The effectiveness of Virtual Reality for pre-treatment of children in Magnetic Resonance Imaging

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A thesis submitted in partial fulfilment of the

requirements for the Degree of

Master of Human Interface Technology

by

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2017

Abstract

The purpose of this research is to explore the potential of using Virtual Reality (VR) to reduce anxiety among children aged 4-6 while undergoing Magnetic Resonance Imaging (MRI) scans. To achieve this, VR was compared to play therapy, which is the current methodology for reducing anxiety in children.

A VR game was designed to mimic the actual MRI room at Christchurch Hospital in New Zealand. The purpose of the VR game is to expose the user directly to the source of their potential anxiety. A study was conducted to test the effectiveness of the VR game. In the study, the participants played the VR game for 10 minutes. As soon as the VR session ended, the participant was led into the actual MRI room to prepare for an MRI scan. The success/failure of the MRI scan was recorded, then compared with results from play therapy. The play therapy data was obtained from Christchurch Hospital's past patients' data.

The results suggest that VR appears to be better than play therapy. VR and play therapy have a success rate of 91.3% and 66.7% respectively. However, given the lack of time, and the sparsity of past patient data, insufficient data was available for play therapy to confirm that VR performs better than play therapy.

Despite that, VR is significantly faster in preparation compared to play therapy. In addition to its low cost and portability, it suggests that VR could be a viable clinical alternative.

Acknowledgments

First and foremost, I would like to thank my wife and parents, who supported and encouraged my decision to pursue post-graduate studies and achieve my career goals. I thank my supervisors, Niels de Ruiter and Rob Lindeman, who provided me with insights, comments, and ideas to help me complete this thesis. I also thank Peter Dooley for sponsoring and providing me the required equipment to run the study. He also provided me with suggestions and ideas to make this thesis possible. My thanks to Simon Hoermann for helping me on the statistical analysis. Last, but not least, I thank Ken Beckman for giving me the opportunity to join HIT Lab NZ as a Masters student.

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1. Introduction

Many children develop anxiety when going through a Magnetic Resonance Imaging (MRI) scan. If this leads to the patient unable to remain calm, general anaesthesia (GA) is the common response. In some cases, sedation[1] is used instead. Even though GA helps patients go through MRI scans, it has the disadvantage of increasing patients' healthcare costs and posing a potential risk to their wellbeing [1].

The goal of this thesis is to explore the potential of Virtual Reality (VR) in reducing MRI-related anxiety in children. If VR can contribute to reducing anxiety developed in children, it can make MRI scans more pleasant, and safer considering that GA is not recommended for children [1].

The work in this thesis was conducted at the HIT Lab NZ alongside the Christchurch Hospital. The project was sponsored by the Christchurch District Health Board through a professional radiographer, Peter Dooley. Peter Dooley also acts as the consulting radiographer in this thesis.

[1] Sedation induces a "lighter" sleep, where the patient can still be stimulated by touch, sound, and light. Whereas, for GA, it induces a "deeper" sleep.

1.1. The issue with MRI and anxiety in children

MRI is a popular, non-invasive technology for diagnosing a range of medical conditions such as cancer and sports injuries.

However, MRI scans may trigger anxiety, especially in children. Anxiety is the feeling of worry or a triggered response to a particular object or situation [2]. If the patient is unable to remain calm, the scan will end prematurely. Then, the scan will be rescheduled with GA. This may take up to a few weeks, due to the busy MRI schedule.

Play therapy is the current approach to reducing MRI-related anxiety. It involves a series of consultations conducted before the MRI scan. However, play therapy at Christchurch Hospital in New Zealand requires 4-17 days to prepare, and is not suitable for patients that need immediate scans.

1.2. VR as a possible solution

VR is a technology that allows the user to explore and interact in a three-dimensional computer-generated environment.

It has been around for decades, and its use extends from gaming to designing. It has also found uses in healthcare for training nurses, improving health literacy, promoting healthy behaviours, and therapy for a variety of anxieties [3, 4]. The benefits range from

improving the patients' experience to producing a viable, cheap and portable clinical treatment. This means that it could be a viable alternative to play therapy.

In this thesis, a VR game is created to act as an alternative to play therapy. The VR game design follows closely to the VR philosophy found in several studies for treating anxieties in a VR environment. A study was run to compare the effectiveness between the VR game and play therapy for reducing anxiety in children.

1.3. Structure of the Thesis

Chapter two consists of a detailed problem overview, followed by the VR design in chapter three. Chapter four presents the detailed study methodology. The results of the study are presented in chapter five, followed by chapter six, which discusses the outcomes of the study and presents future directions that may be explored.

2. Problem Overview

Chapter two formally establishes the problem and motivation for the thesis. This chapter presents how anxiety is a major issue in an MRI scan, and how play therapy is used to minimize MRI-related anxiety. Furthermore, this chapter describes how VR could be a better alternative to play therapy if VR can perform better than (or at least on par with) play therapy. Finally, this chapter presents the formal research question to be analysed in this thesis.

2.1. Anxiety in MRI and the current solution for children

Anxiety is one of the most common mental health disorders in the world [2, 5, 6]. Alfano and Beidel elaborated in their book on child anxiety disorders [5], that anxiety in children is not considered serious by mental health professionals as children will outgrow their anxiety in time.

However, this is not proven true for all cases, and if it is not treated, it can lead to more severe disorders. In other cases, such as competitive situations, anxiety can motivate the person to better tackle the problem. Therefore, anxiety can be beneficial within a certain limit, but can create unnecessary mental distress if it exceeds the threshold.

Children undergoing MRI scans may trigger anxiety responses. As discussed by Nash and Schaefer in their book on the source of anxiety responses for children [7], they described how the confined space, the loud noises, the size of the machine, and the “not

to move" instruction can be very intimidating to children. The common anxiety responses include crying, screaming, continuous shaking, and the unwillingness to get onto the MRI bed. Unfortunately, MRI-related anxiety does not provide any benefits to children and the scan.

MRI-related anxiety may disrupt imaging if the patient is unable to remain calm throughout the MRI scan. For example, in a 2010 study conducted by Chapman et al. [8], they pointed out that while having an MRI scan of the brain, MRI-related anxiety may cause neuroimaging disruptions. This is due to the increases in heart rate activity, which results in changes in regional brain activity. Furthermore, a moving child during the scan may cause motion blur artifacts, which results in an inaccurate scan.

A Christchurch Hospital's professional radiographer highlighted that scans may be prematurely terminated due to the patient being unable to stay calm. MRI scans are very costly and incomplete scans will waste valuable resources and time. Scheduling an MRI treatment requires months and many patients are on the waiting list.

GA can help if the patient or caregiver permits it. However, as stated by Viggiano et al. in a study on psychological interventions for reducing anxiety [1], they pointed out that GA may cause unwanted side effects in children such as respiratory depression and heart rhythm disruptions. In this thesis, the motivation for the work is to reduce the need for GA (or sedation).

2.1.1. Play Therapy

The current approach to reducing anxiety in children during MRI scans is play therapy. Play therapy is a treatment for reducing MRI-related anxiety in the form of play. As elaborated by Schaefer in his book on play therapy for preschool children [9], he pointed out that play interventions can involve a set of toys and games that are played by the patient and play therapist. For example, a play intervention can involve a toy schoolhouse, school bus, and miniature dolls to play the sequence of events of attending school.

In a 2016 study conducted by Bharti et al. on play therapy for children [10], the results show that, in India, there are 41% of patients that needed sedation without play therapy. However, with play therapy, there are only 20% of patients that required sedation. This shows that play therapy could be a good target to compare to VR. Plus, if VR is at least on par with play therapy, the researcher can conclude that VR is also better than no play therapy.

Different hospitals have various methods of reducing anxiety. There are even parts around the world where no means of reducing anxiety is applied.

In this thesis, the approach to play therapy at Christchurch Hospital in New Zealand was adopted as the baseline to compare to VR in reducing anxiety in children.

2.1.2. Play Therapy at Christchurch Hospital

At Christchurch Hospital in New Zealand, play therapy is a solution for children to reduce anxiety and it is not just limited to MRI-related anxiety. As stated by a Christchurch Hospital's professional play therapist, a standard play therapy program is at least two sessions, with an optional third. Each session lasts for 30 to 60 minutes, and there is a 2-7 days gap between each session, depending on the availability of the child and the parent. In summary, each play therapy can last up to 4-9 days if conducted in two sessions, and 7-17 days if conducted in three.

For the first session, the child and the parent are invited to a children's play room. This session allows the child to relax, and the play therapist to discuss the plan with the parent. The play therapist will attempt to build trust with the child through a play session. The child is introduced to the concept of MRI through images of the MRI machine, MRI bed, MRI equipment, and the radiographer. Additionally, the child will experience lying on a mock MRI bed with a headphone attached. The play therapist will mimic the loud MRI noises by thudding an object on the table, and briefly, explain how MRI works "like a big magnet." The child is also informed to remain still and watch a movie during the scan.

For the second session, the child and the parent will be brought to the MRI room. The child will be asked to count the butterfly stickers on the MRI machine and is encouraged to explore the MRI room and discuss what they feel. The child will be given the

opportunity to simulate an MRI scan to experience lying down on an actual MRI bed in the MRI tunnel. At the end of the session, the play therapist will discuss the next procedure with the child and the parent, and determine whether the child is ready for the scan. If the child is not ready, the play therapist will hold another session, if necessary.

For the third session, if it is deemed necessary by the play therapist, it may be more of the same of the first or second session.

2.2. VR in medicine

VR could be an effective therapy tool to treat anxiety disorders. In a study on VR for anxiety disorders by Rothbaum and Hodges [4], they discussed that VR could treat anxieties and psychological disorders by exposing the user directly to the source of their anxiety within the VR environment. In addition, Rothbaum and Hodges also pointed out that in a VR treatment, the therapist sees what the patient sees, which enables for real-time physiological monitoring. It allows the ease of determining the exact time, location, situation, and object that triggered the anxiety responses.

Furthermore, the treatment can be conducted anywhere, such as the therapist's office or the patient's home.

VR is cost-effective and time efficient. It allows for customizable environments, repeatability, and immediate termination if the procedure does not go as intended. For example, in the case of a patient who has a flight landing anxiety, VR enables the therapist

to set up the environment quickly rather than having to go on an actual flight where the patient needs to go through the whole flight procedure (check-in, departure, and landing) [2, 11, 12].

In a 2008 study on VR exposure for anxiety disorders conducted by Powers and Emmelkamp [11], they described that using VR to reduce anxiety increases the likelihood of patients willing to be treated as it is an indirect approach to tackling anxiety. In particular, Powers and Emmelkamp pointed out that it can be challenging for most patients to minimize anxiety by going to a specific location to exercise in real phobic situations. They feel that their anxiety increases the longer they are exposed. Hence, VR is preferable by patients as they feel that it is not as realistic to real world situations.

Still, studies have shown that patients have no problem triggering anxiety within a VR environment [2, 11]. Patients who are immersed in the VR environment naturally shape their own experiences [12]. For example, in a book on VR therapy for anxiety disorders by Wiederhold et al. [2], they mentioned that a patient might say that he "smells jet fuel," in a VR environment even when there was no such smell present. Another patient imagined that the flight attendant asked her "what would you like for dinner, chicken or beef?" in the VR environment as the flight attendant walked by. To summarize, experience obtained in VR for minimizing anxiety does transfer to real-world applications.

Despite the advantages of using VR, it has some drawbacks. For VR to be useful for a patient, the patient needs to be able to be quickly immersed in the VR environment, not prone to cyber sickness, and not on a medical drug that could affect the process.

VR is a promising technology that could offer a potential clinical alternative to play therapy. Therefore, in this thesis, the primary focus is to explore the application of VR in reducing anxiety in children.

2.3. Purpose of study and research question

In the previous sections, the issue of anxiety for children undergoing MRI scans was discussed. The current solution is either GA (or sedation) or play therapy. As GA poses a risk to the patient, it is not recommended. Play therapy has been proven to be effective, yet it takes a long time to complete.

Furthermore, VR has shown to be an effective therapy tool in treating anxiety in related fields. Therefore, in this thesis, the aim is to investigate the effectiveness of VR for pre-treatment of MRI. This study will focus on children aged 4-6 because this is the age range where anxiety responses are seen the most. The research question is formally defined as follows:

How does VR compare to traditional play therapy in reducing anxiety in children around MRI procedures?

Since VR has proven to help reduce anxiety responses, the researcher predicts that VR could reduce the need for GA as effective as play therapy. If the outcomes are as expected, and since VR takes less time than play therapy, VR could be a superior solution to play therapy.

3. VR Game

Chapter three presents the ideas and decisions behind creating the VR game design. In particular, the design, interaction and gameplay of the VR game are discussed.

3.1. VR game design

The VR game was developed for the HTC Vive and programmed in Unreal Engine 4. The intention is that the VR game is played moments before the MRI scan takes place. This is similar to how play therapy's final session leads to the MRI scan. The end-goal is to produce a VR game that reduces MRI-related anxiety in children.

To achieve this goal, first, the researcher decided that the VR design philosophy should be based on the design of other VR studies [2, 4, 11, 12, 13]. According to those studies, the idea behind the VR design is to expose the user directly to the source of anxiety within the VR environment. Therefore, the VR game aims to mimic the representation of the actual MRI room.

Second, the researcher thinks that by including interactions that could be performed both in the VR game and in real world increases the effectiveness of the VR game. This is because it gives the user a sense of familiarity and comfort when seeing the actual MRI room.

Finally, the researcher made the VR game to match aspects of play therapy to establish a common ground between VR and play therapy.

3.1.1. Representation of the VR game

Figure 1: Comparison between the MRI room in the VR (left) and the actual MRI room (right).

As shown in Figure 1, the VR game mimics the actual MRI room at Christchurch Hospital to help the user get accustomed to the real environment. The virtual MRI room contains a single MRI scanner along with cubes, spheres, drawers, butterflies, and the MRI operating room.

While the VR game has most of the content mimicking the actual MRI room, it is not perfectly accurate. The VR game does not contain plastic chairs unlike the actual MRI room. However, such items were background props with no utility for the MRI scan, or the play therapy process. Hence, their omission is not expected to affect the study.

Furthermore, the butterflies in the VR are animated and flying around the room, instead of just stickers on the MRI machine in the actual MRI room. In this case, the aim is to encourage the user to walk and explore within the VR game.

In a 2013 study on how the level of realism influences anxiety conducted by Kwon et al. [14], they pointed out that having a high level of realism in the VR is ideal, but it is not required to elicit anxiety. Hence, emphasizing on the level of realism of the VR concerning textures, shape, lighting, colour and the size would be ideal, but not essential. Thus, the researcher did not emphasize the degree of realism to focus more on the content, interaction, and gameplay.

For the 3D models in the VR game, the HIT Lab NZ bought the 3D MRI model from Siemens. The 3D radiographer and 3D clock were obtained from Blend Swap and made by Ragstorich and Stalk respectively [15]. The 3D furniture, 3D door, and 3D electronics were obtained from Arbitrary Studio [16]. The remaining 3D models were obtained from Marketplace examples and produced from basic 3D models in Unreal Engine 4.

In the VR game, the drawers have coloured and labelled cartridges stored in them (as shown in Figure 2). These cartridges can be inserted into the cartridge slot to trigger MRI sounds (refer to section 3.1.2 for more details). The purpose of having cartridges stored in the drawers, and the cartridge slot close to it, are to promote multiple interactions (opening/closing drawers, picking up and inserting cartridges). The cartridge slot has an

instructional image to provide a hint to the user as to where the cartridge should be inserted.

The cubes and spheres (as shown in Figure 3) in the VR mimic the MRI foam positioners[2], which are stored on the shelves of the actual MRI room. The actual MRI foam positioners are coloured in grey. However, in the VR, the cubes and spheres are varied in colour to make them more attractive to the target user.

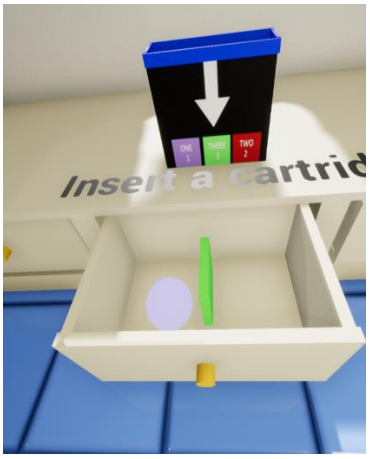

Figure 2: The drawers in the VR. A cartridge is stored in every drawer.

[2] MRI foam positioners are used to align patients on the scanner bed to provide more comfort during the scan.

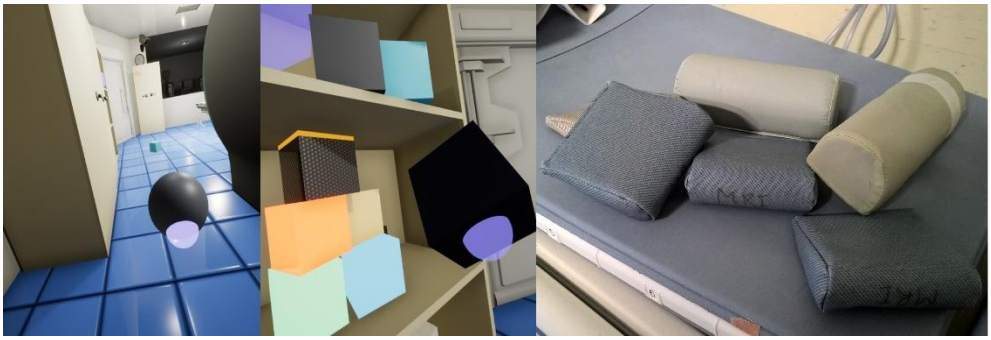

Figure 3: Comparison between the sphere (left) and cubes (middle) in the VR and the actual MRI foam positioners (right).

The actual room decorations such as window curtains and butterflies are also present in the VR, as shown in Figure 7 and Figure 1 respectively. The purpose of butterflies is to make the child count the butterflies in the VR game. Having the butterflies flying around the room encourages the user to explore to search and count them. This interaction could be replicated in the actual MRI room by having more butterfly stickers within the room, instead of just stickers on the MRI machine.

The researcher created the VR game to match a few aspects of play therapy. Play therapy is conducted prior to the MRI scan. Hence, the VR game mimics it by having the user play the VR game before the MRI scan. Furthermore, the VR game mimics play therapy's second session by having the user count the butterflies in the VR game.

3.1.2. Interaction of the VR game

In the VR game, a few interactions can be performed. The cubes, spheres, and cartridges are each dynamic objects that the user can pick up, throw, and roll. The user is required to move the controller, which is viewed as a purple sphere in the VR game, onto the dynamic objects to perform an interaction. Figure 3 illustrates this process. The motion required to perform these tasks mimics the actual motion required in the real world.

Figure 4: Picking up an object. Press the trigger at the back of the controller (marked in red circle).

Picking up an object (as shown in Figure 4) requires the user to hold a trigger at the back of the controller to mimic the grabbing motion. Releasing the trigger while picking up an object will release the object in the VR game. To throw an object (as shown in Figure 5), the user is required to make a throwing motion and release the trigger in the middle

of the motion. To roll an object (as shown in Figure 6) the user is required to pick up a rollable object, like a sphere, and roll it on the floor while releasing the trigger.

The purpose of having throwable objects in the VR game is to enable the user to throw objects into the MRI scanner. This game of throwing objects can be replicated in the actual MRI room by using the MRI foam positioners to encourage a sense of dominance over a big and intimidating machine.

Figure 5: The throwing motion. The motion is indicated from left to right (sequence 1, 2, 3). The controllers (above) show when to press the trigger, and when not to.

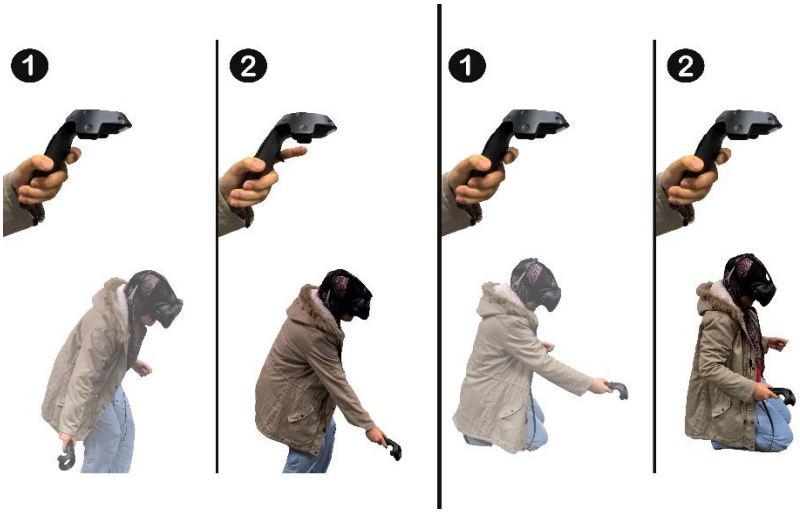

Figure 6: The rolling motion (left) and opening a drawer (right). The motion is indicated from left to right (sequence 1, 2). The controllers (above) show when to press the trigger, and when not to.

Additionally, the user will be able to open and close drawers (as shown in Figure 6) by holding the same trigger on the controller.

To access the cartridges, the drawers must first be opened. They can then be picked up and inserted into the cartridge slot. Figure 7 illustrates this process. There are three drawers with a cartridge stored in them. The purpose of storing cartridges in drawers is to promote interaction. Inserting a cartridge to the cartridge slot (as shown in Figure 7) will trigger an MRI sound. Different coloured and labelled cartridges will trigger different MRI sounds. Since there are three cartridges, there are three sounds that can be played. These MRI sounds are to get the user accustomed to the actual MRI sounds, as they can be very intimidating. Furthermore, there is a default MRI sound, in addition to

the three cartridge sounds, that is continuously played in the VR game to mimic the actual MRI room. The default MRI sound is paused if there is a cartridge inserted, to allow another sound to be played by the cartridge. The default MRI sound is resumed when the user pulls out the cartridge from the cartridge slot.

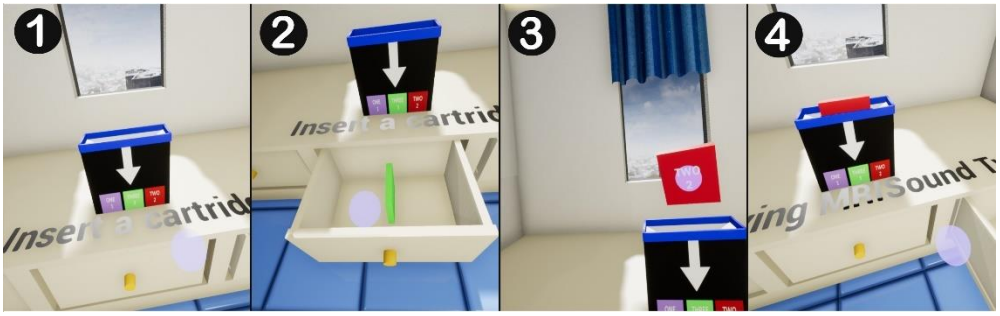

Figure 7: Playing a cartridge. The sequence is indicated from left to right (1, 2, 3, 4).

The user can walk in the VR game by walking within the VR area in the real world. The VR area is an area in the real world where the user must always remain, to interact and move, in the VR game. The placement of the sensors determines the VR area. For the study, the VR area was set to 4.5 meters × 4.5 meters. If the VR area is bigger than that, it may cause tracking issues. However, the VR area is too small for the virtual MRI room. To overcome this problem, the user can teleport to any location within the VR game. The teleport feature is to ensure that the user can explore the VR game with minimal walking in the VR area. Pressing on the trackpad of the controller (as shown in Figure 8) will activate this feature.

Figure 8: Pressing on the trackpad to perform the teleport feature (left). The teleport position will be marked in the VR while pressing the trackpad (right)

The VR allows the person in-charge (e.g., therapist, doctor, radiographer) to see what the user sees through a computer monitor. In the case of intense anxiety responses occurring during the VR game, the VR game can be quickly terminated by pressing the "ESC" key on the computer keyboard.

For preparing the VR game for the next user, the "Enter" key can be pressed on the keyboard to reset the VR game to its initial state quickly.

3.1.3. Gameplay of the VR game

The VR game is essentially a sand box where the user is free to explore and discover the interactions on their own. However, in expected use case, the therapist plays an important

role to choose which interactions, and in what order, the user should perform. The choice of interactions can be made based on the time available and their observations of the user. The therapist instructs the user by communicating verbally to complete various interactions. The interactions that can be completed are as follows:

- Playing MRI sounds with the cartridges.
- Throwing cubes into the MRI scanner.
- Looking behind the MRI scanner to see the MRI tunnel.
- Rolling spheres.
- Counting butterflies.

For the study, a Christchurch Hospital's professional radiographer decided the order of events for the participants.

3.1.4. Preliminary testing

A preliminary test was performed to look for potential issues and risks of the VR game. The researcher found out that the drawers in the VR game were too high for the average child, the controllers were too big for their hands, and that the VR headset is rather heavy for children (unsuitable for extended use).

The original goal was to use two controllers because that is the standard setup for the HTC Vive. Also, the target user was initially expected to play the VR for at least 15 minutes. The reason behind the initial goal of 15 minutes is to make sure the user fully explores the virtual MRI environment.

The problem with two controllers is that children were unable to grip both controllers comfortably, due to their hands being too small. By using only one controller, the user will be able to use two hands to have a better grip.

Since the VR headset is heavy, wearing it for an extended period can be tiring. Hence, the researcher decided to reduce the expected time from 15 minutes to 10 minutes to lessen the burden. Other than that, the headset fits nicely to the user without any additional padding.

As for the height of the drawers, they were resized to fit the average child better.

3.2. Summary of Chapter 3

The VR game design follows closely to the VR design philosophy in numerous studies [2, 4, 11, 12, 13]. The VR game mimics the actual MRI room to expose the user directly to the virtual MRI environment. To enhance the experience further, the researcher included four common MRI sounds in the VR game to expose the user to one of the main factors that trigger anxiety responses, the loud MRI sounds. The VR game allows the person in-charge to see what the patient sees to enable real-time monitoring. It allows

the user to perform simple and fun interactions to encourage the user to play the VR game, and a few of them can be replicated in the real world. Also, some aspects of play therapy are integrated in the VR game to establish a common ground between VR and play therapy. Lastly, if the VR game does not go as intended, it can be quickly terminated by the person in-charge.

4. Method

Chapter four details the plans for the study to evaluate the VR game against play therapy. First, the goals will be established, followed by a description of what measurements are required to meet the study goals. Second, this chapter presents the target participants for the study, followed by the detailed procedure and the required resources for the study. Finally, this chapter discusses the risks, mitigation, and ethics to conclude the chapter.

4.1. Study goals

The goal of the study is to measure the effectiveness of the VR game for reducing anxiety in children. To evaluate that, the effectiveness will be compared between the VR game and play therapy for reducing anxiety in children during MRI scans. The research question is reprinted here for convenience:

How does VR compare to traditional play therapy in reducing anxiety in children around MRI procedures?

4.2. Measurements

The initial plan was to use a self-report measure such as a questionnaire that suits children aged 4-6. The researcher found "State-Trait Anxiety Inventory for Children" questionnaire, developed by Charles D. Spielberger, to use for the study [17]. However, the questionnaire requires a suitable literacy level. This means that it is not recommended for children aged 4-6. Therefore, no questionnaire is used in this study.

Focusing on the most important aspect of the study goal, a straightforward and objective qualitative measurement is used to investigate the research question. The analysis is based on the primary goal of the study: observe and record the outcome of the MRI scan. This means that the primary measure records either a success, or a failure.

The criteria for the success of the MRI scan is decided upon by the Christchurch Hospital's professional radiographer in charge of the procedure. The MRI scan is considered a success if following criteria are met:

- The participant can remain still for 30 seconds during the scan. According to the professional radiographer, most anxiety responses occur during this period.

- No continuous movement for longer than 3 seconds (e.g., shaking continuously for 4 seconds or longer). According to the professional radiographer, the constant movement may cause excessive image blurring.

- No actions indicating intense fear (e.g., screaming, crying, etc.)

At the end of each scan, the professional radiographer decides whether the MRI scan is a success or a fail.

Additionally, a video is recorded during the VR sessions to act as supplementary data. This data may be used retrospectively to determine the probable causes for results obtained, if necessary. The video was recorded while the headset was on, and no

identifying information was collected. However, the researcher was unable to record videos during the MRI session, due to the strict "no metal" rule in the MRI room. Instead, the researcher made personal notes during the MRI session to also act as supplementary data.

4.3. Participants

Patients from Christchurch Hospital and healthy children from the general public are the primary and secondary target participants respectively. The researcher allowed healthy patients because Pinquart and Shen [6] stated in a 2011 study that the differences in anxiety levels between a healthy child and a child with a chronic physical illness are "very small to small." Furthermore, it is expected that play therapy patients only have mild symptoms. The patients with serious symptoms cannot wait for play therapy to be completed.

Age (4-6) is the only factor in selecting participants. The participants were chosen based on a first in, first served basis, regardless of whether the target participant is from the primary or secondary source.

The original goal was to perform play therapy tests, in addition to VR. However, play therapy data has already been collected over the past years as part of the play therapy service provided by the Christchurch Hospital. Given years of data, it was expected that there would be more than sufficient data to compare to the VR game. Furthermore, if the

researcher were to conduct 20 play therapy tests, it would require at least 40 hours in the span of 80 days. Plus, it also requires the services of a professional therapist. Unfortunately, due to the time constraints, conducting play therapy tests was impractical. Therefore, it was decided that past patient data will be used for the study.

4.4. Procedure

Before the study, parents of the participants were contacted through email to organize a meeting at Christchurch Hospital's Radiology Department, where the study is conducted. The participants and the parents were briefed about the study by the researcher. The parents and children were given a demographic questionnaire, a participant information sheet, a child assent form, and a parent consent form. The consent was obtained by the researcher when the parent had signed the consent form and the child had given an indication of consent.

The study was conducted in two sessions and lasted for 20-30 minutes per participant. For both sessions, the researcher acted as an observer, and a Christchurch Hospital's professional radiographer guided the participants and the parents.

In the first session, the parent was asked to play the VR game for 3-5 minutes to act as a role model for their child. While the parent was playing the VR game, the participant can see what their parent sees in the VR game on a monitor. The parent performed two tasks in the VR game: playing sounds with the cartridges and throwing cubes into the

MRI scanner. Soon after that, the VR game was reset to allow the participant to play the VR game for 5-10 minutes. The participant performed four tasks: playing sounds using the cartridges, throwing cubes into the MRI scanner, rolling spheres on the ground, and looking behind the MRI scanner to see the MRI tunnel.

Immediately after the first session, the second session started by bringing the participant and the parent to the actual MRI room. The participant and the parent were given MRI foam positioners to act as the 'real' cube to throw into the MRI scanner. The participant and the parent were brought to the back of the MRI scanner to see the MRI tunnel. Then, the participant was asked to get into the MRI bed to prepare for the scan. During the scan, standard protocols were followed for the Christchurch Hospital. The participant watched a movie[3] with a headphone attached. The parent rested their palm on the participant's leg to make the participant feel the presence of their parent. The researcher and the parent were given earmuffs to protect their ears from the MRI sounds. As soon as the scan ended, it indicated the end of the study.

4.5. Apparatus

The VR environment was presented by HTC Vive and a custom-built computer. It is comprised of a VR headset, a controller, and two base stations. The computer provides the required hardware and processing power to run HTC Vive. The VR headset and the

[3] Participant watched a movie through a reflective mirror. The reflective mirror is attached to the head cage. The movie was projected to a whiteboard and placed at the end of MRI bed (at participant's feet).

controller allow the user to navigate and interact in the VR environment respectively. The two base stations are the sensors and they act as a tracking system to make navigating and interacting possible in the VR environment. Refer to Chapter three for more details on the VR game design.

The MRI machine used for the study to perform the MRI scans, is the GE 1.5 Signa. The MRI scan lasted for 30 seconds for each participant, and no images were taken.

4.6. Risk and mitigation

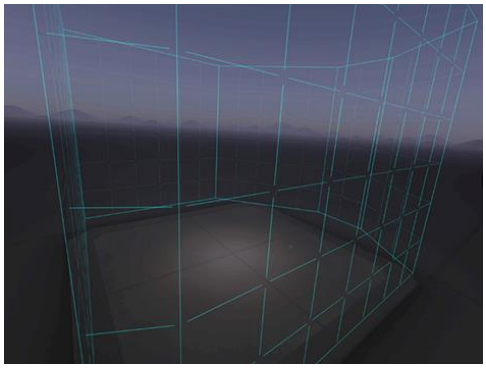

Figure 9: The "Chaperone" system by HTC Vive.

While designing the study, a few risks were identified and mitigated. There is a high chance that the target user will collide with walls in the real world while playing the VR game. HTC Vive has its safety feature built in in the VR, the "Chaperone" system. When a user is nearing a wall, a blue grid will appear (as shown in Figure 9) indicating a

wall nearby. However, for children aged 4-6, it is highly likely that the "Chaperone" system is not intuitive to them.

Plus, children tend to be highly immersed in the VR. Therefore, there is also a possibility that children have a tendency to do actions that may result in accidents, such as climbing on the virtual objects in the VR game.

Furthermore, the VR headset is connected by long wires to the computer. While the user is unaware of the real-world surroundings when playing the VR, the wires may get tangled around the user as the user moves around, and this may cause unwanted accidents.

To minimize these problems, throughout the VR session, the professional radiographer accompanied the user and made sure that the user was safe at all times.

4.7. Ethics approval

The study was approved by University of Canterbury Human Ethics Committee (UC HEC), Christchurch Health District Board Research Office (CDHB RO) and Christchurch Health District Board Maori Support (Te Komiti Whakarite).

The corresponding references for the approval are Ref 2016/125 for UC HEC, and RO 17011 for CHDB RO and Te Komiti Whakarite.

5. Results

In evaluating the research question, the data are drawn from two sources: the MRI scan outcome from the VR tests and the MRI scan outcome from Christchurch Hospital's play therapy past patient data.

The results are presented by using IBM SPSS Statistics.

5.1. Sample demographics

There were 23 participants, and all of them were healthy individuals from the general public. There were nine males and 14 females, aged 4-6. Participants consisted of wide range of ethnicities, including New Zealander, Cambodian, Chinese, Malay and Singaporean.

For play therapy, there were six former patients from Christchurch Hospital from the years of 2014-2016. There were two males and four females, aged 4-6.

5.2. Virtual Reality VS Play Therapy

The success rate and the chi-square tests for VR and play therapy are shown in Table 1.1 and Table 1.2 respectively.

Table 1: The success rate of VR and Play Therapy

Priming Technique * MRI Outcome Crosstabulation

			MRI Outcome		
			Failure	Success	Total
Priming Technique	VR	Count	2	21	23
		% within Priming Technique	8.7%	91.3%	100.0%
	PT	Count	2	4	6
		% within Priming Technique	33.3%	66.7%	100.0%
Total		Count	4	25	29
		% within Priming Technique	13.8%	86.2%	100.0%

Table 2: The Chi-Square Tests for VR and Play Therapy.

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	2.429[a]	1	.119	.180	.180	
Continuity Correction[b]	.799	1	.371			
Likelihood Ratio	2.041	1	.153	.180	.180	
Fisher's Exact Test				.180	.180	
Linear-by-Linear Association	2.346[c]	1	.126	.180	.180	.160
N of Valid Cases	29					

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .83.

b. Computed only for a 2x2 table

c. The standardized statistic is -1.532.

Table 1 shows that VR and play therapy have a success rate of 91.3% and 66.7% respectively. The results indicate that VR has a 24.6% higher success rate than play therapy. However, play therapy has a small sample size.

In Table 2, the chi-square tests were run to assess the dependency of the anxiety treatments (VR and play therapy) and the MRI outcome. The p-value is denoted by "Asymptotic Significance (2-sided)," which is 0.119. This value means that there is an 11.9% chance to find the observed relationship if the anxiety treatments and the MRI outcome were perfectly independent of the population.

Since the p-value is much bigger than the accepted value of 0.05 (p-value >> 0.05), there is not enough evidence available to show that there is an association between the anxiety treatments and the MRI outcome ($X^2(1) > = 2.429$, $p = 0.119$). The high p-value is due to the low number of samples for play therapy.

5.2.1 Additional comments

For the VR game case, there is one failed participant who could have experienced a bias during the experiment. The researcher observed that this participant heard the MRI sounds from the outside of the MRI room before this participant had an MRI scan. This participant appeared to be frightened by the MRI sounds. Hence, this participant already showed anxiety responses before the participant entered the MRI room. Regardless, this participant was considered a fail for this study.

For the play therapy case, there is one patient who the researcher considered to be a fail for this study, instead of a success. During the MRI scan, this patient experienced an elevated anxiety level that made the scan unable to proceed. Hence, the scan had to stop and was considered a fail. However, this participant was calmed down and underwent a second scan. The second scan was a success. However, during the VR game study, the researcher did not perform or attempted a second scan when a participant failed. Therefore, to ensure fairness, this patient was considered a fail in this study.

5.2.2 Additional data

Table 3: Total number of MRI patients that received GA from 2014-2016.

	Year 2014/2015		2014/2015 Total	Year 2015/2016		2015/2016 Total	Grand Total
Age	Patients received GA?			Patients received GA?			
	No	Yes		No	Yes		
4	3	32	35	3	23	26	61
5	3	12	15	8	28	36	51
6	9	12	21	12	9	21	42
Grand Total	15	56	71	23	60	83	154

Table 3 is a subset of the records of all MRI patients at Christchurch Hospital for the years 2014-2016 for the ages 4-6. The records show whether the patient goes through the MRI scan with or without GA. As a record of all patients, it consists of MRI patients that had MRI scans with play therapy and without play therapy. A total of 154 patients, aged 4-6 went through MRI, and only six of them had their MRI scans through play

therapy. Therefore, a total of 148 (96.1%) patients went through MRI without play therapy.

However, there is no clear indication whether the patients that did not go through play therapy opted for GA from the very start or needed urgent MRI scans.

6. Discussion

As can be seen with the results, the study can conclude that VR appears to have a potential for reducing MRI-related anxiety in children. With 91.3% success rate, compared to 66.7% for play therapy, it appears that VR is better than play therapy. However, due to the small sample size of play therapy, the researcher is unable to validate this claim.

As shown in Table 3, play therapy is not as common as the researcher originally thought. Regrettably, Table 3 does not have a clear indication of the patients' groups. If the data in Table 3 could be analysed, this would lead to a reliable comparison between VR and no play therapy. Additionally, if more play therapy data is recorded in the future, the VR data could be re-evaluated to provide a better comparison. Given the lack of time, this thesis is unable to complete this goal.

According to the professional radiographer, "most MRI patients aged 4-6 require immediate scans," and play therapy needs at least 4-9 days to prepare. Therefore, this indicates that most patients could not go through play therapy. This explains why the sample size was surprisingly small. On the other hand, this means that VR could be a viable option to treat patients that needed urgent MRI scans, due to the short amount of time needed to prepare. Unfortunately, as access to this information was restricted until ethics approval was achieved, these details could not be identified on time.

Given that 96.1% of patients over 2014-2016 in Table 3 could not go through play therapy, this advantage cannot be overlooked. While patients that immediately opt for GA may not opt for VR instead, a sizeable number of the non-play therapy patients could go through VR. This means that an important study in the future would be to quantify how VR performs against non-play therapy patients.

Table 4 shows a simple comparison of costs between play therapy and VR. In this table, it is assumed that the hourly working rate for play therapy and VR are the same ($55 per hour). The hourly working rate is based on the Kia Ora Hauora website [18] for play therapists that work in private practice in New Zealand.

Table 4: Play therapy cost VS VR cost. All costs are in New Zealand Dollars.

	Play Therapy	**VR**
Working pay per patient	$110-$165 *(2-3 hours)*	$9.20 *(10 minutes)*
Additional costs		VR - $1,500 [19] Computer - $3,100 [20]
For 10 patients	$1,100-$1,650	$4,692 *($92 for working pay and $4,600 for full VR setup)*
For 50 patients	$5,500-$8,250	$5,060 *($460 for working pay and $4,600 for full VR setup)*
For 100 patients	$11,000-$16,500	$5,520 *($920 for working pay and $4,600 for full VR setup)*

If VR is at least as effective as play therapy, it reduces play therapists' time to treat patients. As can be seen in Table 4, significantly more resources are spent on play therapy after 100 patients. Hence, more valuable resources could be saved in the long term that could be used for other medical needs.

One drawback of the VR game is that the educational aspects of play therapy is superior to VR. Play therapy teaches the patients how the MRI works, in addition, to reducing MRI-related anxiety in children. However, VR only exposes the user directly to the potential source of anxiety. Considering that VR needs only 10 minutes to prepare, as compared with at least 4-9 days for play therapy, it is justifiable why VR lacks in the educational aspect.

According to the professional radiographer, the first 30 seconds of the scan is when most anxiety responses occur. However, further verification is needed to justify the 30 seconds of MRI scan for the study although the professional radiographer recommended it. This is because most MRI scans take 5-45 minutes.

In this study, all participants were healthy, and since most MRI patients in the data had a physical illness, this could pose a potential bias. However, it was mentioned in a study that the differences in anxiety levels between a healthy child and a child with a chronic physical illness are "very small to small" [6].

6.1. Future research

Several items of future research are suggested by the results and the discussion. First, VR appears to be better than play therapy. However, the study suffered from the lack of play therapy data available to prove that statement. Hence, more play therapy data is needed to fully complete the goal of the study. Second, the VR data could be re-evaluated to compare with other patient groups, such as, patients that do not go through play therapy. Third, further verification is needed to justify the 30 seconds of the MRI scan. Although it was recommended by the professional radiographer, most MRI scans take 5-45 minutes. Fourth, further verification is needed to find the most effective length of time for the VR game. The 10 minutes used is an arbitrary choice that may be optimised. Finally, integrating the education aspects of MRI into the VR game could be a valuable research in the future.

6.2. Conclusion

In conclusion, VR appears to show potential in reducing MRI-related anxiety. However, due to the lack of play therapy data, the researcher is unable to validate this observation. Although VR lacks in the educational aspect, it offers numerous advantages over play therapy, such as low cost, portability, and quick preparation. Therefore, the researcher believes that VR will be a viable clinical solution in the near future.

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