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety?					chi-square	p-value
		I don't know	I strongly disbelieve	I disbelieve	Yes I believe	I Strongly believe		
		N (%)	N (%)	N (%)	N (%)	N (%)		
Respondent's age	< 16	8 (14.0%)	0 (0.0%)	4 (7.0%)	28 (4.1%)	17 (29.8%)	36.88	.012*
	16-25	18 (10.2%)	1 (0.6%)	6 (3.4%)	77 (43.5%)	75 (42.4%)		
	26-35	87 (13.9%)	8 (1.3%)	30 (4.8%)	302 (48.3%)	198 (31.7%)		
	36-45	46 (17.8%)	3 (1.2%)	16 (6.2%)	122 (47.3%)	71 (27.5%)		
	46-50	11 (16.2%)	2 (2.9%)	5 (7.4%)	39 (57.4%)	11 (16.2%)		
	> 50	13 (28.3%)	0 (0%)	4 (8.7%)	22 (47.8%)	7 (15.2%)		
Total		183 (14.9%)	14 (1.1%)	65 (5.3%)	590 (47.9%)	379 (30.8%)		

4.2 System Testing Results

The results of the two testing steps are described in this section.

4.2.1 Post-Design Questionnaire Analysis

- **Validity of the Measure**

  Pearson's correlation coefficients between the degree of each statement were measures to assess the internal consistency. The results of Table 4.24 show that the measurement has a high correlation coefficient with each of its related statements, the correlation coefficients range between (0.68 - 0.80), and

the significance was within a level less than 0.01. This indicates that the measurement and its related statements have a high amount of validity.

Table 4.24: The Correlation coefficients between the statements

Item	**Dimension**	**Person Correlation**	**p-value**
1	Do you expect that the child is interested in playing Virtual Reality Game?	0.74	0.001**
2	Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain?	0.77	0.001**
3	Do you believe the VR Game will help distract your child during a painful procedure	0.80	0.001**
4	the virtual reality game is adapted/-suitable to the age group of children	0.68	0.001**
5	Virtual reality is an intervention worth implementing to distract children during medical procedures	0.78	0.001**

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- **Reliability of the Measure**

The reliability of the overall measure was calculated by finding the Cronbach's alpha coefficient, as seen in Table 4.25. The value of Alpha is 0.80; this implies that the whole measure has high reliability, which meets the requirements of applying the measure to the sample of the study.

Table 4.25: Constancy coefficient using Cronbach's Alpha

Dimension	**N**	**alpha**
Measurement	5	0.80

- **The Demographic Characteristics of the Sample**

Table 4.26 shows that the sample size of the questionnaire was 151. Most of the sample, 63.6% were parents, 19.2% were Aunt or Uncle, 7.3% were Sibling, 4.6% were Grandparent, 4.0% were teachers, and 1.3% were Children's specialists. As for the gender, most of the sample, 94.7%, were female, and 5.3% were male. Respondents ages were as follows: 5.3% aged < 16 y, 6.0% aged 16- 25 y, 62.3% aged 26- 35 y, 15.2% aged 36- 45 y, 7.9% aged 46- 55 y, and 3.3% aged > 55 y. About the child gender, 47.0% were male, while 53.0% were female. As for ages, 17.9% aged two years and less, 48.3% aged between 3- 5 years, and 33.8% aged more than five years.

Table 4.26: Distribution of the sample according to the demographic characteristics

variable	categorize	n	%
What is your relationship with kids?	Parent	96	63.6%
	Sibling	11	7.3%
	Grandparent	7	4.6%
	Aunt or Uncle	29	19.2%
	Teacher	6	4.0%
	Children's specialist	2	1.3%
	Total	151	100.0%
Your Gender?	Male	8	5.3%
	Female	143	94.7%
	Total	151	100.0%
Choose your age group	16	8	5.3%
	16-25	9	6.0%
	26-35	94	62.3%
	36-45	23	15.2%
	46-55	12	7.9%
	55	5	3.3%
	Total	151	100.0%
Gender of the child?	Male	71	47.0%
	Female	80	53.0%
	Total	151	100.0%
How old is the child?	Younger than one	4	2.6%
	1 year	8	5.3%
	2 year	15	9.9%
	3 year	22	14.6%
	4 year	27	17.9%
	5 year	24	15.9%

	Older than 5	51	33.8%
	Total	151	100.0%
The child age group	2 years less	27	17.9%
	3-5 years	73	48.3%
	more than 5 years	51	33.8%
	Total	151	100.0%

⋆ **Do you expect that the child is interested in playing Virtual Reality Game due to the children's age (0-2 y, 3-5 y, more than 5 years)?**

Table 4.27 shows that 7.3% of the sample expected their child not to be very interested in playing the Virtual Reality Game, 10.6% were Neither interested nor not interested, 39.7% were Fairly interested, and 42.4% were Extremely interested, which means that most of the sample expect their child to be interested in playing Virtual Reality Game. There are no statistical differences (p-value > 0.05) in children interested in playing the Virtual Reality Game due to children's ages.

Table 4.27: The result of chi-square of children interest in VR game due to age

Q	categorize	Child age group				chi-square	p-value
		2 years & less	3-5 years	more than 5 years	Total		
		N (%)	N (%)	N (%)	N (%)		
Do you expect that the child is interested in playing Virtual Reality Game?	Not interested at all	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	5.55	0.476\\
	Not very interested	1(9.1%)	6 (54.5%)	4 (36.4%)	11 (7.3%)		
	Neither interested nor not interested	4 (25.0%)	10 (62.5%)	2 (12.5%)	16 (10.6%)		
	Fairly interested	13 (21.7%)	27 (45.0%)	20 (33.3%)	60 (39.7%)		
	Extremely interested	9 (14.1%)	30 (46.9%)	25 (39.1%)	64 (42.4%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

- ⋆ **Do you expect that the child is interested in playing Virtual Reality Game in medical centers when he/she is in pain due to the children's age (0-2 y, 3-5 y, more than 5 years)?**

Table 4.28 shows that 2.6% of the sample expect their child not to be interested at all in playing Virtual Reality Game in medical centers when they are in pain, 6.0% were not very interested, 18.5% were Neither interested nor not interested, 49.7% were Fairly interested, and 23.2% Extremely interested, which means that most of the sample expect their child to be interested in playing Virtual Reality Game in medical centers when they are in pain.

There are no statistical differences (p-value > 0.05) in children interested in playing the Virtual Reality Game in medical centers when they are in pain due to children's ages.

Table 4.28: The result of chi-square of children interest in VR game in medical centers due to age

Q	categorize	Child age group				chi-square	p-value
		2 years & less	3-5 years	more than 5 years	Total		
		N (%)	N (%)	N (%)	N (%)		
Do you expect that the child is interested in playing Virtual Reality Game in medical centers when he/she is in pain	Not interested at all	0 (0.0%)	0 (0.0%)	4 (100.0)	4 (2.6%)	11.70	0.165\\
	Not very interested	2 (22.2%)	6 (66.7%)	1 (11.1%)	9 (6.0%)		
	Neither interested nor not interested	7 (25.0%)	13 (46.4%)	8 (28.6%)	28 (18.5%)		
	Fairly interested	13 (17.3%)	35 (46.7%)	27 (36.0%)	75 (49.7%)		
	Extremely interested	5 (14.3%)	19 (54.3%)	11 (31.4%)	35 (23.2%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Do you believe the VR Game will help distract your child during a painful procedure due to the children's age (0-2 y, 3-5 y, more than 5 years)?**

Table 4.29 shows that 20.5% of the sample Don't know, 0.7% strongly disbelieve that the VR Game will help distract their child during a painful procedure, and 11.9% disbelieve. In comparison, 44.4% and 22.5% strongly believe in that, which means that most of the sample believe that the VR Game will help distract their child

during a painful procedure. There are no statistical differences (p-value > 0.05) in "Do you believe that the VR Game will help distract their child during a painful procedure" due to children's ages.

Table 4.29: The result of chi-square of VR Game as pain distraction due to age

Q	categorize	Child age group				chi-square	p-value
		2 years & less	3-5 years	more than 5 years	Total		
		N (%)	N (%)	N (%)	N (%)		
Do you believe the VR Game will help distract your child during a painful procedure	I don't know	4 (12.9%)	16 (51.6%)	11 (35.5%)	31 (20.5%)	5.79	0.67\\
	I strongly disbelieve	0 (0%)	0 (0.0%)	1 (100.0%)	1 (0.7%)		
	I disbelieve	4 (22.2%)	10 (55.6%)	4 (22.2%)	18 (11.9%)		
	Yes I believe	15 (22.4%)	31 (46.3%)	21 (31.3%)	67 (44.4%)		
	I Strongly believe	4 (11.8%)	16 (47.1%)	14 (41.2%)	34 (22.5%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

- ⋆ **The virtual reality game is adapted/suitable to the age group of children due to the children's age (0-2 y, 3-5 y, more than 5 years)?**

Table 4.30 shows that 0.7% of the sample totally disagree that the virtual reality game is adapted/suitable to the age group of children, 9.3% disagree, 21.3% are neutral about that, while 43.3% agree, and 25.3% totally agree that which means that most samples believe that the virtual reality game is adapted/suitable to the age-group of children. There are no statistical differences (p-value > 0.05) in "the virtual reality game is adapted/suitable to the age-group of children" due to children's ages.

Table 4.30: The result of chi-square of VR game suitable due to age

Q	categorize	Child age group				chi-square	p-value
		2 years & less	3-5 years	more than 5 years	Total		
		N (%)	N (%)	N (%)	N (%)		
the virtual reality game is adapted/-suitable to the age-group of children	Totally Disagree	0 (0%)	1 (100.0%)	0 (0%)	1 (0.7%)	6.39	0.603\\
	Disagree	3 (21.4%)	4 (28.6%)	7 (50.0%)	14 (9.3%)		
	Neutral	4 (12.5%)	16 (50.0%)	12 (37.5%)	32 (21.3%)		
	Agree	10 (15.4%)	34 (52.3%)	21 (32.3%)	65 (43.3%)		
	Totally Agree	10 (26.3%)	17 (44.7%)	11 (28.9%)	38 (25.3%)		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

- ⋆ **Virtual reality is an intervention worth implementing to distract children during medical procedures due to the children's age (0-2 y, 3-5 y, more than 5 years)?**

Table 4.31 shows that 2.7% of the sample disagree that Virtual reality is an intervention worth implementing to distract children during medical procedures, 15.3% neutral about that, while 42.0% agree and 40.0% totally agree with that, which means that most of the sample believe that Virtual reality is an intervention worth implementing to distract children during medical procedures.

There are no statistical differences (p-value > 0.05) in "Virtual reality is an intervention worth implementing to distract children during medical procedures" due to children's ages.

Table 4.31: The result of chi-square of VR is worth implementing due to age

Q	categorize	Child age group				chi-square	p-value
		2 years & less	3-5 years	more than 5 years	Total		
		N (%)	N (%)	N (%)	N (%)		
Virtual reality is an intervention worth implementing to distract children during medical procedures	Totally Disagree	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2.44	0.875\\
	Disagree	1 (25.0%)	2 (50.0%)	1 (25.0%)	4 (2.7%)		
	Neutral	4 (17.4%)	10 (43.5%)	9 (39.1%)	23 (15.3%)		
	Agree	10 (15.9%)	35 (55.6%)	18 (28.6%)	63 (42.0%)		
	Totally Agree	12 (20.0%)	26 (43.3%)	22 (36.7%)	60 (40.0%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Virtual reality is an intervention worth implementing to distract children during medical procedures due to the respondent's relation with children?**

There are no statistical differences (p-value > 0.05) in "Virtual reality is an intervention worth implementing to distract children during medical procedures" due to the respondent's relationship with children, as seen in Table 4.32.

Table 4.32: The result of chi-square of VR is worth implementing due to respondent's relation

Q	categorize	Virtual reality is an intervention worth implementing to distract children during medical procedures				chi-square	p-value
		Disagree	Neutral	Agree	Totally Agree		
		N (%)	N (%)	N (%)	N (%)		
What is your relationship with kids?	Parent	4 (4.2%)	16 (16.8%)	43 (45.3%)	32 (33.7%)	19.882	.177\\
	Sibling	0 (0.0%)	1 (9.1%)	3 (27.3%)	7 (63.6%)		
	Grandparent	0 (0.0%)	2 (28.6%)	2 (28.6%)	3 (42.9%)		
	Aunt or Uncle	0 (0.0%)	1 (3.4%)	12 (41.4%)	16 (55.2%)		
	Teacher	0 (0.0%)	3 (50.0%)	1 (16.7%)	2 (33.3%)		
	Children's specialist	0 (0.0%)	0 (0.0%)	2 (100.0%)	0 (0.0%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

- ⋆ **Do you expect that the child is interested in Playing Virtual Reality Game in medical centers when he/she is in pain due to children's interest in Playing Virtual Reality?**

Table 4.33 show that there are statistical differences (p-value < 0.05) in children interested in playing VR Game due to their interest in playing the VR game in medical centers while in pain. The results show that the sample who expect their child to be not very interested and Neither interested nor not interested in playing Virtual Reality Game become 27.3%, 43.8% fairly interested in playing in medical centers when he/she is in pain.

Table 4.33: The result of chi-square of children interest in VR Game vs in medical centers

Q	categorize	Do you expect that the child is interested in playing Virtual Reality Game?				chi-square	p-value
		Not very interested	Neither interested nor not interested	Fairly interested	Extremely interested		
		N (%)	N (%)	N (%)	N (%)		
Do you expect that the child is interested in playing Virtual Reality Game in medical centers when he/she is in pain?	Not interested at all	3 (27.3%)	0 (0%)	0 (0%)	1 (1.6%)	78.76	.000*
	Not very interested	4 (36.4%)	0 (0%)	5 (8.3%)	0 (0%)		
	Neither interested nor not interested	1 (9.1%)	9 (56.3%)	11 (18.3%)	7 (10.9%)		
	Fairly interested	3 (27.3%)	7 (43.8%)	33 (55.0%)	32 (50.0%)		
	Extremely interested	0 (0%)	0 (0%)	11 (18.3%)	24 (37.5%)		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

4.2.2 Pressure Pain Simulation Results

Forty volunteers were involved in the study aged 2 - 10 years, 57.5% aged 2-6 years, and 42.5% aged 6-10 years. In a randomized order, the pain pressure measures were taken three times, P1, P2, and P3. Table 4.34 shows that the VR Pressure measure between 16 - 61 N with a mean of 35.4 ± 10.3 N, the no VR Pressure measure between 10-44 N with a mean of 25.7 ± 8.1 N, and the Color game Pressure

measure between 10 - 51 N with a mean of 30.0 ± 9.8 N.

The interactivity score is between 107 - 494 with a mean of 241.2 ± 94.7.

Table 4.34: Pressure's descriptive statistics

measure	Minimum	Maximum	Mean	Std. D
P1: VR Pressure	16	61	35.4	10.3
P2: No VR Pressure	10	44	25.7	8.1
P3: Color game Pressure	10	51	30.0	9.8
Interactivity	107	494	241.2	94.7

Table 4.35 shows that the model is statistically significant (p-value < 0.01) and that there are statistically significant differences (p-value < 0.05) between the values of the three measures of pressure.

Table 4.35: The result of repeated measure

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
factor	1,815.3	2	907.7	52.8	0.001**
factor * age group	31.1	2	15.5	0.9	0.409\\
Error(factor)	1,306.8	76	17.2		
Intercept	112,675.4	1	112,675.4	598.4	0.001**
Age group	1,933.3	1	1,933.3	10.3	0.003**
Error	7,155.0	38	188.3		

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

The results of the LSD test to find the difference between the three measures is presented in Table 4.36, which shows that P1's pressure value is more than the values of (P2, P3), and P3's value is more than P2. It is important to note that the pain pressure data shows how much pain tolerance the child handled during three different conditions. That means that the pain was tolerated more during the

proposed VR design P1, then during the color game P3, and lastly, P2, which is the No VR condition. So, the results evidence that the proposed VR design was the most effective distracting method for the children feeling pain.

Table 4.36: The result of the LSD test between the values of pressure

Factor	Mean	Std. d	Post hoc		
			1	2	3
P1:VR Pressure	35.9	1.6	1	.000**	.000**
P2:No VR Pressure	26.3	1.1	-	1	.000**
P3:Color game Pressure	30.7	1.4	-	-	1

****statistical significant at 0.01** ***statistical significant at 0.05** **\\ not significant**

There is a statistically significant difference (p-value < 0.05) between the values of the three pressure measures due to age group, as seen in Table 4.37. The results indicate that children aged between 6-10 with a mean (of 35.1) tolerated more pressure than children aged 2-to 6 with a mean (of 26.9).

Table 4.37: The means of pressure value due to age group

Age group	**Mean**	**Std. Error**
2-6 Years	26.9	1.7
6-10 Years	35.1	1.9

Table 4.38 shows the statistically significant difference (p-value < 0.05) between the values of VR pressure due to age group. As seen, there are statistically significant differences (p-value < 0.05) in the three measures due to age group, which indicates that children aged 6-10 years tolerated more pressure in all conditions.

Table 4.38: The result of the t-test of the values of pressure due to age group

Measure	Age group	N	Mean	Std. D	t-test	p-value
VR Pressure	2-6 Years	23	32.5	9.2	-2.21	0.033*
	6-10 Years	17	39.4	10.6		
No VR Pressure	2-6 Years	23	22.3	7.1	-3.48	0.001**
	6-10 Years	17	30.3	7.3		
Color game Pressure	2-6 Years	23	26.0	7.7	-3.40	0.002**
	6-10 Years	17	35.4	9.9		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

Table 4.39 shows no statistically significant differences (p-value > 0.05) in the interactivity score due to the children's age group.

Table 4.39: The result of the t-test of the interactivity score due to age group

Measure	Age group	N	Mean	Std. D	t-test	p-value
Interactivity	2-6 Years	23	252.8	103.4	0.90	0.372\\
	6-10 Years	17	225.4	81.8		

****statistical significant at 0.01 *statistical significant at 0.05 \\ not significant**

4.3 The Clinical Results

This study is ethically approved by the IRB from the Ministry of Health by National Registration Number with NCBE-KACST, KSA: (H-02-J-002), see Appendix D. The research was proposed to five hospitals, four approved the research, and one declined it. Unfortunately, one of the hospitals doesn't admit children to the burns unit, so the study was performed in three hospitals: Alnoor Specialist Hospital in Makkah, King Abdulaziz Hospital, and International Medical Center (IMC) in Jeddah.

4.3.1 Participants

Fifteen children were recruited for the experiment by parents signing both the informed consent and the media release form, presented in Appendix E. ten children completed the sessions, while five were excluded, as illustrated in Figure 4.1.

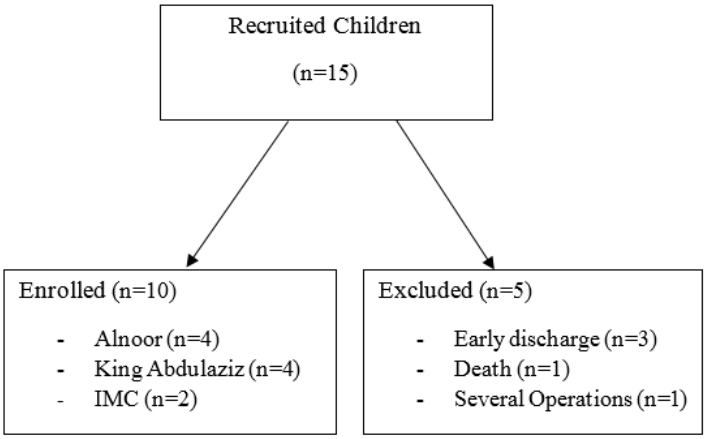

Figure 4.1: Participants Recruitment

Table 4.40 shows the demographic characteristics of the participants. 70% of the children were female, 30% were male, 80% were hospitalized in the burn unit, and 20% were at the outpatient clinic. Most of the burns are caused by a hot substance (Thermal), while one of the children had a non-burn injury (fingertip amputation). All children take paracetamol in different forms (syrup, IV, pills, suppository) and doses as background medication, and as for hospitals distribution: four children were at King Abdulaziz Hospital, four children were at Alnoor Hospital, and two were at IMC Hospital.

Children were aged from 10 months – to 5 years, the mean age in months was (24.5) which means two years, and as for their weights, the lowest weight was (8 kg), the

highest was (16 kg), and the mean weight was (10.68 kg). As for the extent of the burn (burn size), the lowest value was (3%), and the highest value was (22%), the mean value was (10%) with a standard deviation (of 0.06). As for the number of previous sessions, the lowest was (1), and the highest was (15), with a mean of (4.2).

Table 4.40: Demographic characteristics of the participants

		Frequency	**Percent**
Gender	Male	3	30.0%
	Female	7	70.0%
Hospitalised	Yes	8	80.0%
	No (Clinic)	2	20.0%
Cause of Injury	Thermal (Scaled) Burn	9	90.0%
	Injury *not Burn	1	10.0%
Hospital	King Abdulaziz	4	40.0%
	Alnoor	4	40.0%
	IMC	2	20.0%
Background Medication	Paracetamol	10	100.0%
Total		10	100.0%

	Minimum	**Maximum**	**Mean**	**Std. D**
Age in months 10	10	68	24.50	22.96
Weight	8	16	10.68	2.53
Burn extent	0.03	0.22	.10	.06
Previous wound care sessions	1	15	4.20	3.967

Table 4.41 describes the injury/burn characteristics of the participants. 20% have deep partial-thickness (second degree), 30% have a superficial thickness (second degree), 20% have both superficial and deep thickness (second degree), 10% have both superficial (first degree) and superficial thickness (second degree), 10% has both superficial thickness (second degree), full-thickness (third-degree), while 10% has a fingertip amputation injury. The areas of burns are at different body parts for

each patient, including the face, chest, anterior trunk, posterior trunk, limbs, hands, legs, thighs, and genitalia.

Table 4.41: Injury/Burn characteristics of the participants

Injury/Burn Type	**Frequency**	**Percent**
Deep partial thickness (second degree)	2	20.0%
Superficial (first degree), Superficial thickness (second degree)	1	10.0%
Superficial thickness (second degree)	3	30.0%
Superficial thickness (second degree), Full-thickness (third degree)	1	10.0%
Superficial thickness (second degree), deep thickness (second degree)	2	20.0%
*Fingertip amputation *not burn*	1	10.0%
Total	**10**	**100.0%**
Areas of Burn	**Frequency**	**Percent**
*A finger in the Lefthand *not burn*	1	10.0%
Anterior trunk, right legs, right posterior trunk, right hand	1	10.0%
Both Legs	1	10.0%
Chest	1	10.0%
Face and Chest	2	20.0%
Left leg and hand	1	10.0%
Right hand, left leg	1	10.0%
The right side of the face, right upper limb, and truck, hand	1	10.0%
Thigh, both legs (anterior aspect), genitalia	1	10.0%
Total	**10**	**100.0%**

4.3.2 Observational Scales of Pain and Anxiety Results

Table 4.42 shows the results of the Mann-Whitney test to measure the differences in each of the previous sessions, session duration, pain (before - during - after), and anxiety (before - during - after) between VR and Traditional treatment. The results indicate a significant reduction in pain during and after VR treatment compared to traditional treatment, as shown in Figuer 4.2. While anxiety shows a non-significant reduction in VR treatment compared to traditional treatment, As illustrated in Figure 4.3. As for time, also a non-significant reduction in VR treatment compared to traditional treatment, as shown in Figure 4.4. As for the pain before, anxiety before, and previous sessions are more likely to have similar or very close values, therefore non-significant difference.

Table 4.42: The Mann-Whitney test Results for The Observational Scales

	Group	N	Mean ± Std.D	Mean Rank	Sum of Ranks	P-value
Previous sessions	VR	10	5.00 ± 3.94	10.50	105.00	1.000//
	Traditional	10	5.40 ± 4.88	10.50	105.00	
Time(min)	VR	10	9.50 ± 3.31	8.00	80.00	0.063//
	Traditional	10	12.10 ± 3.76	13.00	130.00	
Before Pain	VR	10	2.60 ±2.22	10.60	106.00	0.971//
	Traditional	10	2.60 ± 2.37	10.40	104.00	
During Pain	VR	10	3.80 ± 2.20	7.75	77.50	0.035*
	Traditional	10	6.20 ± 2.74	13.25	132.50	
After Pain	VR	10	1.40 ± 1.17	7.85	78.50	0.043*
	Traditional	10	3.00 ± 1.94	13.15	131.50	
Before Anxitey	VR	10	9.50 ± 11.86	10.20	102.00	0.853//
	Traditional	10	7.10 ± 7.22	10.80	108.00	
During Anxitey	VR	10	13.00 ± 8.68	8.40	84.00	0.123//
	Traditional	10	19.20 ± 9.15	12.60	126.00	
After Anxiety	VR	10	2.10 ± 1.85	8.30	83.00	0.105//
	Traditional	10	5.50 ± 4.84	12.70	127.00	

***significance at 0.05 level // no statistical significance**

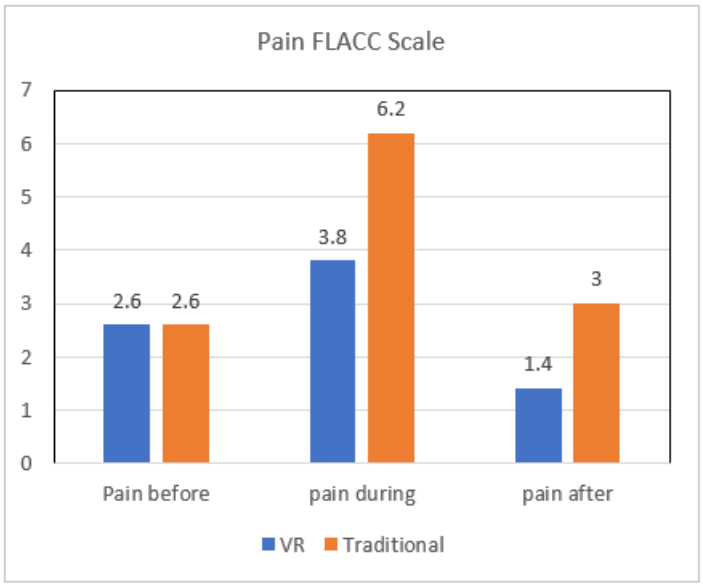

Figure 4.2: FLACC Scale Results

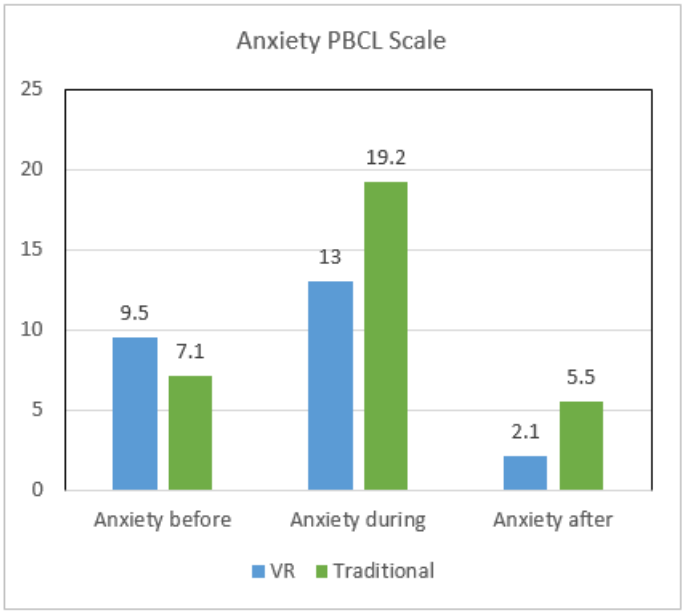

Figure 4.3: PBCL Scale Results

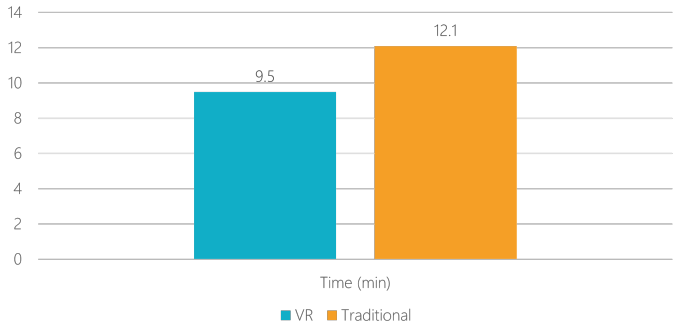

Figure 4.4: Time Results

4.3.3 Parents' Ratings of Pain and Anxiety Results

Table 4.43 shows the results of the Mann-Whitney test to measure the differences in pain (before - during - after) and anxiety (before - during - after) assessed by parents (mostly mothers) between VR treatment and Traditional treatment. The results indicate that the parents noticed a significant reduction between VR treatment and traditional treatment in both pain and anxiety during VR treatment. At the same time, the results did not show significant differences in anxiety and pain before and pain after. Figure 4.5 and Figure 4.6 illustrate the results of the parent's rating. Again, parents were stratified in both treatments, as shown in Figure 4.7.

Table 4.43: The Mann-Whitney test Results for Parents' Ratings

	Group	N	Mean ± Std.D	Mean Rank	Sum of Ranks	P-value
Before Pain	VR	10	1.90 ± 1.01	10.15	101.50	0.796//
	Traditional	10	2.00 ± 1.05	10.85	108.50	
During Pain	VR	10	2.40 ± 1.08	7.60	76.00	0.029*
	Traditional	10	3.80 ± 1.23	13.40	134.00	
After Pain	VR	10	1.60 ± 0.84	8.70	87.00	0.190//
	Traditional	10	2.40 ± 1.35	12.30	123.00	
Before Anxitey	VR	10	2.90 ± 1.79	10.70	107.00	0.912//
	Traditional	10	2.70 ± 1.83	10.30	103.00	

During Anxitey	VR	10	2.70 ± 1.42	6.95	69.50	0.005**
	Traditional	10	4.50 ± 0.85	14.05	140.50	
After Anxiety	VR	10	1.50 ± 0.85	7.85	78.50	0.043*
	Traditional	10	2.90 ± 1.52	13.15	131.50	
Satisfaction	VR	10	5.00 ± 0.00	11.50	115.00	0.481//
	Traditional	10	4.50 ± 1.08	9.50	95.00	

***significance at 0.05 level** ****significance at 0.01 level** **// no statistical significance**

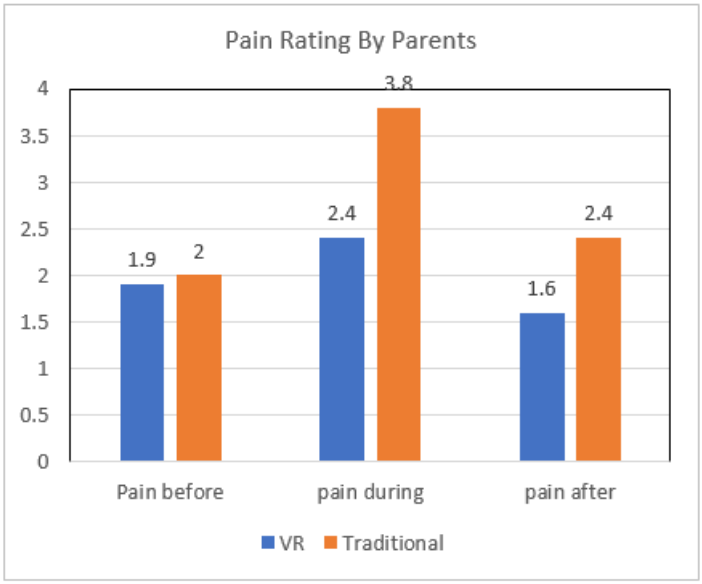

Figure 4.5: Results of Parents' Pain Rating

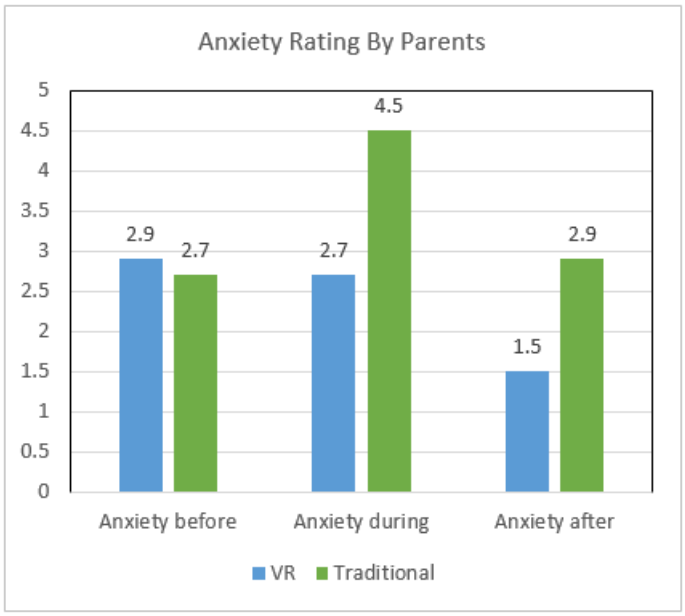

Figure 4.6: Results of Parents' Anxiety Rating

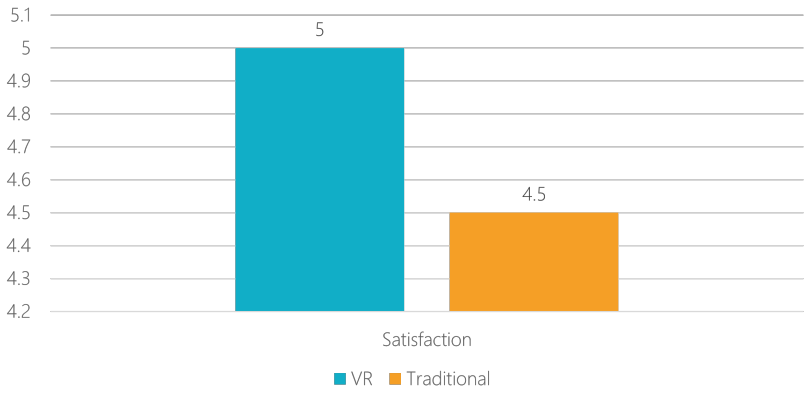

Figure 4.7: Results of Parents' Satisfaction

4.3.4 Joy Scale Results

Table 4.44 shows the results of the Mann-Whitney test to measure the differences in children's joy between VR treatments and the traditional treatment. 2 out of 8

were children who self-reported their joy while the parents assessed the other six. The results indicate significant differences in the degree of joy between the VR treatments and the traditional treatment in which the VR was more enjoyable, as illustrated in Figure 4.8.

Table 4.44: The Mann-Whitney test Results for Joy Scale

	Group	N	Mean ± Std.D	Mean Rank	Sum of Ranks	P-value
Joy	VR	8	2.38 ± 1.06	12.13	97.00	0.001**
	Traditional	8	0.25 ± 0.71	4.88	39.00	

****significance at 0.01 level**

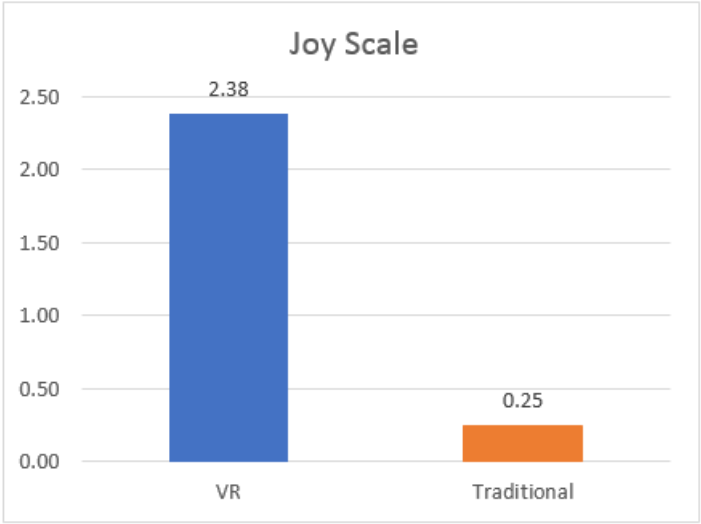

Figure 4.8: Results of Joy Scale

4.3.5 Children's Self-Reporting Results

Table 4.45 shows the results of the Mann-Whitney test to measure the differences in pain anxiety based on the children's self-reporting of pain and anxiety during

both VR treatments and the traditional treatment. Again, the results indicate a non-significant reduction in pain and anxiety, as illustrated in Figure 4.9.

Table 4.45: The Mann-Whitney test Results for Self-Reporting

	Group	N	Mean ± Std.D	Mean Rank	Sum of Ranks	P-value
Pain	VR	2	3.00 ± 0.00	2.25	4.50	0.667//
	Traditional	2	5.00 ± 0.00	2.75	5.50	
Anxiety	VR	2	0.00 ± 0.00	1.50	3.00	0.333//
	Traditional	2	2.50 ± 0.71	3.50	7.00	

// no statistical significance

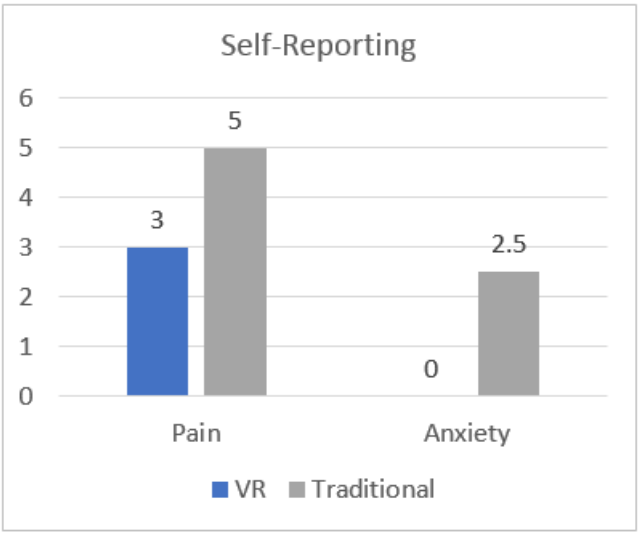

Figure 4.9: Results of Self-Reporting

4.3.6 VR Tools

This study evaluates the effectiveness of VR for burn children aged less than six years; two VR tools were used during the Experiment, HMD and Screen, As seen in Figure 4.10 and Figure 4.11. All the patients used the screen-VR tool during VR

treatment and didn't accept the HMD. The two children aged five years tried the HMD before the session, but during the wound care, they took it off and used the screen instead.

Figure 4.10: A Patient during Screen VR Treatment

Figure 4.11: A Patient during HMD VR Treatment

4.3.7 Feasibility and Acceptability of the Intervention

A survey was distributed to doctors, nurses, and parents to assess the feasibility and acceptability of the intervention, including seven questions related to the VR experiments. Twelve people participated in the survey; they all agreed that VR helps children control their pain and be cooperative. In addition, they agreed that it was suitable for children's age group and medical environment and that it's worth implementing. Also, All of them disagreed that VR delayed the wound care treatment. All survey question results are described in the Figures 4.12 - 4.18 and Appendix C.

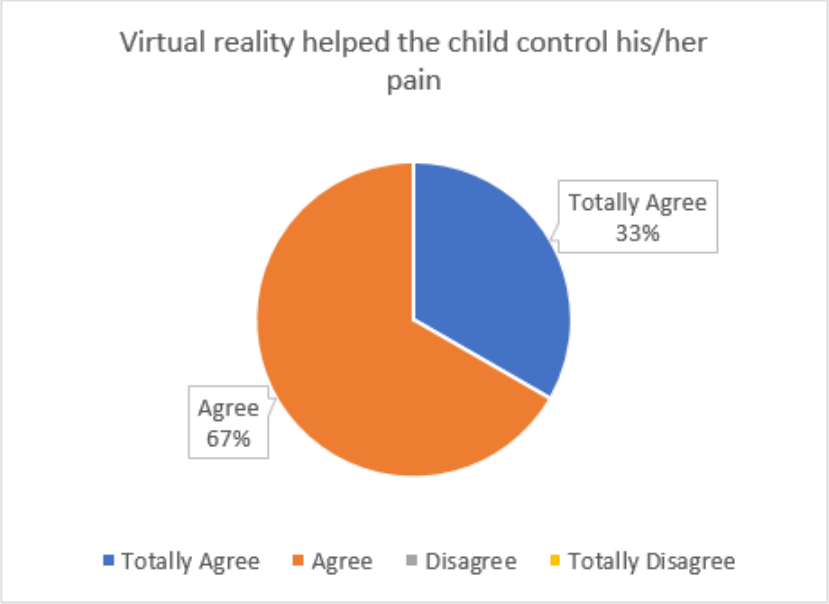

Figure 4.12: VR helped the child control their pain

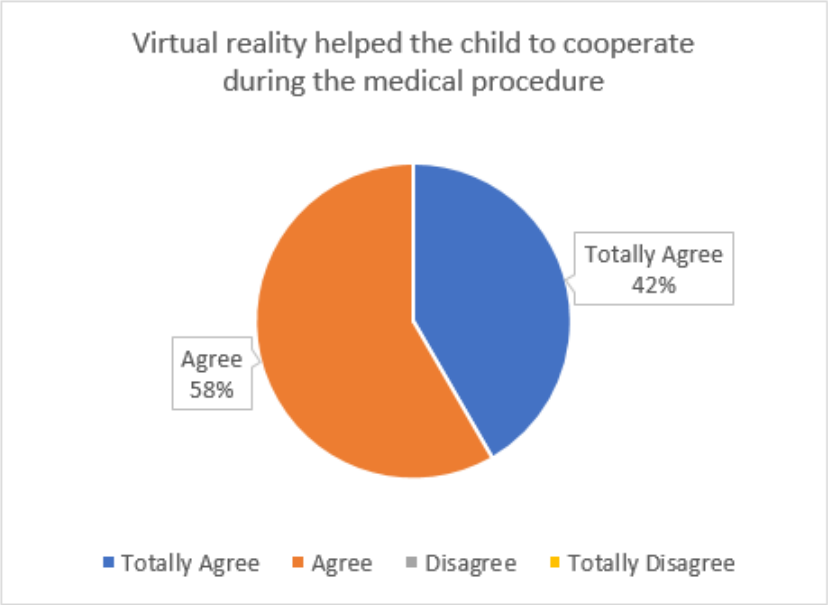

Figure 4.13: VR helped the child to cooperate during the medical procedure

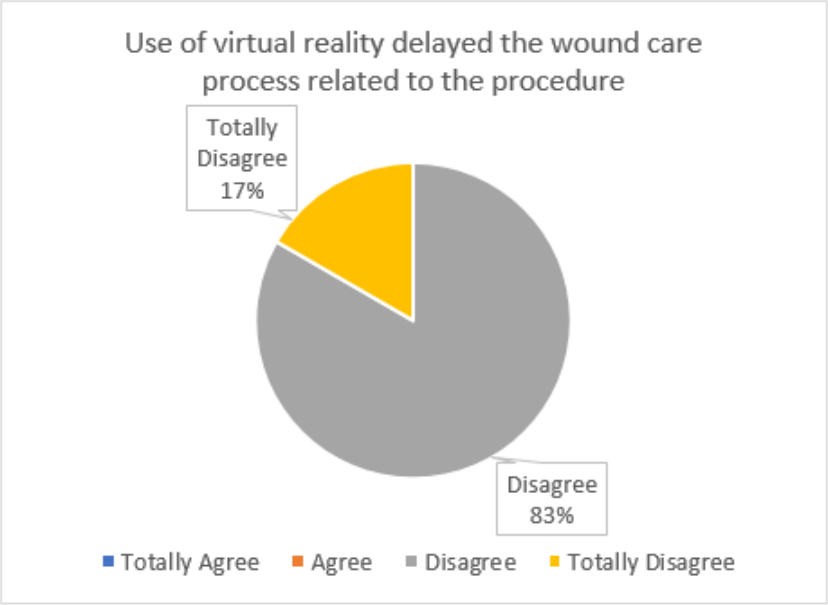

Figure 4.14: Use of VR delayed the wound care process related to the procedure

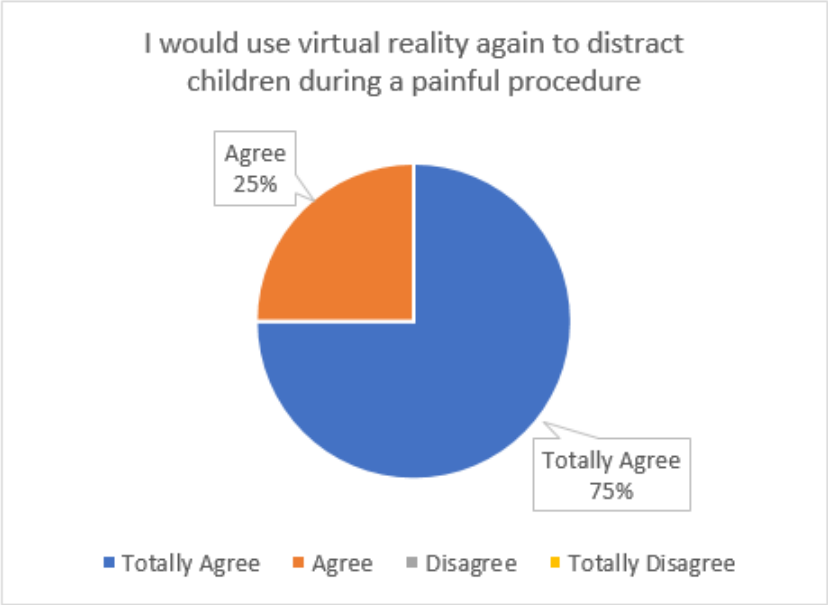

Figure 4.15: I would use VR again to distract children during a painful procedure

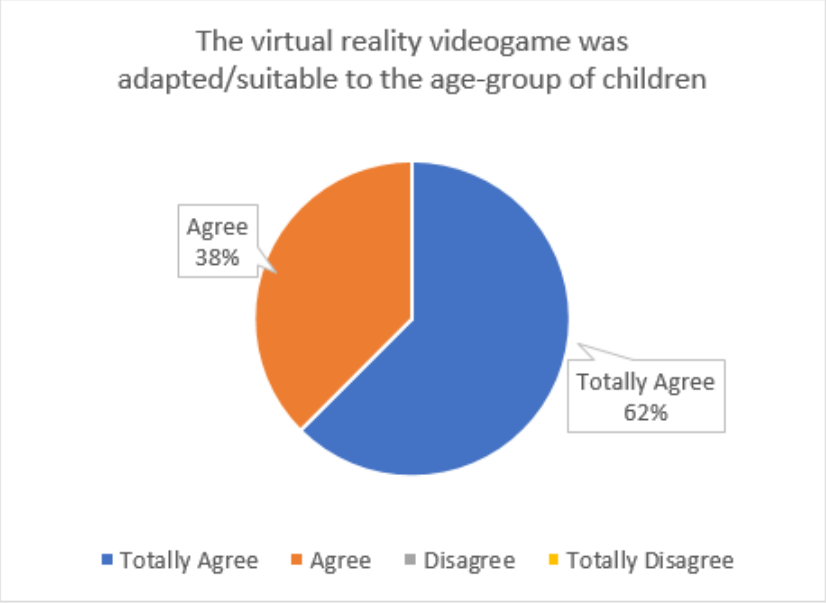

Figure 4.16: The VR game was adapted/suitable to the age group of children

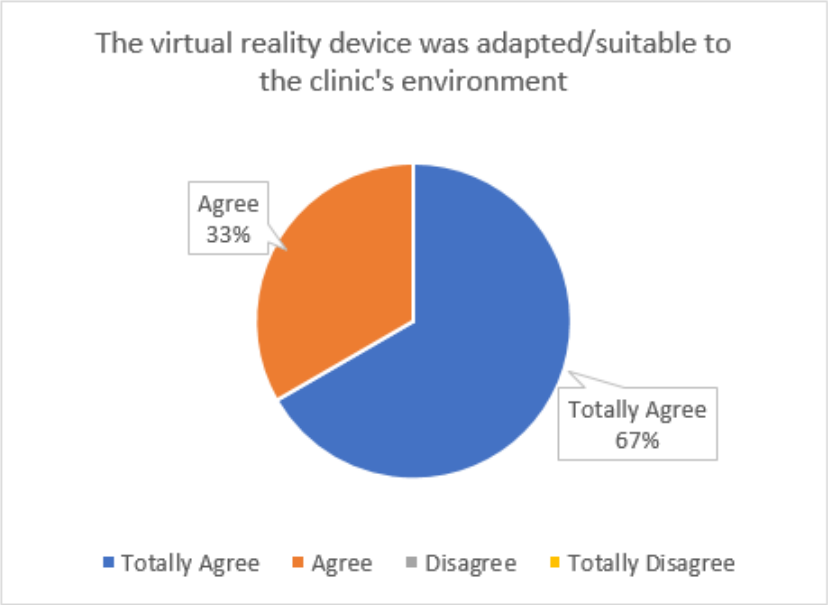

Figure 4.17: The VR device was adapted/suitable to the clinic's environment

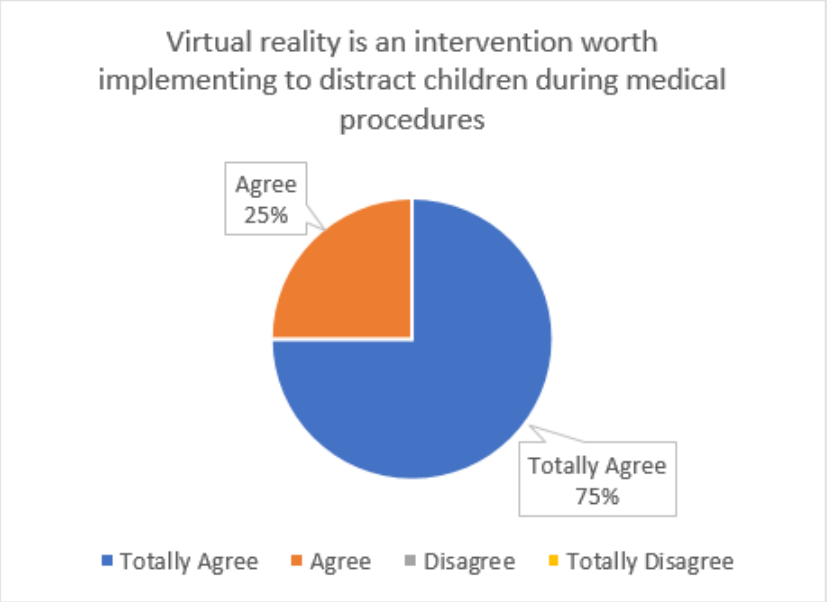

Figure 4.18: VR is an intervention worth implementing to distract children

4.4 Children Experience

Children enrolled in the study have shown different responses to VR treatment. Responses differ depending on the child's nature, injuries, and associated pain, as it is not a single entity. Also, each child's injury type and place differed, and the burn body extent ranged from 3% to 22%. All these factors explain the observed outcomes. Children's individual experiences are presented below by case identifiers to protect their personal data.

Case1: A ten-month-old boy who got burned on his legs, Right hand, and left leg by hot coffee (5%). The boy cries a lot during the dressing change. In both sessions, he cried, but he didn't kick his legs or scream loud during VR, which indicated that

the pain and anxiety were reduced. However, the boy did not accept the HMD, so screen VR was used, as shown in Figure 4.19.

Figure 4.19: Case1 during VR treatment

Case2: A ten-month-old girl was burned by hot water on her left leg and hand (10%). The girl cried a lot during the dressing, but she cried less during VR as she was distracted by animal sounds and movements. The girl also did not accept the HMD, so screen VR was used, as seen in Figure 4.20.

Figure 4.20: Case2 during VR treatment

Case3: A ten-month-old baby girl who got burned on her legs by hot coffee (6%). The girl usually does not show any pain and anxiety, but whenever she sees any nurses, she starts frowning, and when they touch her legs, she begins constantly crying until they finish the dressing. The girl is difficult to distract and console. She was exposed to VR before the wound care session, and she was watched in interest and gazing at the animals, as shown in Figure 4.21. When the nurses came, she became anxious and started to cry even during VR. Nevertheless, after placing headphones on her head, she looked at the screen once in a while, stopped crying for a few seconds, and continued crying. However, her anxiety was scored less than in the traditional session.

Figure 4.21: Case3 during VR treatment

Case4: A one-year-old boy who got burned by hot coffee on his right side of the face, right upper limb, and truck (12%). The boy constantly cries during dressing. When experiencing the VR screen, as seen in Figure 4.22, the boy was calm and focused on the animals. The nurses started the dressing removal, and he didn't look at them because he was gazing at the screen. Pain and anxiety were significantly decreased during the VR treatment. The mother and nurses were delighted.

Figure 4.22: Case4 during VR treatment

Case5: A one-year-old girl was burned by hot coffee on her face and chest (11%). The girl becomes anxious during wound care and cries a lot. The girl danced to the rhythms during the VR treatment even when frowning from pain. The girl stops crying and looks at animals and sounds once in a while. The results showed a reduction in anxiety and pain during VR wound care. Screen VR was used, as seen in Figure 4.23, as the girl did not accept the HMD.

Figure 4.23: Case5 during VR treatment

Case6: A one-year-old girl burned by hot food on her anterior trunk, right legs, right posterior trunk, and right hand (22%). The girl was anxious during the dressing, and the VR didn't reduce her anxiety and pain that much as she was scared of any nurses or doctors. The girl used screen VR, as seen in Figure 4.244.

Figure 4.24: Case6 during VR treatment

Case7: A one-year-old girl was burned by hot tea on her chest (3%). The burns are not deep, and the girl is not hospitalized yet does the dressing at a clinic. She always cried when starting the dressing removal, but during VR, she did not cry that much, and she danced to the rhythms, which indicates anxiety reduction. Screen VR was used, as shown in Figure 4.25.

Figure 4.25: Case7 during VR treatment

Case8: A year-and-ten-month-old boy was burned with boiling water on the face and chest area (15%). The boy showed discomfort as his wounds are itching him (especially the face area), and he becomes anxious during wound care sessions. In addition, he starts to cry and look at his mother as he is so attached to her. If she is close, he calms; otherwise, he cries and becomes scared. During the wound treatment, VR helped to distract the child as whenever he heard bubbles and animals' voices, he stopped crying and stared at the screen, which resulted in less pain and anxiety. Unfortunately, no picture is available as his parents did not sign the media release form.

Case9: A five-year-old girl burned by hot water on her legs, thighs, and genitalia (5%). The girl usually feels pain, and during wound care, she becomes highly anxious and scared. She screams and cries painfully and constantly during the session. She experienced VR Headset before the dressing and enjoyed the game,

but she removed the headset, and her anxiety came back high during dressing. In another session with the VR screen, as shown in Figure 4.26, she refused to play during the session but watched her mother play next to her. Her anxiety decreased slightly by the screen, and once the dressing was finished, she asked to play the game. The observational scale didn't show that much difference, but the subjective rating of pain and anxiety by the girl indicated that she was feeling less pain and anxiety and enjoyed the VR.

Figure 4.26: Case9 during VR treatment

Case10: A five-year-old girl who had a fingertip amputation. She has wound care sessions in the clinic. The girl sometimes shows a high level of stress and anxiety during the session. However, during VR, she was happy, and she cooperated. Her parents were so pleased with the intervention. She tried the HMD and then got

anxious, so she removed it in used screen VR, as seen in Figure 4.27.

Figure 4.27: Case10 during VR treatment

4.5 Discussion of the Findings

This clinical study has shown promising results regarding VR distraction's effectiveness on burned children younger than six years old. Also, the study has answered very important research questions discussed below.

- ⋆ **What are the design considerations that contribute to the distraction of children?**

Design considerations were determined by reading the literature review and needs assessment (questionnaire) results analysis. From the literature review, researchers

listed the successful features of apps for each age group based on their cognitive abilities. These features include simplicity, large shapes, easy interactivity, a sense of wonder, distinct patterns, supported audio, and visual qualities such as an attractive colorful environment. Additionally, researchers identified some design consideration elements that guided the selection of the VR environments, providing a perception of safety by using familiar elements in the scene and perceptions of control and empathy [60]. Also, they mentioned the importance of the purpose of the design.

To incorporate these findings into our research, we distributed the pre-design questionnaire to gather children's requirements from our society. We believe that it is very important to understand the behaviors of the targeted age group toward technology and VR. Therefore, in the first section, we learned that children aged less than two usually are not exposed to any devices due to their young age, while other children mostly use the TV, then mobile phones, tablets, and game consoles. In addition, the main activities used by children are watching videos or cartoons and listening to rhythms and songs. Moreover, most children use the devices with the help of a guardian, so we had in mind that children might need assistance.

The second section was about VR awareness, and we wanted to see how children and respondents are familiar with VR and what is their preferred VR theme. The results indicated that the VR awareness was high, and the preferred themes were playing with cartoon characters and adventure with animals. Additionally, we asked about the most suitable tool for children, and most respondents chose the VR screen. Finally, statistical tests were performed on all questions to find the differences due

to age and gender. The analysis aims to generalize the results and avoid bias toward a certain age or gender. Many differences were spotted due to age and gender; for example, the highest frequency in VR preferred experience was playing cartoon characters, but from the analysis, we found out that the theme was chosen by girls more than boys and by 3-5 age group more than 0-2 age group. On the other hand, adventure with animals was the second high-frequency option with no difference due to age and gender, so it was considered.

These findings helped us capture the primary needs regarding the tool and the design. Thus the VE considered the targeted age group and cognitive development as the game objects are large, simple, and easy to interact with. Furthermore, according to the literature review, familiar themes provide a sense of safety, and we believe that children are very familiar with animals. So, our design provides safety and control perceptions by making children interact with animals. Also, we tell the children that the animals need to be rescued by them, which provides an empathy perception. More importantly, Immersion is improved by combing sensory elements like attractive colors, sounds with a sense of wonder and adventure, and above all, interactivity.

- ⋆ **To what extent does the designed VR environment provide pain and anxiety distraction for children with burns during wound care sessions?**

Our VR environment (Animal Rescue) was investigated in the experimental (testing) and clinical study.

In the testing phase, 40 healthy children participated (57% aged 2-5 years; and

42.5% aged 6-10 years old). According to our sensory testing of just noticeable pain, VR significantly reduced children's "just noticeable" pain sensitivity compared to No VR and the verbal game. In addition, children tolerated 27% greater pressure during VR vs. during No VR. Our study is the first laboratory pain study showing VR analgesia in children aged 2-5, and Overall, VR was able to reduce the pressure pain sensitivity of healthy young children aged 2-10.

Also, ten children were included in the clinical study aged 10 months to 5 years. The VE significantly reduced children's pain by 38.7% during the VR treatment based on the observational FLACC scale, while anxiety was reduced by 32.2%. Anxiety results showed a non-significant reduction, but we believe that the results will show a significant reduction by increasing the sample size. It is important to note that children exhibited different responses during wound care, depending on their injuries and different nature. Some of them were very distracted by the VE, which resulted in a higher pain and anxiety reduction, while some were a little distracted and more anxious. Also, the scale did not capture some important factors, for example, if the child cried constantly or got distracted and stopped for a few seconds to gaze at the VR environment. We believe such factors may have affected the results of the anxiety scale.

As for the parents' observations, there was 36.8% pain reduction and 40% anxiety reduction during VR treatment. All the results from the parent's observation indicated a significant reduction. Parents are the best people who know and understand their children's behaviors and when they are showing real pain and anxiety. Accordingly, their ratings are considered very reliable during the clinical study.

In addition, we asked parents to rate their children's enjoyment during the VR and traditional treatments using the graphical joy scale. The results reported that joy was increased by 89.5% during VR compared to the traditional treatment. Furthermore, two children were old enough to self-report their pain and anxiety. Both of them reported less pain and zero anxiety during VR wound care. Also, the treatment time was reduced by a non-significant amount; we believe that the number of nurses and the different staff factors may have affected the results.

Parents, nurses, and doctors were very pleased by the intervention. In addition, the feasibility and acceptability questionnaires results indicated that all of them agreed that VR helped children cooperate and control their pain. They also agreed that the game was suitable for the age group and clinical environment and that they would use it again during painful procedures.

Besides, parents requested that their children experience the VR treatment every day; they described it as an interesting method for reducing their children's discomfort. These results indicated that our VR system is an efficient, significant, low-cost tool for children's pain and anxiety distraction.

- ⋆ **What is the most suitable VR tool for children younger than six years old?**

This study used two VR tools, VR HMD and a VR screen. Children aged less than two didn't accept the HMD; they immediately cried and tried to remove it from their heads, while the other two children aged five refused to wear it during wound care but did wear it before/after the wound care.

It was noticed that children feel more relaxed and comfortable in the presence of their parents and feel anxious from the medical staff at the same time. So even when the headset blocks their view from the medical staff and things yet, not seeing their parents increase their anxiety much more. With these observations, we can agree with the existing knowledge that the HMD VR does not fit children's physical and psychosocial needs.

On the other hand, screen VR was an acceptable tool for children as all of them could interact with the VE using it. Besides, according to the pre-design questionnaire, the most used device by children was the TV. In addition, parents chose the screen over the headset when asked which one was the most suitable VR tool for their children. Moreover, Screen VR has less contact with patients and it is the most low-cost VR tool. So, based on the findings, screen VR is an adaptable and suitable VR tool for children during wound care.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

There is growing evidence that immersive virtual reality can be a powerful non-pharmacological pain reduction technique that can be used in addition to traditional pain medications for patients receiving little or no medications. Virtual reality distraction techniques have indicated significant results in burn patients' pain reduction during medical procedures (wounds care, physical therapy), but an effective distraction for young children (aged < 6 years) has not been extensively studied. As a result, this research evaluates the effectiveness of designing a VR environment (VE) used in pain and anxiety distraction for young children (aged < 6 years) with burns during wound care. The VE was designed based on the needs and requirements of the targeted people, and it was tested on healthy volunteers. The VE significantly reduced the "just noticeable" pain sensitivity of children younger than 6 in the test-

ing phase. Also, ten burned children with wound care were recruited in the hospital for the VR clinical study. All children received a wound care session with VR and another with traditional treatment on different days. The results showed a significant reduction in the pain by 38.7% during the VR treatment based on the observational scale, while anxiety was reduced by 32.2%. As for the parents' observations, there was 36.8% pain reduction and 40% anxiety reduction during VR treatment. In addition, the children's enjoyment during the VR treatment was increased by 89.5% compared to the traditional treatment. These results indicate that our designed VE was efficient for children's pain and anxiety distraction.

5.2 Limitation

One of the factors that might have affected the time results during the clinical study is having different nurses doing the dressing change for the children. Each nurse has their way of treating their patients; some take more time than others. Also, the number of nurses was not the same in each session. Another limitation is that there was a gap in the patients' ages in our study, as eight children were aged less than two, two were aged five, and no children were aged two to four years. Also, the sample size was relatively small, although the study duration was six months.

5.3 Challenges

Many challenges were encountered during the completion of this research, as listed below:

- The ethical approval took so much time (around 8 months) until finalized in some hospitals.
- Hospital did not provide us with a fixed room for the study, so it was performed in each patient's room.
- Some doctors did not allow their patients to participate in the study.
- Doctors were discharging patients early even with no full recovery due to the covid pandemic and the infection risk.
- Doctors were discharging patients early even with no full recovery due to the covid pandemic and the infection risk.

5.4 Future Work

For future work, further investigation of VR effectiveness for children can be done by:

- Using different VR tools that could be suitable for children's needs.
- Having the same staff in each session to ensure more sufficient results.

- Using our VE to distract pain from other injuries than burns.
- Including a larger sample size involving all ages less than six.
- Considering additional pain and anxiety measurements.
- Including older children in future experiments.

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Appendix A

Pre-Design Questionnaire

1. What is your relation with kids? ما علاقتك بالأطفال؟
    - Teacher – معلم ة
    - Parent – والد ة
    - Sibling – اخت اخ
    - Aunt or Uncle – خالة أو عمة
    - Grandparent – جدة
    - Children's specialist – متخصصة في مجال الأطفال
    - None لا يوجد علاقة (انهاء الاستبيان)
2. Your Gender? ماهو جنسك؟
    - Female/ انثى
    - Male/ ذكر
3. Choose your age group اختر فئتك العمرية
    - < 16
    - 16-25

- 26-35
- 36-45
- 46-55
- <55

Note ملاحظة

نود منك إكمال هذا الاستبيان نيابة عن أحد الأطفال.

لاحظ أن هذا الطفل يجب ألا يزيد عمره عن ٥ سنوات و ٠ شهر

We would like you to complete this survey on behalf of one of the children. This child should be no older than 5 years 0 months.

4. Gender of the child? ماهو جنس الطفل؟
    - Female/ انثى
    - Male/ ذكر
5. How old is the child? ماهو عمر الطفل
    - 1 سنة
    - 2 سنتان
    - 3 سنوات
    - 4 سنوات
    - 5 سنوات
    - Older than 5 اكبر من خمس سنوات (انهاء الاستبيان)

Children and Devices الأطفال والأجهزة

6. Which of the following devices does the child make use of the most?
   أي من الأجهزة التالية يستخدمها الطفل أكثر من غيرها؟

- Tablet (iPad, galaxy tab, etc) تابلت مثل الايباد
- Mobile Phone الجوال
- Game Console جهاز لعبة مثل الاكس بوكس والبلايستيشن
- TV التلفاز
- None لا يستخدم اي جهاز

7. Which of the following activities does the child use the device for?
أي من الأنشطة التالية يستخدم الطفل الجهاز من أجلها؟

- Drawing and painting الرسم والطباعة
- Colouring in التلوين
- Making collages تجميع الصور
- Making videos تصوير فيديو
- Taking photographs التقاط صور
- Reading stories قراءة القصص
- Watching video مشاهدة فيديو
- Play with/use apps for gaming اللعب في تطبيقات الالعاب
- Play with/use apps for social اللعب في تطبيقات التواصل الاجتماعي
- To help learning/education للتعلم والدراسة
- Listen to stories/audio books سماع القصص والكتب الصوتية
- Listen to music سماع الاناشيد
- Look at pictures/photos مشاهدة الصور
- Voice/video communication, e.g. FaceTime/Skype
التواصل عن طريق الصوت والصورة
- Using a search engine (e.g. typing key words into Google and searching)
البحث فالانترنت

- Watching music videos on YouTube مشاهدة اناشيد على اليوتيوب
- Watching videos made by other children on YouTube
  مشاهدة مقاطع لأطفال على اليوتيوب
- Watching Cartoon مشاهدة افلام الكارتون
- None لايستخدم

8. Who are they typically using the device with?
   مع من يستخدم الطفل الجهاز عادةً؟

- On their own بمفرده.
- With me or another parent or guardian مع احد الوالدين
- With brother(s)/Sister(s) مع الاخ او الاخت
- With another family member مع احد افرادالعائلة
- With a friend مع صديق
- Other adult, e.g. Nursery worker, childminder, school teacher
  شخص بالغ آخرمثا
- None لايستخدم

9. Which of the following statements are most true when the child is using a device?
   ماهي اكثر عبارة صحيحة من العبارات التالية عندما يستخدم الطفل الجهاز

- The device is being used as a form of distraction or quiet time, whilst I complete other tasks or relax
  يستخدم الطفل الجهاز كشكل من أشكال الإلهاء
  أو وقت الهدوء، بينما أكمل المهام الأخرى أو أرتاح
- The device is providing a sit-back experience e.g. watching video
  يوفر الجهاز تجربة الاسترخاء للطفل على سبيل المثال مشاهدة فيديو
- The device is being used to encourage my child to be creative and/or play
  يتم استخدام الجهاز لتشجيع طفلي على الإبداع أو اللعب

- The device is being used as a social device e.g. co-usage with adults or other children
  يتم استخدام الجهاز كجهاز اجتماعي على سبيل المثال الاستخدام المشترك مع البالغين أو الأطفال الآخرين
- The device is being used for educational purposes (e.g. learning the alphabet)
  يتم استخدام الجهاز لأغراض تعليمية (مثل تعلم الحروف الأبجدية)
- The device is being used for bedtime stories
  يتم استخدام الجهاز لقصص ما قبل النوم
- None لايستخدم

الواقع الافتراضي **VR**

10. How familiar are you or the child with the term VR?
    ما مدى معرفتك أنت أو الطفل بمصطلح الواقع الافتراضي؟

    - know exactly what this is اعرف هذا المصطلح تماما
    - have used this I'm familiar with it لقد جربته واعرفه جيدا
    - I've definitely heard of it سمعت عنه
    - Unaware لا اعرفه

11. Do you expect that the child is interested in experiencing Virtual Reality?
    هل تتوقع أن يكون الطفل مهتمًا بـ تجربة الواقع الافتراضي؟

    - Extremely interested مهتم للغاية
    - Fairly interested مهتم الى حد ما
    - Neither interested nor not interested محايد
    - Not very interested غير مهتم جدا
    - Not interested at all غير مهتم على الاطلاق

12. What sorts of experiences would the child you like to have in virtual reality?
ما أنواع التجارب التي سيرغب الطفل بالحصول عليها في الواقع الافتراضي؟

- Go on an adventure with animals الذهاب في مغامرة مع الحيوانات
- See Space رؤية الفضاء
- Visit the Sea World زيارة عالم البحار
- Snow Playing اللعب بالثلج
- Drive a Car قيادة السيارات
- Playing with Cartoons characters اللعب مع الشخصيات الكرتونية
- Go to virtual theme park الذهاب الى الملاهي
- Visit a fantasy world زيارة عالم خيالي
- Fly like a bird الطيران كعصفور
- Flying a plane ركوب طائرة

VR in Medical Field الواقع الافتراضي في المجال الطبي

13. Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain?
هل تتوقع أن يكون الطفل مهتمًا بـ تجربة الواقع الافتراضي في المراكز الطبية او المستشفيات حتى وهو يشعر بالألم ؟

- Extremely interested مهتم للغاية
- Fairly interested مهتم الى حد ما
- Neither interested nor not interested محايد
- Not very interested غير مهتم جدا
- Not interested at all غير مهتم على الاطلاق

14. Which VR tool you think is more comfortable and suitable to your child?
ما أداة الواقع الافتراضي التي تعتقد أنها أكثر راحة وملاءمة لطفلك؟

- VR glasses نظارات الواقع الافتراضي
- VR screen شاشة الواقع الافتراضي

15. Do you believe that having VR technology in medical centers and hospitals will help distract the children from pain and anxiety?
هل تعتقد أن وجود تقنية الواقع الافتراضي في
المراكز الطبية والمستشفيات سيساعد في تشتيت انتباه الأطفال عن الألم والرهبة؟

- I Strongly believe اعتقد وبشدة
- Yes I believe نعم اعتقد
- I don't know لا اعلم
- I disbelieve لا اعتقد
- I strongly disbelieve لا اعتقد وبشدة

Appendix B

Post-Design Questionnaire

1. What is your relation with kids? ما علاقتك بالأطفال؟
    - Teacher – معلم ة
    - Parent – والد ة
    - Sibling – اخت اخ
    - Aunt or Uncle – خالة أو عمة
    - Grandparent – جدة
    - Children's specialist – متخصصة في مجال الأطفال
    - None لا يوجد علاقة (انهاء الاستبيان)
2. Your Gender? ماهو جنسك؟
    - Female/ انثى
    - Male/ ذكر
3. Choose your age group اختر فئتك العمرية
    - < 16
    - 16-25

- 26-35
- 36-45
- 46-55
- <55

4. Gender of the child ؟ماهو جنس الطفل

- Female/ انثى
- Male/ ذكر

5. How old is the child? ماهو عمر الطفل

- Younger than one اصغر من سنة
- 1 سنة
- 2 سنتان
- 3 سنوات
- 4 سنوات
- 5 سنوات
- Older than 5 اكبر من خمس سنوات

6. Do you expect that the child is interested in playing Virtual Reality Game?
هل تتوقع أن يكون الطفل مهتمًا بـ تجربة لعبة الواقع الافتراضي؟

- Extremely interested مهتم للغاية
- Fairly interested مهتم الى حد ما
- Neither interested nor not interested محايد
- Not very interested غير مهتم جدا
- Not interested at all غير مهتم على الاطلاق

7. Do you expect that the child is interested in experiencing Virtual Reality in medical centers when he/she is in pain?
هل تتوقع أن يكون الطفل مهتمًا بـ تجربة لعبة الواقع الافتراضي في المراكز الطبية او المستشفيات حتى وهو يشعر بالألم ؟

   - Extremely interested مهتم للغاية
   - Fairly interested مهتم الى حد ما
   - Neither interested nor not interested محايد
   - Not very interested غير مهتم جدا
   - Not interested at all غير مهتم على الاطلاق

8. Do you believe the VR Game will help distract your child during a painful procedure
هل تعتقد أن لعبة الواقع الافتراضي ستساعد في تشتيت انتباه طفلك أثناء العمليات المؤلمة

   - I Strongly believe اعتقد وبشدة
   - Yes I believe نعم اعتقد
   - I don't know لا اعلم
   - I disbelieve لا اعتقد
   - I strongly disbelieve لا اعتقد وبشدة

9. The virtual reality game is adapted/suitable to the age-group of children
لعبة الواقع الافتراضي المعروضة مناسبة للفئة العمرية للطفل

   - Totally Agree اتفق بشدة
   - Agree اتفق
   - Neutral محايد
   - Disagree لا اتفق
   - Totally Disagree لا اتفق بشدة

10. Virtual reality is an intervention worth implementing to distract children during medical procedures
تقنية الواقع الافتراضي تستحق التنفيذ لإلهاء الأطفال أثناء الإجراءات الطبية

- Totally Agree اتفق بشدة
- Agree اتفق
- Neutral محايد
- Disagree لا اتفق
- Totally Disagree لا اتفق بشدة

Appendix C

Feasibility and Acceptability of the Intervention

Name(optional): _____ Child Relation (e.g., Parent, Dr, Nurse): _____

1. **Virtual reality helped the child control his/her pain**
   □Totally Agree □ Agree □Disagree □Totally Disagree

2. **Virtual reality helped the child to cooperate during the medical procedure**
   □Totally Agree □ Agree □Disagree □Totally Disagree

3. **Use of virtual reality delayed the wound care process related to the procedure**
   □Totally Agree □ Agree □Disagree □Totally Disagree

4. **I would use virtual reality again to distract children during a painful procedure**
   □Totally Agree □ Agree □Disagree □Totally Disagree

5. **The virtual reality videogame was adapted/suitable to the age-group of children**
   □Totally Agree □ Agree □Disagree □Totally Disagree

6. **The virtual reality device was adapted/suitable to the clinic's environment**
   □Totally Agree □ Agree □Disagree □Totally Disagree

7. **Virtual reality is an intervention worth implementing to distract children during medical procedures**
   □Totally Agree □ Agree □Disagree □Totally Disagree

Other Notes:

_____
_____
_____
_____
_____
_____
_____
_____
_____
____

اسئلة لقياس جدوى فعالية الواقع الافتراضي

الاسم (اختياري):_____ علاقتك بالطفل (مثال: والد، طبيب،ممرضة):_____

1- ساعد الواقع الافتراضي على التحكم بألم الطفل
□ اتفق بشدة □اتفق □لا اتفق □لا اتفق بشدة

2- ساعد الواقع الافتراضي الطفل على التعاون أثناء العملية الطبية
□ اتفق بشدة □اتفق □لا اتفق □لا اتفق بشدة

3- أدى استخدام الواقع الافتراضي إلى تأخير عملية العناية بالجروح
□ اتفق بشدة □اتفق □لا اتفق □لا اتفق بشدة

4- سأستخدم الواقع الافتراضي مرة أخرى لإلهاء الأطفال أثناء العمليات المؤلمة
□ اتفق بشدة □اتفق □لا اتفق □لا اتفق بشدة

5- لعبة الواقع الافتراضي المعروضة تناسب مع الفئة العمرية للطفل
□ اتفق بشدة □اتفق □لا اتفق □لا اتفق بشدة

6- تم استخدام جهاز للواقع الافتراضي مناسب لبيئة العيادة
□ اتفق بشدة □اتفق □لا اتفق □لا اتفق بشدة

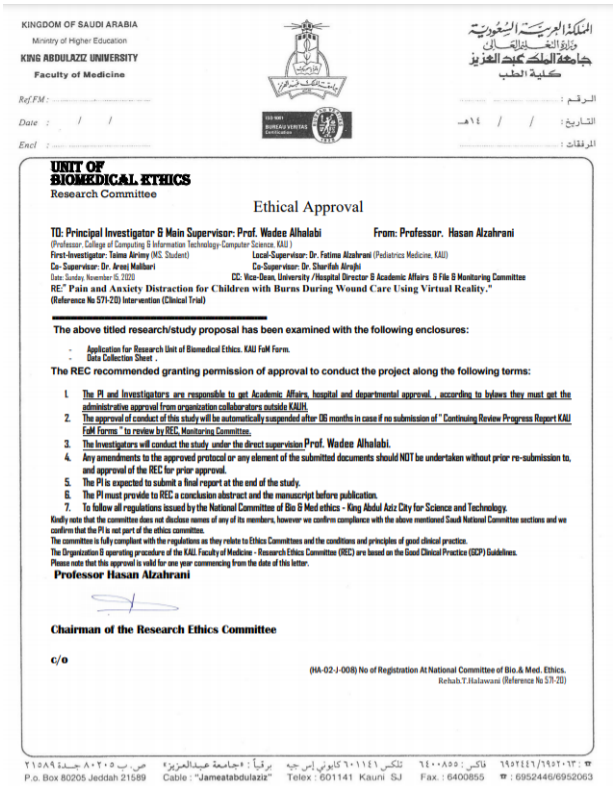
7- تقنية الواقع الافتراضي تستحق التنفيذ لإلهاء الأطفال أثناء الإجراءات الطبية
□ اتفق بشدة □اتفق □لا اتفق □لا اتفق بشدة

ملاحظات أخرى:

_____
_____
_____
_____

Appendix D

Ethical Approvals (IRB)



KINGDOM OF SAUDI ARABIA
Ministry of Higher Education
KING ABDULAZIZ UNIVERSITY
Faculty of Medicine

المملكة العربية السعودية
وزارة التعليم العالي
جامعة الملك عبد العزيز
كلية الطب

Ref.FM : ..... الرقم : .....
Date : / / التاريخ : / / ١٤هـ
Encl : ..... المرفقات : .....

UNIT OF BIOMEDICAL ETHICS
Research Committee

Ethical Approval

TO: Principal Investigator & Main Supervisor: Prof. Wadee Alhalabi **From: Professor. Hasan Alzahrani**
(Professor, College of Computing & Information Technology-Computer Science, KAU)
First-Investigator: Taima Alrimy (MS. Student) Local-Supervisor: Dr. Fatima Alzahrani (Pediatrics Medicine, KAU)
Co- Supervisor: Dr. Arwa Mallhari Co-Supervisor: Dr. Sharifah Alrajhi
Date: Sunday, November 15, 2020 CC: Vice-Dean, University /Hospital Director & Academic Affairs & File & Monitoring Committee

RE:" Pain and Anxiety Distraction for Children with Burns During Wound Care Using Virtual Reality."
(Reference No 571-20) Intervention (Clinical Trial)

The above titled research/study proposal has been examined with the following enclosures:

- Application for Research Unit of Biomedical Ethics. KAU FoM Form.
- Data Collection Sheet .

The REC recommended granting permission of approval to conduct the project along the following terms:

1. The PI and Investigators are responsible to get Academic Affairs, hospital and departmental approval , according to bylaws they must get the administrative approval from organization collaborators outside KAUH.
2. The approval of conduct of this study will be automatically suspended after 06 months in case if no submission of " Continuing Review Progress Report KAU FoM Forms " to review by REC, Monitoring Committee.
3. The Investigators will conduct the study under the direct supervision **Prof. Wadee Alhalabi.**
4. Any amendments to the approved protocol or any element of the submitted documents should NOT be undertaken without prior re-submission to, and approval of the REC for prior approval.
5. The PI is expected to submit a final report at the end of the study.
6. The PI must provide to REC a conclusion abstract and the manuscript before publication.
7. To follow all regulations issued by the National Committee of Bio & Med ethics - King Abdul Aziz City for Science and Technology.

Kindly note that the committee does not disclose names of any of its members, however we confirm compliance with the above mentioned Saudi National Committee sections and we confirm that the PI is not part of the ethics committee.
The committee is fully compliant with the regulations as they relate to Ethics Committees and the conditions and principles of good clinical practice.
The Organization & operating procedure of the KAU. Faculty of Medicine - Research Ethics Committee (REC) are based on the Good Clinical Practice (GCP) Guidelines.
Please note that this approval is valid for one year commencing from the date of this letter.

Professor Hasan Alzahrani

Chairman of the Research Ethics Committee

c/o

(HA-02-J-008) No of Registration At National Committee of Bio.& Med. Ethics.
Rehab.T.Halawani (Reference No 571-20)

ص.ب ٨٠٢٠٥ جدة ٢١٥٨٩ برقياً : «جامعة عبدالعزيز» تلكس ٦٠١١٤١ كابوي إس جيه فاكس : ٦٤٠٠٨٥٥ ☎ : ٦٩٥٢٤٤٦/٦٩٥٢٠١٣
P.o. Box 80205 Jeddah 21589 Cable : "Jameatabdulaziz" Telex : 601141 Kauni SJ Fax. : 6400855 ☎ : 6952446/6952063

Kingdom of Saudi Arabia

Ministry of Health

المملكة العربية السعودية
وزارة الصحة
مديرية الشؤون الصحية بمحافظة جدة

اللجنة المحلية لأخلاقيات البحوث بصحة جدة

Institutional Review Board

National Registration Number with NCBE-KACST, KSA: (H-02-J-002)

5. All researchers are required to have a valid research ethics certificate on protecting human research participants.
6. The research team is not allowed to disclose personally identifiable data of the participants to any other party.
7. The PI is required to keep the study data securely for at least three years after the completion of the study.
8. The collected data should only be used for this research.
9. It is required to collect three copies of informed consent forms (unless waived) as follow:
   I. One copy to be kept with the PI
   II. One copy to be kept with the study participant
   III. One copy for the IRB committee OR to be kept in the participant file in case of clinical research
10. The PI is required to submit a progress report **every six months**
11. The PI must ensure adequate close-out of the study.
12. Publication by any means is not allowed except after getting an approval letter from the IRB and MOH research department.

Sincerely yours,

Signature

Dr. Hanouf BinHimd ,MD

Chairman of Jeddah IRB, MOH, KSA.

Appendix E

Informed Consent and Media Release Form

Kingdom of Saudi Arabia
King AbdulAziz University
Faculty of Computing and Information Technology
Faculty of Medicine

استمارة الموافقة على المشاركة في البحث

أنت مدعو/ أنت مدعوة من قبل طالبة الماجستير **(تيماء أحمد الريمي)** بقسم علوم الحاسب في كلية الحاسبات وتقنية المعلومات، تحت عنوان

"تشتيت الألم والرهبة لدى الأطفال المصابين بالحروق خلال جلسات العناية بالجروح باستخدام الواقع الإفتراضي"

الذي يجرى في **"قسم العناية بالحروق"**

الغرض من الدراسة:

الغرض من هذا البحث هو دراسة فعالية الواقع الافتراضي لتشتيت الألم والرهبة لدى الأطفال دون سن الخامسة المصابين بالحروق. ستقيس الدراسة ما إذا كان استخدام الواقع الافتراضي فعالاً في تقليل درجة الألم والرهبة وفترة العلاج أم لا، وسيتم تضمين تقنية الواقع الافتراضي اذا تم ثبوت فعاليتها كأداة للسيطرة على الألم بالإضافة إلى الأدوية القياسية.

الإجراءات / الأعمال المطلوبة من الطفل المشارك:

استخدام الواقع الافتراضي للعب خلال جلسات العناية بالحروق.

وسيتم قياس مستوى الألم للطفل عند خضوعه للتجربة وبدون تجربتها لمقارنة النتائج.

الفترة الزمنية المطلوبة لمشاركة المريض:

خلال جلسات العناية بالجروح المحددة للطفل من قبل الطبيب في المستشفى.

المخاطر:

سيتعرض الطفل المشارك إلى شاشة عرض كبيرة أو نظارات الواقع الافتراضي والتي غالبا لا يصاحبها اي مخاطر للطفل.

الفوائد للمشارك والمجتمع:

إذا شارك طفلك في هذا البحث، فقد يكون لديه فرصة لتقليل درجة الألم وتسريع عملية العلاج. قد لا تكون النتيجة فورية، ولكن مشاركته ستساعدنا في العثور على إجابة لسؤال البحث وهو عن مدى فعالية تشتيت الألم عن الاطفال المصابين بالحروق خلال جلسات العناية بالجروح عن طريق الواقع الافتراضي.

المشاركة تطوعية:

المشاركة في البحث أمر طوعي وللطرف المشارك الحق في الانسحاب في أي مرحلة من مراحله (وقتما شاء) دون التعرض لخسارة أو فوات منفعة يستحقها.

البدائل المتاحة للمريض في حالة عدم الرغبة في المشاركة:

سيتم علاج الطفل بالشكل التقليدي المقدم من الأطباء بدون استخدام تقنية الواقع الافتراضي.

حماية خصوصية المشارك و سرية البيانات:

ستبقى المعلومات التي نجمعها من هذا المشروع البحثي في قاعدة بيانات تخص الباحثين القائمين على هذا البحث. لن يتم تخزين أو نشر المعلومات المتعلقة بهوية طفلك (كالاسم) فقط المعلومات العامة كالعمر والجنس ونتائج البحث. يمكن عرض النتائج في المؤتمرات والمنشورات ونشرها على الإنترنت. يقوم موظفو الجامعة أحيانًا بمراجعة دراسات مثل هذه الدراسة للتأكد من إجرائها بأمان وبشكل قانوني. إذا تم إجراء مراجعة لهذه الدراسة، فقد يتم فحص سجلات طفلك. سيحمي المراجعون خصوصيته ولن يتم استخدام سجلات الدراسة لتعريضك لخطر الضرر القانوني. سنحتاج الى التقاط صور للمشاركين وعرضها في المؤتمرات والمنشورات بعد اخذ موافقة ولي الأمر عليها.

هل توافق على أخذ صور لطفلك المشارك في البحث واستخدامها في المؤتمرات والمنشورات؟

☐ موافق ☐ غير موافق

☐ اخرى :_____

أرقام وعناوين التواصل للحصول على أي معلومات تتعلق بالبحث، أو بحقوق المشارك، أو التبليغ في حال حدوث ضرر:

- الباحث: تيماء الريمي هاتف 0566504248 والبريد الالكتروني talrimy@stu.kau.edu.sa
- المشرف على الباحث: د. وديع الحلبي هاتف 0555506232 والبريد الالكتروني wsalhalabi@kau.edu.sa

إذا كنت توافق على الاشتراك فى هذه الدراسة، قم بالإشارة فى المكان المناسب فى الجزء التالي:

– أقر أنا بأن هذا البحث العلمي وإجراءاته قد تم شرحها لي. لقد سمح لي بأن اسأل كل سؤال لدي الآن ويمكنني أن اسأل أي أسئلة إضافية في أي وقت لاحق. كما يمكنني إنهاء المشاركة في هذا البحث العلمي في أي وقت دون أن تتأثر الرعاية الصحية المقدمة لطفلي. ☐

– أوافق بموجبه على استخدام أي تسجيلات فيديو أو صور فوتوغرافية أو شرائح أو تسجيلات صوتية أو أي نسخ مرئي أو صوتي لطفلي كمشارك في هذه الدراسة. أصرح باستخدام أي نسخ فوتوغرافية أو إلكترونية لطفلي لأي غرض، بما في ذلك ، على سبيل المثال لا الحصر، برامج البحث / التعليم ووسائل الإعلام العامة الأخرى التي قد يراها الباحثون في هذه الدراسة مناسبة. ☐

أوافق طواعية على مشاركة طفلي كمشارك في هذه الدراسة بالتوقيع أدناه.

اسم الطفل المشارك: _____ تاريخ ميلاد الطفل: _____

اسم الشخص المسؤول عن المشارك (ولي الأمر): _____ توقيعه: _____

التاريخ: _____

شاهد على إجراءات الموافقة : _____ توقيعه: _____

توقيع مسؤول الدراسة (الباحث الرئيس) : _____

التاريخ: _____

استمارة الإذن بالنشر الإعلامي

المملكة العربية السعودية ، جامعة الملك عبد العزيز ، كلية الحاسبات وتقنية المعلومات

استمارة الإذن بالنشر إعلامي لأولياء أمور الأطفال المشاركين في البحث بعنوان " تشتيت الألم والرهبة لدى الأطفال المصابين بالحروق خلال جلسات العناية بالجروح باستخدام الواقع الإفتراضي"

وصف البحث العلمي:

الغرض من هذا البحث هو دراسة فعالية الواقع الافتراضي لتشتيت الألم والرهبة لدى الأطفال المصابين بالحروق. ستقيس الدراسة ما إذا كان استخدام الواقع الافتراضي فعالاً في تقليل درجة الألم والرهبة وفترة العلاج أم لا، وسيتم تضمين تقنية الواقع الافتراضي اذا تم ثبوت فعاليتها كأداة للسيطرة على الألم بالإضافة إلى الأدوية القياسية.

إقرار بموافقة المشارك:

أقر أنا بأن هذا البحث العلمي وإجراءاته قد تم شرحها لي. لقد سمح لي بأن اسأل كل سؤال لدي الآن ويمكنني أن اسأل أي أسئلة إضافية في أي وقت لاحق. كما يمكنني إنهاء المشاركة في هذا البحث العلمي في أي وقت دون أن تتأثر الرعاية الصحية المقدمة لي. أوافق بموجبه على استخدام أي تسجيلات فيديو أو صور فوتوغرافية أو شرائح أو تسجيلات صوتية أو أي نسخ مرئي أو صوتي لطفلي كمشارك في هذه الدراسة. أصرح باستخدام أي نسخ فوتوغرافية أو إلكترونية لطفلي لأي غرض، بما في ذلك ، على سبيل المثال لا الحصر، برامج البحث / التعليم ووسائل الإعلام العامة الأخرى التي قد يراها الباحثون في هذه الدراسة مناسبة.

اسم الطفل المشارك _____ اسم ولي أمر الطفل _____

توقيع ولي الأمر _____ التاريخ _____

توقيع الباحث الرئيسي _____

أرقام وعناوين الاتصال لمن يمكن الحصول على أي معلومات تتعلق بالبحث، أو بحقوق المشارك، أو الإبلاغ في حال حدوث ضرر:

- الباحث الرئيسي: غناء الرميلي هاتف 0566504248 والبريد الإلكتروني talrimy@stu.kau.edu.sa
- المشرف على الباحث: د. وديع الحلبي هاتف 0555506232 والبريد الإلكتروني wsalhalabi@kau.edu.sa

تشتيت الألم والرهبة لدى الأطفال المصابين بالحروق خلال جلسات العناية بالجروح باستخدام الواقع الافتراضي

تيماء أحمد الريمي

بحث مقدم لنيل درجة الماجستير في علوم الحاسبات

إشراف

د. أريج ميلباري

كلية الحاسبات وتقنية المعلومات
جامعة الملك عبدالعزيز
جدة، المملكة العربية السعودية
ذوالقعدة ١٤٤٣ هـ - يونيو ٢٠٢٢ م


بسم الله الرحمن الرحيم

إهداء

أهدي هذا العمل إلى جميع من يعاني من إصابات الحروق .

الملخص

تعد إصابات الحروق لدى الأطفال من أكثر إصابات الأطفال المسببة للصدمة، حيث يعاني الأطفال من الألم الجسدي والرهاب العاطفي. أشارت تقنيات إلهاء الواقع الافتراضي إلى نتائج مهمة في تقليل آلام مرضى الحروق أثناء الإجراءات الطبية (العناية بالجروح، العلاج الطبيعي) ، ولكن لم تتم دراسة إلهاء فعال للأطفال الصغار (أقل من ٦ سنوات) على نطاق واسع. قام هذا البحث بتقييم فعالية تصميم بيئة واقع افتراضي في إلهاء الألم والرهبة للأطفال الصغار المصابين بالحروق (الذين تقل أعمارهم عن ٦ سنوات) أثناء جلسات العناية بالجروح. تم تصميم البيئة الافتراضية بناءً على احتياجات ومتطلبات الأشخاص المستهدفين، وتم اختباره على متطوعين أصحاء. قلل الواقع الافتراضي بشكل كبير من الاحساس بالألم للأطفال الأصغر من ٦ سنوات في مرحلة اختبار التصميم. كما تم عمل دراسة تجريبية على عشرة أطفال مصابين بالحروق اثناء جلسات العناية بالجروح. تلقى جميع الأطفال جلسة العناية بالجروح بالواقع الافتراضي وأخرى بالعلاج التقليدي في أيام مختلفة. أظهرت النتائج انخفاضاًا ملحوظاًا في الألم بنسبة ٧.٨٣٪ أثناء علاج الواقع الافتراضي، بينما انخفض القلق بنسبة ٢.٢٣٪. أما بالنسبة لملاحظات الوالدين، فقد تم تقليل الألم بنسبة ٨.٦٣٪ وتقليل القلق بنسبة ٠٤٪ أثناء علاج الواقع الافتراضي. بالإضافة إلى ذلك، تمت زيادة استمتاع الأطفال أثناء علاج الواقع الافتراضي بنسبة ٥.٩٨٪ مقارنة بالعلاج التقليدي. تشير هذه النتائج إلى أن الواقع الافتراضي المصمم لدينا كان فعالاً في تشتيت آلام والرهبة لدى الأطفال.

الكلمات المفتاحية : الواقع الافتراضي، الخروف، الأطفال، تشتيت الألم، تشتيت الرهبة