Navigating the Pixelated Waters of Voxel Bay: Designing a Virtual Reality Game for the
Pediatric Patient-Player Experience

Thesis

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Abstract

Voxel Bay is a virtual reality game created in collaboration with Nationwide Children’s Hospital to distract pediatric hemophilia patients from the anxiety related to the prophylaxis infusion procedure they must undergo regularly. This paper documents answers to the question when designing a game to serve as a pain management distraction technique for pediatric patients, what factors should be considered for the overall experience of the patient-player, clinicians and caregivers, and what may be unique or different from conventional approaches to game development? The answers to the research question are presented in context to the development of Voxel Bay. They are a list of factors to be considered and a documentation of my contribution to the project. The game design concepts discussed include spatial level design for virtual reality and ways to world build without cut scenes. This paper also mentions the hardware configuration used to create an entertaining hands-free system without sacrificing the integrity of the player’s medical experience. After an exploration of these concepts, the paper describes the novel processes used to realize them. The design choices and process documentation are supported by a review of research precedents regarding virtual reality as a distraction tool for medical settings as well as games designed to be used with breathing peripherals, games that use a networked system with different user roles and games that directly inspired the design of Voxel Bay. The document closes with some observations about the clinical trial data for this project and some reflection on its further development.
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Chapter 1: INTRODUCTION

The field of game design is an important part of the evolution of current systems and technologies that can be split into many shifting paradigms. Right now, game design emerges as a field of study with applications outside of the entertainment industry. People are using game design in combination with studies of player psychology for purposes of motivation, simulation, training, and distraction. Examples of this can be seen in learning and life management, in the world of insurance, banking and, as exemplified in this thesis, in applications designed for patients at a hospital. The possibilities of creating games that have non-entertainment applications are growing with the development of modern technologies that make them more accessible and more robust. One such developing field of study is immersive virtual reality games. This thesis documents my work at Nationwide Children’s Hospital (NCH). At NCH, I have worked on a wide variety of applications and games for different patient groups, including mobile games, virtual and alternate reality games and others which use proprietary hardware. The first and most developed project of this group is a game called Voxel Bay. Voxel Bay is used as a distraction technique, targeting hemophilia patients receiving intravenous infusions.

The question guiding the development of Voxel Bay and the surrounding research is when designing a game to serve as a pain management distraction technique for pediatric patients, what factors should be considered for the overall experience of the patient-player, clinicians and caregivers, and what may be unique or different from conventional approaches to game development? The roles of the patient-player, caregiver and clinician are all inseparably linked and influence one another’s experience, efficiency and the outcome of the overall procedure from each perspective. Designing around the patient-player is a creative problem solving challenge because the fully engaged player’s role is a physically active state of being, while the role of the patient is instead passive and the contradiction can be a confusing parameter to design for. Our design team had to encourage nervous children undergoing a painful medical procedure to hold still and cooperate with clinicians by fully capturing their attention with a game. We also considered the nervous onlooking caregivers and clinicians who need to customize each procedure to the patient, but still efficiently repeat it.
The environment and gameplay of our game needed to have a set of specially designed features that would together outweigh the medical procedure's magnitude of intimidation for patient-player and caregiver. These objectives require the careful redirection of attention, or distraction. Virtual Reality (VR), a medium known to immerse players into the game environment, fills the entire range of vision and reduces peripheral visual distraction. The medium of virtual reality is an established technology that is undergoing development alongside other technologies such as mobile devices. Through the course of my work on this project, I have observed some techniques for directing player attention in virtual reality environments. Voxel Bay was developed to distract pediatric patients from the pain and cope with anxiety. My personal investment in this project and research problem has grown with the project since I started working on it in June of 2015. For me, the project was an opportunity to create characters, environments and means of interaction that feel natural and hold player attention, all in a virtual reality context. One of my goals as a graduate student learning about interactive media is to understand some of the many strategies designers use to facilitate effective and novel interaction to help identify which are best for my own creative process.

I began to approach these goals by rooting my understanding of fundamental concepts inherent in game design and virtual reality development. One such fundamental is interaction. A good starting place to understand interaction is Katie Salen and Eric Zimmerman's definition found in Rules of Play: Fundamental of Game Design. Salen and Zimmerman describe explicit Interaction as, “Overt participation” or interaction with designed choices and procedures (Salen, 2004, p. 72). Designing not to disrupt leads the game designer to walk on a fine line between overt participation in a virtual reality game and overt observation of a virtual reality media experience. Directing players to participate in virtual reality games can amount just to knowing how to ask the player to, “Look at that!”.

1.1 Methodology
The research investigates techniques which designers can use to create novel interactions for patient-player use cases. The methodology used in the project was a two-pronged approach of making a concerted effort to anticipate the needs of those interacting with the clinical system and then to apply several different strategies to meet those needs even when they appear to conflict. Creating mini-games specifically was one of the strategies used to compartmentalize
these approaches inside of one media experience. We started to anticipate the needs of the patient-player population by forming an impression based on introductory conversations with Dr. Dunn and clinicians that oversee the procedure regularly such as Karen Hughes McFornadel of NCH’s Patient Life Services. Professionals like McFornadel assist with many different types of procedures, in addition to the hemophilia patients that Dr. Dunn’s team work with. In these meetings, our team learned about the positions clinicians are expected to keep their patients in and techniques used to reduce their anxiety, such as waving keys or glitter wands, singing or making faces. These types of distraction techniques quickly lose their initial impact and require the clinicians to multi-task or involve parents who are not trained to help with medical procedures. We continued to develop an understanding of patient needs throughout the development process by observing patient playtests, and meeting as a group with clinicians to evaluate them. As the game developed into a deployable application, we also reviewed surveys answered by patients’ parents and doctors from other departments in Nationwide Children’s Hospital about their interest in a better distraction technique for their children. By taking in information from people involved in all parts of the medical procedure at different times in the process we maintained a comprehensive sense of the patient-players’ needs.

After taking measures to understand the design problem solving our team would need to face, we further developed our preliminary strategies to address user anxiety and comfort during the procedure. During development, I would build on my ideas as well as those contributed by others. The strategies we spend a significant amount of time investigating were reinforcing physical sensation with in-game visuals, implying narrative and complexity with game elements, appealing to the players’ perceptions of themselves and creating replayable levels that load a different configuration for each play session.

Our team took an interdisciplinary collaborative approach to make this system best meet the needs of the patient-player. We came from different backgrounds, with expertise in art, design, movement, technology applications, technology implementation and game development to consider the project from all critical facets. We consulted with outside help as needed. My contribution to the team and the process is supported by my experiences as a design graduate student and the practice-based research methodology used in my studies. I designed the visual aesthetic of the game by sketching environments and characters that we would then convert to
three-dimensional (3D) assets to add into the game. I also worked to make the assets after we agreed as a team which ones we would be using for each area, as well as taking some decisions about the smaller details into my own hands. Working with another graduate student studying game design, John Luna, MFA Dance, we created the first three game levels, also referred to in this paper as “mini-games”, and the main game navigation area from scratch. We wrote scripts together, alternating work on each area. I went on to make five more game levels on my own over a four-month period and revisited each of them a few months after that. Throughout, we have followed a system of starting with sketches and paper notes, moving to prototypes, and then combining revised prototypes with finished assets. All the games and environments we have created have also employed an iterative approach to design and development by revisiting and editing at minimum two times after feedback from others and our own observations showed us where we could improve. I first encountered the term “practice-based research” when reading Linda Candy’s article, “differences between practice-based and practice-led research”. Candy defines practice-based research as production oriented creative research, as opposed to process-oriented or practice-led research (Candy).

![Figure 1 Brody and mom playtesting Voxel Bay in clinic](image)
We added many new features to the game in response to the outcomes of in-clinic testing, implemented these iteratively, testing in between updates and revising new content alongside old. During development of the game we also playtested the game with several different groups of people with various degrees of removal from the development process, and responded to the feedback from those playtests before making the version of the game that would be tested in clinic. Prior to testing, we informed ourselves about people's attitudes to the project. There was a survey conducted before the in-clinic testing, asking patients' families about their interest in a distraction game as well as a survey internal to NCH asking doctors about their interest in a distraction game and their familiarity with virtual reality. In our development process a hands-free VR head-mounted display took the form of an Oculus Rift head-mounted display, while in our final iteration of the project we used an iPod Touch with Google Cardboard controlled stereoscopic view. The iPod Touch is also head-mounted, using a cardboard headset designed by Robert Strouse, a User Experience Specialist at NCH. Head-mounted virtual reality devices track the rotation of the user's head using a gyroscope, and in doing so track the user's range of vision if not the exact direction of their gaze. For our purposes, the head-mounting of the device offers the additional benefit of blocking the player's view of the room and covering their face from a parent's anxious eye, possibly diffusing anxiety on the side of the parent.
Chapter 2: SYNOPSIS

Patients enter the clinic by way of an elevator that takes them up to the eleventh floor of tower A in the children’s hospital. They meet with a clinician in a small room before the procedure to check in and wait for their turn. Here, patients using virtual reality for pain distraction are given a paper packet to look through, showing the areas to explore and mini-games to play. They look through with their parents and pick a favorite. The patient also receives the cardboard headset they will wear while playing the game. It is an interesting prop that the patient becomes familiar with before playing, so that the procedure does not involve wearing an unfamiliar and potentially frightening piece of equipment on their face. After a small wait, they go down the hall and sit in a room with small alcoves in each wall. The patients sit in an alcove and prepare for the procedure, they don the cardboard headset. The headset is adjustable and ventilated on the front end where the device goes. The device is put into the headset, and connected to the headphones. The clinician checks that the volume is working, looks at the device screen and enters the code displayed into an iPad running the dashboard component of the game. Once the devices are connected the dashboard shows a small duplicate of what the player sees

Once the headset is on the very first thing the player encounters is a pinwheel. The clinician asks the player to blow to verify that the microphone is working and spin the pinwheel by blowing on it. This small step establishes explicit awareness of the microphone as an input source. The clinician confirms that the microphone is working and the Voxel Bay title screen appears. Here the player stands on a dock looking at three creatures sitting on a sandbar. The virtual animal companion the player can choose from are a sea lion, a penguin and a platypus. Behind the animals, the title “Voxel Bay” floats and a sailboat drifts by. If the player looks carefully, they can see a parrot sitting on the “V”, and this is the fourth secret animal guide. The player looks at the platypus, a ring appears and as the player’s gaze is sustained the ring shrinks. The ring shrinks all the way to nothingness and the platypus starts to glow, a chime sounds and the word start
appears floating in the water between the dock and sandbar. The player looks at the word, hears the chime and is taken to Voxel Bay.

Figure 2 The Voxel Bay Title Screen and Character Selection Menu

The player is now sitting in a small sailboat in the titular Bay. The Boat moves forward, towards a jungle island. The platypus sits on the edge of the boat precariously. As the jungle comes closer and trees and vines become distinguishable, the player hears the simian chatter of a monkey jumping on the island’s dock holding a pair of goggles. Platypus wonders what that ridiculous primate is up to. That ridiculous primate asks for the player’s help to capture the rampant jungle spirits. Here the words “Yea” and “Nah” appear floating in the water just like the word “start” earlier. Yea, the player chooses to accept the task. A brief loading screen transitions the scene and the player is in a jungle, surrounded by ghostly humanoids fading in and out of visibility and running totally rampant. The player wears the goggles the monkey was holding on the dock, and in their view a crosshair shows where the player’s gaze is aimed. As the crosshairs passes over the jungle spirits, they give a parting salute and vanish. Once all nine spirits have been captured, the jungle is calm again and the player returns to the bay. A jungle spirit nestled in a large leaf sits at the bow of the boat as a trophy signifying the player’s victory on the jungle island and the gratitude of the monkeys.
While the patient becomes hero of Jungle Island, Jim the phlebotomist has prepared his equipment and swabbed the patient’s arm with some topical anesthetic. Since it is time to insert the needle, the clinician asks the player if they want to play their favorite game from the paper booklet, the crabby crab game. The response is affirmative. The clinician selects the crab icon on the iPad dashboard and the player begins the crab game. The player knows the crab game is played by breathing because of the paper booklet and the clinician’s encouragement to breathe. The player sees a wooden platform, where crabs are scuttling around. The platform is surrounded by a wall dividing the peaceful crabs from the seagull village. The seagulls have started to build their nests along the wall. The player must use a crosshair to select a group of crabs, which become blue and launchable. There are alternating three second intervals in which the player can blow to launch crabs at the seagull buildings. Breathing intervals are marked by the word “now” appearing on screen and by two traffic lights in the seagull village turning green. The player blows crabs at the seagull structures until they have toppled one by one. When the player returns to the boat, still just past the jungle island there is a diving helmet alongside the jungle spirit.
The intravenous connection is made, and the patient wants to say hi to mom. The clinician pressed the camera button on the dashboard, and a panel slides down in front of the player’s view, showing the iTouch camera’s view of the room. Mom waves, she was watching the whole time and saw the battle against the seagulls, from a safe distance. The clinician presses the camera button again and the panel slides back up. The boat has drifted to pirate island, where the one-eyed captain sea lion barks, inviting the player to try a game of tunnel treasure. This game gives the player an aerial view of a mineshaft maze, where wagon boy runs with his loot away from an angry group of pirates. The player’s gaze shines a light in the darkness and leads wagon boy to safety. The player helps wagon boy avoid tunneling crocodiles, while adding more coins to the loot. The player guides Wagon boy towards a row of six shiny coins, and straight into the path of an underground crocodile! The player feels discouraged and asks to return to the bay before trying again. The clinician presses the “back to bay” button, returning the player to the pirate dock.

The boat sails along the cove, passing seagulls and some pirates camping out then turns towards a large icy dome. The boat eases into a small entrance and floats through the iceberg. The player’s breath becomes visible in the cold. At an icy dock, a penguin jumps up and down, imploring the player to “help save my babies”. The player dons ice-blasting gear, complete with a frozen headset and enters a snowy world. They begin floating in the center, looking down on towering icy slopes that are very tall and far apart. Each ice tower has a small space to sit with a sparkling blue pool of water. The penguin waddles sadly on one of these slopes. The ice-blasting
gear works when the player looks at one of the water puddles, then away to draw an ice trail with their gaze. The penguin follows the trails, landing on the next tower. Sometimes the penguin falls in between the towers, but is able to climb back to the last landing spot. After crossing over chasms, through ice tunnels and under frozen stalactites, the penguin lands safely near three penguin chicks. The penguins celebrate being reunited. For the trouble, the penguins reward the player with a barrel of fish, one, big, blinking fish.

Back in the boat with the fish, the player sails out of the iceberg. Meanwhile in the clinic, Jim the phlebotomist removes the iv, this part of the procedure is over. The patient continues to play the game, sailing past a long orange dragon in a sunset sky. The player wants to ride the dragon, so the clinician presses the dragon mini-game button on the dashboard. The clinician minimizes the dashboard page to open the hospital’s record keeping application and fill out hospital records. The player begins another game featuring a breathing mechanic. They are looking down from the dragon’s back as they fly together. As the player turns their gaze, the dragon follows and flies in that direction. As the player breathes, the dragon also makes a fiery exhale. The goal
of this mini game is to light ten glowing torches that stand on islands floating in the sea and sky. The player blows fiercely, zooming past the torches. Once ten are lit, the player returns to the boat. As a prize, a wooden dragon head has been added to their collection at the bow. The boat has reached the end of the bay circuit, it begins to loop and the jungle comes back into view. The player asks for another try at the pirate game as clinicians wrap up the procedure. After beating the game on the second try, the patient-player is ready to say goodbye to their platypus friend, until next time. They can bring home the cardboard headset as a souvenir of their trip to Voxel Bay. If the same patient-player returns to clinic in a few months, or perhaps a year they might encounter new mini-games, a foam headset that looks like the dragon and even have access to this resource at home.
Chapter 3: BACKGROUND

3.1 Collaborative Design Team

In June 2015 I was hired onto the Nationwide Children’s Hospital User Experience (UX) team as an intern along with my friend and collaborator John Luna (MFA Candidate in Dance). The UX team is very small. John and I were assigned to this virtual reality game project, but our specific roles were largely left up to us. My role in the collaboration tended towards concept art and asset development, but between the two of us we each designed, modelled, animated, set-dressed, lighted and programmed many pieces of the game. Prior to starting at NCH I had worked on several smaller scale projects using the Unity3D Game Engine, but with a very different subject matter and audience. I have continued to work with Unity3D, and expanded on work with Virtual Reality, games for mobile devices and one AR project as well. Also prior to starting this work, John Luna and I collaborated on two other projects that shaped our friendship and creative workflow. While my background is rooted in visual art and illustration, John’s original area of expertise is in dance and performance. We continued to work together on this project and at least two others. Throughout our extensive collaborative efforts, we have attempted several approaches to working on one unity project and incorporated influences from both of our areas of study, such as improvisational design choices and choreographic animation. We have discovered recurring themes in each other’s work that we would not have identified otherwise, and then combined the themes in a collaboration which utilized the strengths of both of our backgrounds. These range from analyzing dichotomies, nesting, recursion, and altered points of view to designing characters of ambiguous gender and for a gender non-specific audience. I find that the work we create together is more interesting because we improve each other’s ideas, and the result is a more dynamic world. Our collaboration on Voxel Bay started when we began the internship at NCH.
3.2 Defining Audience and Objectives

Dr. Amy Dunn, Director of Hematology at NCH was the first to recognize the need for an anxiety management method in her clinic for children with hemophilia. Dr. Dunn sought out Jeremy Patterson, the User Experience R&D Team lead at NCH, to discuss creating an anxiety management solution for her young hemophilia patients. These patients regularly spend time in clinic undergoing a vital procedure called prophylaxis that is the only treatment for hemophilia and is necessary for sufferers of hemophilia to live a normal lifestyle. Prophylaxis is the regular intravenous infusion of clotting factor into a hemophiliac's bloodstream (Hemophilia Federation of America). Injections can be performed as quickly as five minutes, but without child cooperation can take as long as twenty minutes (Hemophilia Federation of America). The clinic experience for families bringing their children in to receive prophylaxis treatment and families learning to administer injections for at-home use can be traumatic, especially if the child is afraid of needles, also known as “Needle Phobia” (Hemophilia Federation of America). Learning to cope with prophylaxis is as difficult for parents as it is for children, as they may have to watch or even administer the procedure knowing that they have passed the disorder on to their child. After meeting with Dr. Dunn, Jeremy in turn approached me and John with the idea of developing a virtual reality game to address Dr. Dunn and her patients' needs. Her patients are the initial target group of this project, but we developed the work with an eye to the future and other potential patient groups. The hemophilia patients we began designing for originally are boys (hemophilia is a sex-linked recessive disorder) between the ages of six and fifteen. To this end, we began thinking of game environments that would be appealing to boys, while not totally excluding the potential demographic of girls, with hemophilia or otherwise.

3.3 Precedents

When work began on this project, the team performed a preliminary review of other VR healthcare games. The review was cursory from necessity because our initial deadline was imminent. As I realized that this project had the potential to become a thesis topic, I began to recursively look at more studies that could provide similar design insights. The idea to use virtual reality in a medical setting to benefit patients is not a new one, but the execution is something that is still not standardized. It was helpful for us to review others’ approaches and to confirm the contexts in which virtual reality had succeeded. From this review, we can possibly draw parallels, or perpendicualrs, to our own research. I have supplemented our initial research by
searching for precedents in virtual reality games for pain management, games that make use of breathing controls and networked games systems with different user roles. I have also included a section to summarize the works that we have been inspired by in concept or aesthetics.

3.3.1 Virtual Reality Games for Pain Management, Control or Distraction

A well-known precedent for the application of Virtual Reality games to benefit patients in a medical setting is the University of Washington's HITLAB study which demonstrated the effectiveness of virtual reality as a pain management tool for burn victims. This study presents a comparison of the pain relief provided by Nintendo video games versus the pain relief provided by a VR game, Snow World 2003. Snow World 2003 is not available for hospitals to use as they want, it is rather a licensed asset a hospital may acquire. It also incorporates the use of a joystick which might provoke too much movement for the procedure being conducted (Hoffman). Dr. Dunn and others who work in children's clinics require a tool specifically designed to address the needs of a pediatric patient demographic. In the study, patients reported considerably lower levels of pain while using Snow World than they do when using Nintendo games during their procedures (Hoffman). The effectiveness of pain relief was measured by fMRI scans that show pain-related brain activity in the study participants (Hoffman). The patients in this study were burn victims using the tool during wound care such as cleaning and bandage replacement (Hoffman). Snow World 2003 was developed by Ari Hollander and Howard Rose, who worked at the Human Interface Lab (HITLab) at Washington University and co-founded Firsthand Technology in 1995 (Firsthand). In 2014, Deepstream VR emerged out of Firsthand Technology (DeepStream VR). These companies offer their products for purchase to hospitals and other institutions. While there do not seem to be many competitors in the field, one might say this kind of work is already being explored. A primary difference between the work created at DeepStream VR and our research is that our work is presented on a mobile device and features the custom design of hands-free and breathing mechanics built to meet the needs of a children's hospital clinic. Furthermore, our research does not claim to affect pain, only anxiety.

Another related research study focuses on Virtual Reality games to distract children during their visits to the dentist. In this study, a group of Dutch game designers, dentists and a dental fear clinician look to prove that interactive games designed for use in context (the dentist’s chair) are more effectively distracting than attractive virtual environments (Bidarra, 207). The design team
on this project created a unique control system and hardware setup designed around the following constraints: The system must not interfere between patient and dentist, there must be clearance area around the patient’s mouth, the patient should not move their head and the patient should not need to look at the game controller (Bidarra, 210). The design constraints are as limiting as ours, but lead to a totally different system. One of the defining differences between our projects is that head movement is not a possible input method for patients undergoing dental procedures, whereas it is one of the only possible input methods for our group. The prototype developed through this research was a virtual reality game that did not use the head-tracking or stereo display of the virtual reality goggles being used, the Vuzix 1200 VR goggles, because their only purpose was to hide the dentist from the patient’s line of sight (Bidarra, 210). Without head tracking functionality, I am not sure that I would consider this game to actually be a virtual reality game. Nevertheless, it successfully served the same purpose as Voxel Bay, and worked around another very limiting set of constraints.

*Cryoblast* is a game developed at Simon Fraser University to help patients with chronic pain and make virtual reality interventions more accessible to them outside of a clinical setting. This study aims to create a virtual reality game for a mobile platform that can be easily accessed by patients in their own homes or other locations outside of clinic (Tong, 1). *Cryoblast* is a first-person shooter game with a win-state that depends on a coin collection mechanic. While the final product and mechanics of *Cryoblast* are not particularly innovative or remarkable, the distraction principles outlined in the research are relevant to my research for *Voxel Bay*. The distraction principles considered when developing *Cryoblast* were cognitive load and sense of immersion both in the context of affecting relaxation and anxiety control in virtual reality (Tong, 4-5). The notion of cognitive load is like the idea of cognitive flow, a term coined by psychologist Mihaly Csikszentmihalyi and used in game design to describe a heightened level of player engagement (Baron). These distraction principles were some of our primary considerations when developing *Voxel Bay*, though an important distinction is the focus on a medical procedure as opposed to distracting patients from chronic pain unrelated to ongoing medical procedures. Because *Voxel Bay* was developed to be used during a medical procedure, we have more design considerations that build on top of these basic distraction principles. *Cryoblast* is a unique example because it is one of the only research studies that used a mobile platform for its virtual reality game, and that is a point of similarity that warrants review.
I found a helpful secondary source in “Virtual Reality in Paediatric Rehabilitation: A Review” by Thomas Parsons et al. The subject review aggregates and provides cursory explanations of the use of virtual reality technology in pediatric medical care settings with the intention of assessing its current state and potential use in future applications. It is striking how many different patient groups are specifically focused on by the studies covered. The review mentions applications for patients suffering from autism, fetal alcohol syndrome, attention deficits, cerebral palsy, burns, visual impairments and cancer (Parsons, 225-230). This review concludes that virtual reality technology for medical application is still in the early stages of development with trials that are promising but too small to be conclusive. It is important to note that the review was written in 2009 so that part of the conclusion is due to be reassessed. The conclusion also stresses the importance of challenging but not overly difficult gameplay, and hardware setup. The mention of hardware setup notes that head mounted displays and head tracking, if applicable, tend to improve outcomes based on the studies reviewed (Parsons, 236). The most useful quality of this review is that it demonstrates a comprehensive spectrum of applications for virtual reality technology in a medical setting. It also suggests that focusing on a specific patient group is a successful design strategy, which I had not considered before but must agree with.

3.3.3 Games that incorporate breath

In my research, I have reviewed accounts of other games that have similarly innovative control systems, and are “tailor-made” for healthcare applications (Kato, 116). One of these games, SpiroGame, also incorporates breathe-based interaction where an asthmatic child helps a caterpillar crawl across a branch in thirty seconds or helping a bee fly from flower to flower. SpiroGame functions using a pneumotachograph and pressure transducer instead of a microphone, which is important to its function of a creating a spirograph for asthmatic patients (Vilozni, 2201). The microphone used in Voxel Bay is a simpler but less accurate way of gaging a player’s breathing and is only usable in our project because we don’t care to measure the quality of the breath, except in some cases the duration it is sustained. It is important to note examples like this to more deeply incorporate breathing into the gameplay.

The idea to ask users to blow into a microphone as a form of input is also seen in many games for the Nintendo DS and Nintendo Wii U. In addition to many music-themed games that ask the player to sing or multiplayer games that support player conversation, there are games for
Nintendo systems ask the player to blow into the microphone to create some physical effect in game. Some examples of physical effects that result from player breath are blowing to dust for fingerprints in *Phoenix Wright: Ace Attorney*, lighting a fire in *The Sims 2: Castaway*, playing a flute in *Legend of Zelda: Spirit Tracks*, blowing bubbles in *Nintendogs*, and *Mario Party DS* which includes ten microphone based mini-games. In the feature-length game experiences blowing into the microphone is an interlude into the normal gameplay that breaks up the action. Otherwise, if blowing is the primary game mechanic, then the game must be brief like the *Mario Party* mini-games. Being able to physically affect the virtual environment creates a sense of immersion for the player. In a virtual reality context, all the different immersion factors magnify one another, so being able to blow into the space and move the camera with one’s head is even more convincingly immersive than just one of those features by itself.

3.3.4 Networked Systems with different User Roles

The Nintendo Wii U is also a well-known precedent that resembles our remote-control setup for the dashboard. The Nintendo Land games that come with the console are an example of designing different user roles that also use different physical hardware to interact in one virtual environment. The Wii U uses a unique setup with one special controller in addition to the other standard controllers. The Nintendo land games that are sold with the console are multiplayer with a unique user role and an extra viewpoint for the player with the Wii U gamepad. The choice to add another screen into the system promotes either multiplayer interaction or constant task switching by one player between the two screens. Players that do multi-task are on uneven footing. It is very common to give players different roles in video games, such as the common vehicle driver and machine gun operator setup seen in *Halo* and other shooting games. Special roles also exist in board and party games like *Werewolf* were one player is an unknown enemy to the others. The choice to give videogame players different hardware changes their physical roles or abilities in a more pronounced and fundamental way than a normal hardware modification might do. The hardware setup of the Wii U encourages, but is not limited to party game style play with all players in one room. In our remote-control setup, the clinician is a special participant in the gameplay that is largely inactive and has different abilities as well as different hardware. There is something interesting about the mixture of different gameplay equipment and player roles when the players are in the same space.
3.3.5 Stylistic References and Inspiration
Our team reviewed many examples of fun and inspiring games to guide our process throughout the development of Voxel Bay. We reviewed hands free VR experiences such as the google cardboard tropical roller coaster and followed this model for the main track in the Voxel Bay experience. Also for the main bay area, we repeatedly looked at the *The Legend of Zelda: The Wind Waker* for ideas about what the boat might look like and how to make sailing an interesting part of the game. As for the mini-games, the dragon flying game was a natural evolution of seeing the dragon, but a precedent that helped guide its design is the dragon flying in *Secret of Mana*, even though the dragon in *Secret of Mana* serves primarily as an engaging transportation mechanic. At some point the observation was made that the crab launching game resembles angry birds, and that affected the decision to add more collapsible buildings into the background one the second pass of development.

3.4 Assumptions
The precedents reviewed above allowed our research to move forward without the need to recreate studies and prove the fundamental ideas on which our research is based. In summary, those fundamental ideas are that virtual reality games are a successful anxiety distraction technique, cognitive load and immersion both contribute to the patient’s level of distraction and linking a player’s physical sensations to in-game visuals will deepen the player’s sense of immersion. The development of Voxel Bay moved forward with information from our own research, ideas generated in response to circumstance and support of our design principles from the body of knowledge gathered by these precedents.

3.5 Contribution/Justification
This work contributes to the field of Design because it considers a specific user group and use case scenario, and reports the process of developing techniques to address the concerns of users in the scenario as well. The patient-player user group is an expanding group that is different than their predecessors because technologies keep changing to the point that the interaction they have makes them totally different both as players and as patients. While there are precedents mentioned above of VR games, healthcare games and even VR games for patients, the pediatric patient of 2016 who plays the VR games of 2016 warrants different consideration in some ways than the players of Snow World 2003. Focusing on a group as
specific as hemophilia patients can also give designers unique insight into developing for this
group or a similar group, for instance other patients who need prophylactic treatments for a
different reason. Our clinical trials of Voxel Bay included patients receiving a standard blood
draw, which is one such group of patients. Another special consideration of this project was that
we had to design for pediatric patients. Perhaps because most designers are adults, this
demographic consideration seems easy to overlook. Children as a research group are difficult to
access because of patient and test subject protections, which makes them a challenging
audience to design for. Not only did we have to make small cardboard headsets and tried out
giving them narrower pupil-to-pupil measurements, we also had to make content decisions
about how to represent our fictional world to children alongside their parents. For instance, our
original mermaid wore a red shell bikini that could have been misinterpreted as bright red
nipples from a distance and had to be revised because that detail might not be appreciated by
parents. This example could be considered silly, but it is difficult anticipating subjective parental
censorship and trying to work around it even when you may not agree with it or do not have a
parent’s perspective on the subject. Developing this system necessitated a degree of novel,
technical problem solving and could assist others trying to create a similar setup or working with
the similar tools acting as standard methods or best practices. We have had to find the best way
to combine different technologies in a way that is easy to use and functional
Chapter 4: CONCEPT DEVELOPMENT

The setup and combination of the hardware we are using, while part of the project’s research and design, influenced the design of the game content as well. While testing we slowly adjusted the spatial layout of the virtual space to get the physical reaction we wanted from players. We settled with keeping head aiming interaction largely in front of the user to minimize patient movement. The game also has no cut scenes and minimal instructional components that do not interrupt an engaged player. All the games are very short; they can be played in only a few minutes. The whole experience is fast-paced to maintain as much of the user’s attention as possible.

4.1 Patient-player Immersion

Patient-player is one of the key concepts that guided the design of Voxel Bay. It is important that the patient-player feels immersed in the game so that they are distracted from their anxiety during the medical procedure. To distract the patient successfully, they must be subjected to a high cognitive load that does not allow for focus on the hypothetical pressures of anxiety. Creating gameplay that subjects players to an unrelentingly high cognitive load to maintain a focused state throughout the entirety of gameplay is a strategy that is unique to the patient-player’s context (Baron). Our team had to thoroughly consider this factor throughout our development process.

4.1.1 Virtual Reality

Voxel Bay was the first virtual reality project I ever worked on. I had to learn about the medium and designing for it at the same time. I learned to think of virtual reality as an illusion that occurs when great efforts of hardware and software come together in one way or another to convincingly simulate a natural eyes-in-head-like camera navigation system. It must seem real, so we can then create a virtual, manipulatable and somehow unreal “reality” to look at with
new camera eyes. Because of the camera-eye connection, I do not think virtual reality can ever allow for a truly third person experience. Yes, a player in a virtual reality game could control an avatar represented a distance away from themselves, but the camera control afforded by virtual reality camera control systems always implies a first-person presence. even if that presence is the omniscient witness of a third person perspective. Virtual reality experiences are necessarily first-person, and creating the illusion of a surrounding space gives players an impetus to have some existential thoughts relating to identity and corporeality. Necessary first-person perspective is a limitation of virtual reality as a medium, but as a limitation serves as an easily identifiable factor to design around. In *Voxel Bay*, the player selects a character from the title screen who accompanies them in the sailboat and converses with all the island dwellers. We achieve a greater sense of immersion simply shifting the structure of the game from,” you play as a platypus” to “you are guided through the world by a platypus character” because that explanation resonates much better with looking at a platypus through a first-person camera point of view.

Since beginning work on *Voxel Bay*, I have gone on to make virtual reality work for Oculus Rift, mobile platforms and most recently for the HTC Vive. These different platforms all have their specific development needs, but the goal of creating a three dimensional, surrounding experience is trans-platformic, persisting across hardware differences. Thinking spatially does not come very easily to me, and I have never spent as much time thinking about my work spatially as I have when working on these projects. Spatial awareness is one of the key design considerations that separates developing a piece of media for virtual reality from other digital three-dimensional media. It is perhaps more like designing a non-digital piece of three-dimensional media, like an installation. The creator has no direct control over the direction or timing of a viewer’s gaze, but can guide it with the clever use of lighting, sound and spatial composition. The level layouts used in *Voxel Bay* quickly became much more radially structured than any other game project I have worked on. Arranging objects of interest radially is the most obvious and easiest way to modify level design for virtual reality. In *Voxel Bay*, this strategy is slightly modified to cover a limited field of view (about one hundred twenty degrees in front), and discourage patients from turning around in their seats. Of the nine scenes developed for *Voxel Bay*, two do not follow this structure. The two levels, the pirate maze and the flying dragon level use different level design strategies and both rely on procedural generation.
The approach we took in the maze level was to create a small room/giant headset that moves with the camera and strictly limiting the field of view, but also serving as a vection-preventative stable point of reference. The level is arranged as a two-pronged maze system. The player cannot move backwards in the maze (because they are being chased by pirates), so there are no dead-end tunnels and the configuration of tunnels, obstacles and rewards is different every time. This level layout is narrow, so the limited field of view is not a problem. The player views the maze from above, move forward at a constant speed matching the horde of pirates chasing wagon boy. This point of view is that of a drone, it lends a sense of omniscience, or at least dramatic irony since the player knows the maze system and wagon boy just trustingly follows their gaze. The limited field of view generates interest and suspense as obstacles and collectibles enter the screen, like the effect of fog of war used in some strategy games. This sense of world discovery along with the pace of the constantly moving camera compensates for a wide field of view with many surroundings to keep the game interesting. A difficulty with this approach to designing a virtual reality game is that so much of the potential screen real estate is not used. The visuals that are shown must be clearly discernable and hold the viewer’s interest.

Figure 7 The penguin game and jungle game pictures from above show the typical radial layout of the mini-games in Voxel Bay
The dragon flying game is also generated procedurally and linearly, at the start of gameplay. The design twist of this level is that it will generate content endlessly, and always at a certain distance away in whatever direction the camera is facing. The level structure appears to be open world, but becomes some sort of curving pattern depending on the player’s motion. While the limited field of view makes the maze level more interesting, in this level the open world atmosphere and sense of motion are the main point of interest for the player. The difficulty with this level design approach for virtual reality games is creating enough content to fill the space without so much repetition as to lose player interest.
4.1.2 Gaze as Input

I started work on developing this concept after Dr. Dunn and Jeremy Patterson gave me and John the basic outline to work with, a VR game to distract hemophilia patients during infusions. This outline served first as a learning opportunity for me and John. We started just trying to learn how to work with VR and what interesting things we could create with the medium, which was new to both of us. The concepts we focused on in our early explorations on were gaze-based selection systems, audio cues and a first-person camera system with constant forward motion along a preset looping pathway. The gaze-based selection systems referred to here are based on the orientation of the head mounted display device being used, as opposed to eye-tracking technology signaling gaze in the game. We realized after testing our first prototype that we needed to combine audio and visual feedback to create discernable explicit interaction. In that prototype, gaze based selection would trigger associated sounds to play regardless of the player’s spatial position along the track (i.e. looking at a distance fire would trigger the sound of a fire crackling even though the player is not close enough for that sound to be audible). Without a visual cue alongside the audio change users would not necessarily realize that a sound was playing over the basic background track or, in other instances, why it was playing. Furthermore, using this minimal model of interaction did not encourage players to participate in the scene or do anything they would not otherwise be doing. The audio-only feedback model was a good starting point to playtest and asks users for suggestions about visuals or interactions we could incorporate.
4.1.3 Reinforcing Physical Sensation
To further the player’s sense of immersion we reinforced their non-visual senses with in-game visuals. One example of this is the sensation of blowing air into the microphone which is reinforced by in-game physics that mimic the visuals of wind and moving air, like sails blowing in the wind or a pinwheel spinning. The link between this sensation and the visual creates a seamless connection between the player and the game, which allows them to feel further immersed in the gameplay. Another example is the use of virtual headsets. The virtual headsets are an element that helps reduce motion sickness, but also serves the purpose of reinforcing the player’s feeling that there is a headset on their face. With the inclusion of this visual in the game, there is a visual explanation for the feeling. The cohesion of visuals with sensations helps reinforce the player’s sense of immersion as a secondary function of the virtual headset.

4.2 Sustaining Patient-Player Attention
While all games need to sustain player attention at least enough to play, they don’t need to maintain it to the exclusion of other senses for a given time period. Patient-players should not want to put the game down, or at any point decide that the content of the game does not need their attention. To sustain player attention, designers typically use a combination of aesthetics, narrative and gameplay (Lemarchand). *Voxel Bay* is full of dynamic gameplay and moving environments that will keep patient-player attention. We also removed the explicit narrative moments from the game to keep players engaged, and had to find other ways to include narrative in the game. *Voxel Bay’s* gameplay consists of abbreviated mini-game segments that provide a variety of content without the less stimulating punctuation of explicit narrative. In this section of the paper, I will cover the techniques used to keep patient-player attention on *Voxel Bay* for the entirety of their procedure.

4.2.1 Moving Camera Along Track
While the interplay of audio and visual components needed to be adjusted to get the right effect, the preset track was a component of our early work that became fundamental to the final product. It is notoriously *verboten* to move the camera without player consent in a virtual reality space. Without enough peripheral cues to reflect the player’s actual movement, the player will become susceptible to the illusion that the camera’s motion is their own. This illusion will give the player a sense of vection, the feeling that world is moving out of sync with their
vestibular system. Discrepancies between the vestibular system and visual information usually occur when one is sick or intoxicated and create a similar feeling of motion sickness (Rieke, 195). However, moving the camera without player input is also a basic technique to circumvent the limitations of head-mounted display systems that only track head rotation without recording any positional information about where the player’s head is in space. If the camera’s movement is predictable and there are some objects included in the game that remain stationary relative to the camera, then the illusion of motion will not conflict with the vestibular system and the player will not feel sick (Fernandes, 209). In Voxel Bay, the camera moves out of sync from the player in five of the nine scenes the player can experience. In these scenes, the camera movement is gradual and either moves at a consistent, predictable pace or directly in response to player input. These scenes also feature visuals that are stationary in relation to the camera. So far, motion sickness has not been a problem for any patient-players. Working around the problem of vection is a worthy effort, as it allows for a much greater degree of variety in the interaction experiences we were able to offer players, and these scenes became more dynamically visually interesting.

4.2.2 Impling Narrative
The above mentioned fast-pacing of Voxel Bay discouraged the use of cut-scenes or exposition as a means of world-building. Playtesters would often suggest recording voice actors to instruct players and tell a story. We have always noted that this is a wonderful possibility but have never mustered the time or resources to realize it, so have had to resort to other storytelling techniques, at least for the time being. There are no conventional narrative-building elements in Voxel Bay, save for a few sentences that appear in the user interface, overlaid on the world in the viewer’s stereoscopic display. The narrative of the game is the player-patient’s experiential narrative and whatever story they are able to read from the world design. Cutting out explicit explanation of the world of voxel bay lead me to try to convert video clip cut sequences and dialog snippets into character and level designs that would imply story. When creating the characters and levels of Voxel Bay I try to rely on very clear visual cues that will imply something about the character which we do not have time to say otherwise.

To begin with, there are no human-beings in the game. There are some blocky humanoid characters, pirates with green skin, one in a mine who pushes a wagon full of treasure and
humanoid jungle spirits that fade in and out of the ether. None of the above are identifiable as “human”. Furthermore, two of the three humanoid character types are the antagonists of their mini-games. This is one of the qualities that sets the atmosphere of Voxel Bay as a Neverland of non-human creatures that are recognizable from our world, but living in their own.

4.2.3 Mini-games
mini-games are games that have a very small minimum required time commitment to play. They usually focus less on developing narrative in favor of simple game mechanics. I have worked with Unity3D Game Engine on several projects, learning how to use the tools available to me, to make mini-games and understand what is involved in designing a short-term, engaging game experience. I made five of the eight mini-games included in Voxel Bay and worked on all eight of them. While developing the five games solo, I decided to make some prototypes where I could isolate the design of mini-games from designing for our VR and microphone setup and just think about fun abbreviated game experiences. I worked on three prototypes developed for Android and tried out different accelerometer mechanics that could be adapted into an analogous experience for head mount display if the mechanic was successful. The mechanics I explored were flipping tiles on a grid to avoid enemies and collect items, creating a specific trail of items behind a character and using accelerometer controls to rotate and aim a room full of bouncing characters at a fixed target. Since these games were also developed for a mobile platform I used character and level designs somewhat like the low poly aesthetic used in Voxel Bay.
The last of the games mentioned above in particular, which I have been calling *RolyPoly* started with the same concept as the crab launching mini-game. *RolyPoly* and *CrabsCrabsCrabs* developed divergently despite starting with the same game mechanic concept and the same scripts. The differences can be attributed partly to designing around the platforms I was working with and partly to choices I made because I wanted to experiment with different implementations of the same idea. The root of said idea was freeze power controlled by the player’s breath, something written down as one of the most-fun-sounding possibilities for blowing games in a meeting between John, Jeremy, Rob Strouse and myself. Initially the idea for the crab game was to freeze little creatures running around in the game with freeze breath, but the idea became a more dynamic powerful wind breath.

4.3 Character and Environment Art

I worked to create worlds and characters that would appeal to the wide age range of the target patient group. One of the ways our team did this was by referencing the aesthetic of Minecraft and LEGO games which are likely to be familiar and appealing to our target audience because they are both known for their widespread appeal with children and even adults, being said to affect an entire generation of people (Thompson). Minecraft for instance, is the third bestselling
videogame in history (Thompson). The look of these children's games or toys is iconic and nostalgic. We kept that sense of familiarity over more complicated or photorealistic graphics which would not be able to perform on the hardware we are using. Keeping forms simple made for discernable imagery and faster running software (Gallegos).

4.4 Connecting Patients to Clinicians and Caregivers

After our first completed version of the main track and three mini games we added in a microphone input feature, which came to mind easily since John had just finishing work on a game called Cube Island that featured microphone input as a pivotal game mechanic. We added it to the game by having the player’s boat stop at several points of interest and asking them to blow wind into its sails to continue moving. The effect was so successful and easy to integrate that we eventually decided to build five more mini-games around the idea.

The second peripheral device to be added to Voxel Bay was a camera, the feed from which would be rendered to an unlit piece of geometry, placed right in front of the player’s view range and toggled on to look through the camera. We incorporated the camera view at the suggestion of Karen McHughes-Fornadel, one of the group of specialists from Patient Life Services, who we had been meeting with throughout the three months. Karen encouraged us to give children who want the option to look around the clinic room a way to see through the headset and watch the procedure. We were able to solve this easily by using the camera of the mobile device.

Clinicians also requested the ability to trigger this and other effects within the game to make the experience more tailored to each child's needs. We developed a networked remote control station to be operated by the clinician to monitor player progress and trigger features like a breathing exercise, distraction events, exit out of games and pull up the camera view for the patient. Throughout the process, we have been exploring how to best combine technologies for this experience. We have had to consider hardware, avoiding the cumbersome setup of the oculus in favor of a head-mounted mobile device. Decisions regarding a setup connecting the patient-player with the clinicians have lead us to explore a very specific technical setup using Google Cardboard, iPod Touch, a remote server, headphones with microphone input, a customized cardboard viewer and optimizing all this for a mobile device and easy use with minimal training required.
Chapter 5: PROCESS

This project started as the development of two prototypes, the first created in a one month span during June 2015 as a minimum viable product (MVP) for a demonstration scheduled for June. That demonstration was postponed until September. After the postponement, we decided to work on a second prototype in the three months until the new date and show it alongside the first. Due to time constraints, the first prototype was made using free assets developed elsewhere. I use the term **assets** to refer to the files imported into the game engine as foundation element upon which the greater piece is built. These files include images, 3D models, sounds and other components made independently in separate programs. The easiest way to keep a consistent aesthetic using downloaded assets is to use photorealistic models and textures because photorealistic pieces would all match up, whereas more artistic styles of downloaded assets might look out of place next to each other. During early stages of development, we discussed using virtual reality to help our player-patients in two different ways. The first way is to calm the patient with a soothing and engaging virtual environment. The second way is to distract the patient by over-stimulating them with faster-paced gameplay and an exciting virtual environment. Once the photorealistic aesthetic of the prototype was in place, it seemed that calming would be a much easier effect to develop because it is slower paced and would show the viewer less content in the same amount of time, allowing us to make less content in the few weeks that we had. We followed our initial impulse which was to design around the viewer's gaze and create a consistent type of feedback, which we did by using gaze-triggered sound effects. The environment of this prototype was a wooden boat slowly circling a looping river track, surrounded by points of interest. When the player would look at a point of interest, a sound associated with that point would play. This design allowed us to quickly create a prototype for our one month deadline by allowing us to rely heavily on assets made by others.
The most time-consuming features developed in the river track prototype were scripts. We made scripts for a waypoint system to keep the boat circling along the track and a gaze-based triggering system that would work with the oculus headset. We arranged items around the river loop so that the player would always have something to look at and connected a unique sound to each type of item so that all campfires would sound the same, as would all butterflies or all rainy areas. The purpose of this prototype was to learn how to design for the Oculus Rift in the Unity Game Engine, learn about the possibilities of working with VR, understand the constraints and required resources for working with VR, and demonstrate our ability to make a viable product to Amy Dunn and her team.

Though we started developing on Oculus Rift, it became obvious quickly that this would be a development tool only. It was useful to have head-mounted control of the camera so immediately, though this can also be achieved using the unity remote app with a mobile device it was better to use the Oculus because we did not have a mobile VR headset conveniently accessible at the time. We switched our project from the Oculus Rift to a mobile platform using the Google Cardboard API (being replace by Google VR or Daydream). We built the Unity3D project with Google’s API to an iTouch platform and developed custom cardboard headsets that include pieces to support the headphones and microphones we are using. The most recent technological addition to the project was to use socket IO to connect the player’s iTouch to a webpage that can be accessed by one or more iPads handled by clinicians and parents who can monitor and assist player progress. The most challenging part of combining these technologies is optimizing them to work together smoothly and it is an ongoing process as mentioned below.

After developing the river track we started work on our second prototype. Since we had time (three months) to build our own assets we could choose the visual qualities freely, following the Lego and Minecraft aesthetics. We could also create a larger, more diverse environment so we decided to make an ocean where we could place many different islands with different atmospheres, while incorporating the presence of water, which is associated with calming and healing patients (Smedley). This decision allowed for easy rearranging and expansion of the world and created an open-world feel while maintaining our no-steering, looping river track system. We made a looping track that passed through three islands, but when we discussed adding gameplay features directly to the main track area they seemed difficult to integrate with
the constantly moving boat and the changing environment. A game played in the main bay area would not have the same continuity that the mini-games have and the changing scenery, which is currently designed to take the player’s full attention, would distract from a gameplay objective. Our ideas were limited by these constraints so instead of creating games forced into the narrative of staying in the boat endlessly, we wanted to create games that could be played outside of the boat. The mini-games were made in separate unity scenes so that John and I could work on them simultaneously without importing and exporting each other’s work back and forth. We decided to make one mini-game per island, and added docks at which the boat would automatically stop. For the mini-games’ first incarnation, the boat would stop at each dock and the mini-games would start without player consent. Players (John, Jeremy and myself) could close the games using the escape key.

Upon deciding to include mini-games along the track, our team had a meeting to brainstorm ideas that would be fun games with strictly gaze based interfaces. On June 26th, I drafted a list of mini-game concepts that could be adapted to our interface: “\textit{Whack-a-mole, don’t touch the walls, Lead the Lemmings, whirlpool platformer, and Create cloud shapes with mesh manipulation}”. By the 30th, We had decided on a reskinned Whack-a-mole for the jungle game, a game where the player would guide an avatar through a maze for the pirate island, and a penguin sliding game (Originally in the vein of the Lemmings concept). During July, I took a three week break on the project. In my absence, John had created the basic versions of the Jungle and Pirate Games, and positioned, animated or textured many of the assets I made throughout the main track area. We worked on the games together for a few weeks, deciding how to make the maze game appropriately challenging or where to put the jungle spirits. I did a lot of set dressing for the existing scenes and went on to create the script that would draw the ice trail for the penguin in the ice game to slide along.

5.2 Playtesting

Part of the process of developing this game is playtesting. Playtesting can be divided into several levels of removal from the development team and process. These levels are like the convention of alpha and beta release tiers often seen in other forms of software development, with alpha playtests being accessible to a group of people close to or working alongside the development team and beta playtests accessible to a small group of people further removed from the team.
and more representative of the public (Bonin). Our alpha playtests occurred in two forms. The first type of alpha playtest occurred predictably during meetings where we were seeking advice from experts, advisors and medical staff directly involved with the project. For these meetings, we would work to push out a build with a list of features we would like to get feedback on, that were additions made since the last meeting. We did this with a consistent group of people, and several of them were clinicians that will eventually use the game with their patients. The second type of alpha playtest was more circumstantial and improvised. We would show the game under development to curious colleagues walking by as we worked. The curious colleague would walk past with head turned a couple of times, then sidle into our tech pod or lab space. They would ask some questions, that were mostly a lead into the real question, “Can I try it out?”. While our in meeting alpha playtests were carefully planned, and developed for, we did not even have builds for these people to try and we were not prepared to collect information about a specific part of the game. We would have to quickly activate or deactivate some new incomplete addition we were working on, then step aside to watch the curious colleague in action. These improvised demonstrations of our work yielded mixed results.

While imperfect, this unstructured model of playtesting is still viable because the structured alpha and beta test rarely appear in the development process in industry (Bonin). Feedback from the informal alpha group was useful in providing positive reinforcement of features (mostly aesthetic) that playtesters responded to and revealing the apparent but often unexpressed difficulties playtesters had with parts of the game that needed more discrepancy. Something I have observed from playtests is that most alpha playtesters that know and interact with the developers will only reluctantly give direct criticism of the work. Developers should watch these playtesters for interactions where they may pause or ask for direction to know which parts of the game need more work. During alpha playtests, the game is still not near its final form so developers may anticipate the challenges playtesters will face and should construct temporary means to circumvent this as they are moving the project out of the prototyping phase.

Our beta playtests were much more infrequent and subjected our work to a variety of users. As a public event approached, we would prepare the project to show to the expected portion of the public that would be present at said event. As I write this, we have playtested via prepared
public demonstration in three varied instances. These playtests were at the walk for Hemophilia during September 2015, the Ohio Game Developer Expo (OGDE, later renamed GDEX for Game Design Expo) in November 2015, the Advanced Center for Computing Art and Design (ACCAD) open house in April 2016 and at SIGGRAPH 2016 in July of that year. These playtests are useful, with different groups of people attending each. In our first demo, at the walk for Hemophilia, the players were mostly children and were in some way affiliated with the NCH. At the conference venues, we received an insight from gamer and game developer perspectives, useful because they understand some of our process from firsthand knowledge, but also very different from our target audience. The ACCAD open house demonstration was unique because we had the largest volume of playtesters, because this was our first time showing the game with the clinician station, and the first showing of the game operating on a mobile platform.

Developers try to pull together a relatively complete version of the game for beta testing. For our beta playtesting events, the team pushed out a more polished version of the game with finished content that needed to be subjected to extended use for debugging purposes. During these development pushes we would send the game home with coworkers to undergo extensive pre-beta testing with their real children. These pre-beta tests served primarily to confirm the game’s readiness for beta testing, though they could catch larger bugs if we were less thorough.

5.3 Responding to playtesting

After the first clinical trials, the initial changes made to Voxel Bay were focused on parts of the procedure external to gameplay. The headsets have become better ventilated to prevent the headset from heating up, and children now get to look through a booklet that introduces them to each area and mini-game before playing so that they can request the games that seemed most interesting to them. After discovering that John has a larger than normal lung capacity and is not a reliable control for an adult’s breathing, let alone a child’s, we made some adjustments to the sensitivity of microphone input for breath and the pace of exhalation.

Since playtesting Voxel Bay and other applications, I have learned to anticipate that users will want to adjust some settings like the sensitivity of the input devices or level of difficulty. In the breathing games these settings often related to adjusting the input value received from the microphone. In my workflow user interface is one of the last components to be added to the
game. However, when deploying a build for beta level playtesting, developers should include at least a few settings as a safety net measure. With mobile devices, executing this strategy can be tricky. On a standalone build (built for PC, Mac or another computer OS), one can use keyboard input for fast setting control. With mobile devices, one must either create an entire UI to control the settings or work with the inputs that the device allows access to. While designing a UI is a clean solution that allows for precise control and visual feedback, it can be more time consuming than it is valuable, especially if the setting is never going to be included in the game or accessed by users. Once we started the playtesting part of our process, I began including tap-based controls. These controls were generally to circumvent testing or demonstrating the game without connecting to the server and nurse’s dashboard remotely. I created controls with deliberate spacing or sequence to prevent accidental taps from interfering with gameplay, such as three taps to hide the startup UI and another three taps to hide the calibration screen, both of which would normally be hidden via the remote-control system. The last point to make about hidden control or debugging systems is that they should be easy to toggle in and out of activity. In this project, I created a true or false parameter in my scripts that the debugging controls will look to, basically a debugging mode that can easily be turned on and off.

In addition to adding a debugging functionality to the game, I also revised the content in response to the players’ comments and my observations of their playtesting sessions. After I observed that less players were willing to try the balloon and starboy games, based on their descriptions and images as shown in the paper menu, I revised both games. The two games that were totally revised were both designed in anticipation of anxious players needing to calm themselves down. They were slower paced than the other games and required less action on the player’s part. The underwater game was, conversely, an example of a calming game that did very well in the playtesting sessions. The main observable difference is the visual richness and presentation of the underwater level, a travelling camera, open-world layout and a fast-paced but low-stress game mechanic (find and collect fish by looking at them). Restructuring the level design of either the balloon or starboy games to meet these parameters would require so many changes as to make completely new games. Rather than replicate the components of the underwater game, I looked to the most successful mini-game. The crabs mini-game featured easy visual literacy with immediate visual cause-and-effect, reliance on unity’s rigidbody physics, a stationary camera and fast, time sensitive gameplay. These components were much easier to
build into the revised games, which already shared the stationary or constrained cameras and subsequently limited world space.

The balloon game was transformed from a simple color-matching mechanic, aimed at the very youngest possible demographic, to a point-and-shoot game of hoops where the player tried to land an octopus into rock tunnels despite the regularly emerging balloons that shoot out of them. While the game relies on unity’s rigidbody physics to create the entertaining falling and collision effects, the aiming and shooting physics are controlled through a script that calculates the octopus’s parabolic flight path such that the landing place will be exactly where the player looks regardless of their strength of breath. This factor eliminates frustratingly obscure difficulties and allows the player’s attention to focus on the other challenge, timing shots to avoid the balloons. The revised version playtested in one of the most successful cases that I personally witnessed.

Revising starboy was much more difficult and has yet to resolve satisfactorily. The game already had so much visual complexity that changing the level layout would be too much of an overhaul and could not fit in the time allocated without sacrificing the revision of the mini-game mechanic. The pacing of this game was originally loosely constrained. The player would aim, blow and watch starboy move upwards. If the player waited too long, starboy would descend. The unanticipated result was that players could pass through the level very quickly and that even though there were many carefully placed windmills to aim at, players could pass through the game only using those in the front center areas of the screen. To highlight the visuals and exciting features of each windmill in this game I changed the structure so that starboy now jumps from windmill to windmill. To move starboy along to the next mill, the player must blow on the mill at his current location. The current setup of this level makes more sense to explain why the mills propel starboy upwards, limits the speed of gameplay and highlights the details of the area around each mill. However, the revisions made to this game have yet to be playtested in a way that verifies these changes are definite improvements to the game. So far, it has only been played incidentally rather than at player request and I have not had the opportunity to observe a player winning, as I did with the revised balloon mini-game.
5.4 Optimization

Optimization is a familiar and necessary process for developers working in VR or mobile media, and especially to those who are working with both simultaneously. The term refers to optimizing the game’s performance, getting graphics to display at the highest quality possible without lowering the speed at which new frames are rendered. As soon as we moved our project to a mobile device, the Unity profiler window became a constant consultant in our development process. Optimization is a tedious and emotionally draining process. Developers are all probably familiar with the sinking feeling of pinpointing the spike in the profiler’s graph of CPU Usage, then following the dropdown chain to an asset or script that represents hours of work and needs to be downsized. Then, once the profiler is showing a relatively conservative amount of CPU usage the final build will, due to some unanticipated discrepancy between platforms, present new problems that do not appear in the editor. The optimization for Voxel Bay began after the game moved to a mobile platform and occurred in stages. It is a decision intensive process, where the developer needs to decide which states the game components should coexist in, or whether it is better to deprecate one of the game features in favor of game performance. We needed to make big changes as we converted our initial project from targeting computers connected to the oculus, to mobile devices. As we continued to add features to the game we had to make a couple more retrospective passes on content that we were no longer planning on changing.

Figure 12 Screenshot of Unity’s profiler tool
From my work on Voxel Bay and other projects for VR and mobile, I have learned to optimize strategically. It is important to identify the target platform and performance early in development to minimize the efforts required to optimize. Make builds as significant features of the game are developed and test them to check performance. Add debugging features such as a UI element that displays the speed at which frames are rendered and options to run the most computationally demanding scenario possible in the game. Follow the game through all the way to the end. I have a very hard time consuming media multiple times, and this is even more difficult for me when it is a piece of media I have created, so this is the optimization practice that I have the hardest time following. There are several ways I have approached this to maximize the effective use of my time. Sometimes I include shortcuts or faster gameplay for debugging. If the changes made for debugging are not invasive and do not structurally alter the game, they should not be reflected in performance. If a character moves more quickly along a preset track, testing is faster and gameplay is unchanged, though for games such as puzzle platformers this may not be a viable testing strategy. Make lists of the recurring and one-time errors that you observe. Once a list of bugs is established, trying to solve and reproduce them is a balancing act of time and meticulous precision. The most precise approach is to address each bug separately, but because that is extremely time consuming a smaller team without a group responsible solely for quality assurance will want to group bugs that can be approached together in one build without interfering with one another’s debugging processes. This could include grouping bugs that occur in different scenes, times or areas of the game, but ultimately this needs to be done on a case by case basis and can sometimes interfere with optimization.
Chapter 6: EVALUATION

The development of this project is structurally atypical for an MFA thesis project. My personal research interest is nested inside the research interests of others furthering the project as well as the application of the finished game. Because of this, the creative process developed organically in bursts that met the immediate needs of the situation. It would be easier to evaluate if the timeline had been planned explicitly and I could anticipate the progress curve against which to measure my contribution. Voxel Bay evolved repeatedly beyond any original plans that I had for it, and I feel that its success has surpassed any expectations I could have held.

6.1 Clinical Trial Surveys

In July 2016 Voxel Bay entered official clinical trials conducted by Dr. Dunn’s team of clinicians. These continued to February 2017, and included twenty-five users, half of which underwent infusions playing the game alongside the other half who underwent the infusions with no anxiety relief. The latter group is referred to in the trials as the “Standard of Care” group (SOC), while the former is referred to as the “VR” group. Patients, caregivers, and nurses participating in these trials filled out surveys at the end of the procedure. Participants answered questions about their anxiety levels and their interest in using virtual reality equipment as a distraction technique prior to and after the procedure. The survey feedback and observations made during the trials created a comprehensive preview of the way the application could be used in clinic and some of the challenges it may face.

From qualitative observation of the trials, I saw that most children were excited to try the virtual reality game and, for those in the VR group, caregivers almost all agree that the game is an effective distraction that improves the experience for the patient. Patients in the VR group reported significantly lower levels of pain on a scale of 0 to 100, which verifies the basic premise that Voxel Bay is more helpful as a distraction than a non-VR distraction. Furthermore, NCH
statistician Joseph Stanek conducted an analysis of the trial data which demonstrated that the virtual reality group did not spend a longer amount of time on their medical procedures than the SOC group. This means that it is a viable option for use in clinic because it is not a less efficient option for clinicians.

Below are graphs showing the average values of patient and caregiver responses from both groups. The questions are posed so that the lowest value answers are the better situation for the patients. The average values marked in answer to the following questions are included in the graphs:

1. How worried or nervous are you? A "0" means you are NOT AT ALL worried/nervous. The bigger the number, the more worried/nervous you are. A "100" means you are VERY worried/nervous."
2. Did the distraction technique change your level of anxiety? A "0" means the distraction technique DECREASED your anxiety level a lot. The bigger the number, the less the distraction technique decreased your anxiety level. A "100" means the distraction technique INCREASED your anxiety a lot."
3. Did the distraction technique change your level of pain? A "0" means the distraction technique made your pain a lot BETTER. The bigger the number, the less the distraction technique helped your pain. A "100" means the distraction technique made your pain a lot WORSE."
4. Did you like the distraction technique? A "0" means you REALLY LIKED the distraction technique a lot. The bigger the number, the less you liked the distraction technique. A "100" means you really did NOT LIKE the distraction technique.

Looking over the survey data, I’ve made the following observations:

1. The SOC patient group marked the most initial anxiety before the procedure.
2. The VR Patient group liked their distraction technique the most.
3. The SOC patient group had a lower value for the change in pain question, meaning that they’re pain felt more improved than the VR patient group’s pain.
4. The VR caregiver group had the highest values (worst) for change in anxiety.
5. Conversely, The VR patient group had the lowest (best) values for change in anxiety.
6. Both groups’ caregiver answers for change in pain and likeability are almost the same value.

Observation 3 and 4 are unexpected and difficult to explain. I think, this could be partly due to the unintuitive scale system that assigns a value of 0 to “the best change” and 100 to “the worst change”. Observation 5 was anticipated by the study and supported by the assumption garnered from precedent research. The discrepancy between the caregiver’s perception of likability and the patient’s mostly shows that the caregivers do not realize how much the patients like what they are doing. While this data is interesting to review, I think we must sample a bigger trial size and revise the surveys to get more conclusive results.

Figure 13 Multi-question comparison graph
Figure 14 Initial Anxiety Graph

Figure 15 Change in Anxiety Graph
6.2 Clinical Trials Observation

In addition to reviewing patient, caregiver and nurse survey data, I observed clinical trials first hand and was able to notice some interesting and not otherwise unnoted features that emerged in the system that I worked with others to create. One observation of mine is that the multi-player dashboard setup reinforces an open line of communication between clinicians and patients. Though children are often depicted as playing video game silently in isolation, in this experience most children would try to talk to the adults in the room about what they were seeing in the game, going as far as to point out cool virtual sights to their parents/guardians (before the infusion). The clinicians also wanted to create a list of level specific prompts to ask patients, who would then be motivated to engage with the game more to find the answer. To this end, I recorded a list of points of interest throughout Voxel Bay and gave it to the clinicians. The social interaction included in the distraction experience contributes as a distraction factor for the patient-player to focus on and comforts them because they are neither alone during their procedure, nor worried about the group of the people gathered around watching and conducting the procedure.
6.3 List of Factors Contributing to Patient-Player Centric Clinical Game System

My research has allowed me to identify a list of unique factors in the design of the overall experience of a game that serves as a distraction technique for the pediatric patient-player. The list of unique factors is as follows:

1. The patient-player must feel immersed in the game to the exclusion of thinking about their surroundings.
2. The patient-player’s attention to the game must be sustained through the duration of their medical procedure.
3. A connection between the patient-player and the other participants must be maintained.
4. The patient-player must not be required to move their arms to play the game.
5. The game must continue to be interesting for the patient-player over the course of multiple return visits.
6. Playing the game must not significantly increase the amount of time spent in clinic.

As described in previous sections of this paper, our team designed a system that meets these requirements using a combination of techniques and some of which presented new problem solving challenges to be implemented in our system. The components we included in the system to address the list above were a virtual reality head-mounted display platform, game mechanics that reinforce players’ physical sensations, removal of interstitials and abbreviated game format to sustain attention, remote control and camera view features to maintain a connection with other participants, microphone input to keep the patient-player still and designing replayable experiences for players to continue feeling immersed during return visits.

6.4 Evaluation of My Contribution

My contribution was successful in establishing an immersive universe for children to play in, but needed to be improved upon when a few of the breathing input mini-games failed to attract patient-player interest and were not even played very much. The mini-games that I designed with an intention to be soothing were the least popular ones. This result leads me to think that videogames are typically soothing in a distracting way, rather than a deliberately calming way. There are a few exceptions I can think of, (Euphoria, Cloud, and some simulation games that
provide players a facsimile of farming or trucking) and these games have a lot of movement and content that fill the stimulus void created by very repetitive interactions. The relatively small amount of these games, even in hospital settings, indicates to me that attempting to approach patient-player anxiety reduction through deliberate soothing methods is a more experimental choice that relies on different core design choices than other games and may yield less predictable responses from player populations. The games have been revised since the clinical trials ended. I feel that their failures were the temporary type of failure that is a natural part of any creative research process. Overall, I feel that my biggest contribution to Voxel Bay was the design and development of the five breathing games and that this is a successful part of the game.

The character design that I contributed to the game helped a lot with the overall game quality and world building that many viewers have commented sets Voxel Bay apart from other games developed for healthcare. If I could have spent more time on this part of the process, or perhaps budgeted my time a bit differently, I would have liked to develop the characters further and create even more implied narrative throughout the game. I could do this by changing the characters or environments as you return to them on a second loop around the bay, linking the existing characters together somehow or adding new characters that arrived since the player last passed by. The repetition related changes to character or environment design would also make the game more replayable. Most of our efforts to make the game replayable involve procedurally generated levels, but changing the difficulty level or even objective of the game would exponentially improve replayability. Though the development of Voxel Bay has ended in the context of this research paper, it will undoubtedly continue to expand in the clinical setting and could perhaps grow in some of the ways noted above.

6.5 Next Steps
Voxel Bay has grown far beyond the expectations I ever had for it. There is potential to develop more content in the same series of mini-games and continue expanding the same application or even to create a series of related applications. Members of our collaboration and others we have spoken with about developing the project have proposed a variety of ideas about educational content, developing customized hardware and specifically targeting other patient demographics. The potential for growth reflects our position in the overlap of a Venn diagram of
two rapidly evolving fields, healthcare and virtual reality technology. Having worked so closely with the components of the project, I can see that there are many branches to further explore. Even small adjustments in development platform, hardware or target demographic could lead to new insights relating to healthcare, design or both. Personally, I am excited to see what changes time could bring and how those will relate to the content of the game.
Works Cited


