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Exploring Virtual Reality Applications in Pediatric Healthcare – Use Case in Pediatric Radiation Oncology

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At the end of the day, we're all here to help the kids who come under our care.

Sincerely,
Jorge A. Gálvez, M.D. Candidate for Master's in Biomedical Informatics.

Abstract

What is the project?

The project describes a framework for producing and incorporating a virtual reality tour of a pediatric healthcare facility into clinical practice at a children's hospital. The project will focus on establishing the technical requirements to capture video and format the video for optimal display in a virtual reality environment.

Why is it important?

Children undergoing medical treatment in a hospital setting can have anxiety for a number of reasons, including separating from parents, entering a foreign environment, and undergoing uncomfortable. Virtual reality immersion has the potential to provide an introduction to the novel environment to facilitate desensitization as well as to distract children during vulnerable periods. Virtual reality technology is entering the consumer market and is becoming increasingly accessible and portable.

How will it be done?

The project determines the technical requirements of producing a virtual reality video in a hospital setting. The video, which is a tour of a pediatric proton radiation therapy facility at The Children's Hospital of Philadelphia, is optimized for display on consumer-level virtual reality devices including the Oculus Rift (Oculus VR, Facebook, Menlo Park, CA) and smartphones. The virtual reality video allows the

user to experience the tour from a first-person point of view, and allow control of the camera angle with head-motion tracking.

The video was created in collaboration with a child life specialist who is experienced in guiding children and adolescents through the proton radiation therapy facility. Video recording was conducted with GoPro Hero3+ (GoPro, San Mateo, CA), Kodak 360 (Kodak, Rochester, NY) camera mounted on tripods. Video editing was completed with final cut pro and formatted to display on immersive 360 video player, KolorEyes™ (Kolor, GoPro, San Mateo, CA).

How will you determine its value?

The value of the technical requirements will be the successful implementation of the virtual reality video tour at the Perelman Center for Advanced Medicine's Pediatric Radiation Oncology program. The success of the implementation will be assessed through feedback from stakeholders including: Patients, patient's families, radiation therapists, child life therapists, and clinical staff. A protocol will be devised to formally assess the user acceptance of the virtual reality headset in the pilot project.

Background

Virtual Reality

The term virtual reality has been loosely applied to interactive computer game experiences ranging from video games simulating a world to high-fidelity virtual reality experiences that create a fully interactive virtual world that can be experienced by a user. Traditionally, high-fidelity virtual reality simulators were limited to dedicated facilities or laboratories that invested heavily into sophisticated computers and equipment to facilitate creation of the virtual environment. Virtual reality laboratories such as the Human Interaction Laboratory at Stanford University consist of a sophisticated head-mounted display, motion tracking cameras that detect body movement, sophisticated surround sound systems and equipment to manipulate the floor.[A]

Virtual reality applications in healthcare are flourishing. The combination of commercial off-the-shelf (COTS) technology in the areas of video cameras, video editing software and virtual reality headsets is lowering the entry bar for virtual reality production and experience. [B,C] Previously, virtual reality experiences were limited to multi-million dollar, specialized simulation laboratories such as the Human Interaction Lab at Stanford University. Affordable options are available now, such as Consumer the Oculus Rift.[B] This device is currently available for developers

[A] https://vhil.stanford.edu Accessed 6/9/2016.
[B] https://www.oculus.com/en-us/rift/, Accessed 6/9/2016.
[C] https://goo.gl/UOJQ17 Accessed 6/9/2016.

(Software Development Kit 2) and consumers alike. Further, virtual reality video content is becoming widely available via services such as Google cardboard (Google, Mountain View, CA), Kolor Eyes™, and the New York Times NYT Virtual Reality (The New York Times, New York City, NY).

Virtual reality applications in healthcare settings have been explored in various specialties and care settings over the years. The National Library of Medicine Medical Subject Headings lists three subject headings for virtual reality: "Virtual Reality Exposure Therapy" (395 results), "Virtual Reality Immersion Therapy" (42 results), and "Virtual Reality Therapy" (1754 results) [search conducted on May 13, 2016]. Studies describe applications such as Wii video games and computer online video games where users create avatars and engage in a virtual world as 'immersive' virtual reality. As such, the term virtual reality has clearly evolved with the available technology over years. This capstone focuses on current immersive virtual reality interactions that allow the user to view the virtual world without being exposed to visual stimulus that is outside of the camera.

Immersive virtual reality has been applied in various clinical settings for patients across a wide age spectrum, including young children and young adults.[1-12] Therapeutic applications include therapeutic rehabilitation for amputation injuries, chronic pain conditions, Meniere's disease, and stroke rehabilitation.[3-6,8,11,12] Multi-media applications have permeated through pediatric healthcare settings to provide distraction and alleviate anxiety.[13] The development and widespread access to mobile devices and tablets has made access to these applications affordable and easy. There are multiple modes of delivery of interactive videos and experiences; multi-media videos delivered by glasses have been shown to be a successful intervention to alleviate anxiety of entering the operating room and undergoing general anesthesia induction in a pediatric operating room.[14]

Pediatric radiation therapy

Adolescents scheduled for radiation therapy sessions may be able to undergo treatments without requiring general anesthesia. A course of radiation therapy (RT) generally consists of one simulation session followed by 10 to 35 daily radiation sessions. Each treatment session can last between 30 and 90 minutes depending on the treatment set up and delivery.[15] Safe and effective radiation therapy requires precise patient positioning and absolute control of patient movement. Many children require an immobilization device, usually an individually molded plastic shell that fits tightly over the face. For young or anxious children, sedation or general anesthesia is often required, while adolescents and older children may undergo RT without general anesthesia.[15,16]

Child life therapy

Hospital Child life specialists provide introduction to the facilities and coach patients with coping strategies to facilitate successful completion of radiation treatment sessions.[17] Individuals receiving RT without general anesthesia often work with child life specialists to learn about RT and what is involved, as well as to develop coping strategies.

One of the first challenges patients face is learning about the facility. However, it is difficult to provide patients a tour of the facility prior to beginning the treatments because of the clinical demand on the RT rooms. Many patients learn about the facility while watching videos or looking at photographs in albums.

Research Goal

The purpose of this capstone is to establish the technical requirements to produce a virtual reality video that can be delivered via commercial off-the-shelf technology in a pediatric healthcare setting at the bedside. The production evaluation will include sections on videography equipment and video editing software requirements. COTS virtual reality platforms are reviewed and discussed regarding feasibility and usability. The goal is to establish the minimum viable product, targeting the simplest approach to achieve a user-friendly video that requires minimal expertise to use and is acceptable for patients.

Lastly, a case study will be presented involving the production of a virtual reality tour in a pediatric healthcare facility and the requirements to implement the virtual reality application in clinical practice. The tour will be designed for adolescents eligible to complete RT without general anesthesia to facilitate introduction to the RT facility.

Methods and Requirements

In this section, we explore the different options and requirements for virtual reality video production and display, particularly in a pediatric healthcare setting. A summary of the virtual reality requirements is available in Summary of Implementation Requirements for Virtual Reality Applications in a Pediatric Healthcare Setting

The following section consists of two tables that outline the requirements for virtual reality applications in healthcare settings. Table 1 describes the hardware and configuration requirements that should be addressed when designing and implementing a virtual reality program for children in a pediatric healthcare setting. Table 2 summarizes the requirements for virtual reality video production. The production requirements describe video camera categories including benefits and limitations of each system.

Table 1 and video production requirements in

Table 2**.**

Virtual Reality Design Requirements

Presently, commercially available technology for virtual reality viewers is expanding rapidly. Devices such as the Oculus Rift, Google cardboard, Samsung Gear VR (Samsung, Seoul, South Korea), and PlayStation VR (Playstation, San Mateo, CA) to name a few. Content development such as interactive games and videos often require access to specific software development environments, acquisition of developer licenses, and specific hardware configurations. For the purposes of this capstone, the focus will be on producing an interactive video tour of the healthcare facility with a minimalist approach to facilitate clinical application. In other words, the video tour produced should allow for maximal utility. In addition to viewing the video in a virtual reality environment, it should also be possible to view the video in a conventional video player such as a computer, tablet or smartphone.

Virtual reality players rely on two lenses or eye pieces to produce a binocular viewing experience. The binocular configuration relies on the inter-pupillary distance, which is the distance between the eyepieces is optimized for a range of head sizes that is consistent with young adults to adult heads. The range is dependent on variables such as the interpupillary distance, or the distance between each pupil, measured in millimeters. The Oculus Rift is configured with an interpupillary distance of 63.5 millimeters, based on the average distance from a survey of 4,000 U.S. army soldiers.[D] This limits the applications in a pediatric hospital, where many children have much smaller interpupillary distances. If there is mismatch of interpupillary distance between the individual and the device, the individual may not be able to simultaneously see each image projected by the Oculus Rift. This is an inherent limitation of most virtual reality viewers that rely on binocular image projection.

Virtual Reality-induced Motion Sickness

An important consideration for virtual reality simulation development is that the simulation has the potential to cause motion sickness to the user.[18] Visual input obtained from the virtual reality headset can simulate motion while the viewer is in a stationary position (i.e. simulation of a rollercoaster while the user is sitting in a stationary chair), so the vestibular system is not detecting movement. Such discordant sensory input can trigger motion sickness including nausea, vomiting, increase or decrease in heart rate, and increase in perspiration. This illusion of movement that can occur from visual input in a virtual reality environment is referred to as vection.[18]

Another factor contributing to 'cyber-sickness' is the tracking performance of the virtual reality headset. When a user wearing a head-mounted virtual reality viewer turns his/her head to the right, the virtual reality environment would also show a comparable movement. If the rate of movement is different in the virtual world,

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[D] https://developer.oculus.com/documentation/intro-vr/latest/concepts/bp_app_imaging/ Accessed 6/9/2016.

either faster, slower, or not a smooth, in contrast with the actual head movement, there may be a higher chance of experiencing motion sickness.[18] As such, virtual reality developers are continuously improving the head-tracking technology with accelerometers, gyroscopes and external markers such as infrared beams and motion tracking cameras.

Strategies to minimize motion sickness from virtual reality environments cover general principles:[E]

- Minimize non-forward movements
- Minimize vection
- Minimize acceleration
- Minimize camera yaw
- Use a static frame of reference

Video Recording Considerations

Camera Motion

In order to minimize the risk inducing motion sickness, virtual reality videos can be recorded with a stationary camera using a tripod or appropriate mounting bracket. Many successful virtual reality videos in the public space use this technique. Rather than traversing in space, the video is recorded from stationary locations and scenes transition from one location to another using standard transitioning effects.[F] The videos recorded applied some of the factors mentioned in the Virtual Reality-induced Motion Sickness Section. Specifically, the recordings involved minimal

[E] http://uploadvr.com/five-ways-to-reduce-motion-sickness-in-vr/ Accessed 6/9/2016.
[F] http://www.nytimes.com/2016/01/21/opinion/sundance-new-frontiers-virtual-reality.html?_r=1 Accessed 6/9/2016.

camera movement thus reducing (1) non-forward movements, (2) vection, (3) acceleration and (4) camera yaw. Static frame elements such as a dashboard or cockpit were not applicable in this setting, therefore were not used.

If the video must use motion, it is important to stabilize the camera to minimize unintended camera shake. Gyroscopic stabilizers provide excellent tools to facilitate smooth video capture (

Figure 1). Smooth movements with minimal acceleration and deceleration are ideal. The videographer should focus on minimizing sudden movements of the camera, including zooming in or out. The only scene that involved motion in the video was the simulation of laying down on the proton beam table. This was achieved with a gyroscope mount and a GoPro Hero3 camera (

Figure 1).

Figure 1 – Gyroscopic stabilizing gimbal.[G] The device shown above (G3 Ultra, GuiLin Feiyu Electronic Technology Co, Ltd. Guilin, China) was used to record parts of the video tour.

Camera Perspective

The camera's position in relation to the scene is also critically important. The goal of a virtual reality video tour is to provide a realistic first-person perspective. The end-user should be kept in mind. In the case of adolescents and adults, the camera should be placed at the approximate height of an average-sized adult. Alternatively, if the intention is to demonstrate the point of view of a child, the camera should be at a lower height.

Video Recording Equipment

Video cameras optimized for virtual reality recordings tend to have wide-angle lenses that provide a large field of view. In some cases, the cameras can provide hemispherical views (180 degrees) or full-spherical views (360 degrees). One advantage of using a single camera is that video editing is simpler since only all of the video is contained on a single file from a single point of view for each scene recorded. Most commercially available video editing software suites may be suitable to edit video recorded in this way. However, a limitation of single-camera recording is that the field of view may be limited. For example, if a fully immersive, 360-degree scene recording is necessary; it may not be possible with most

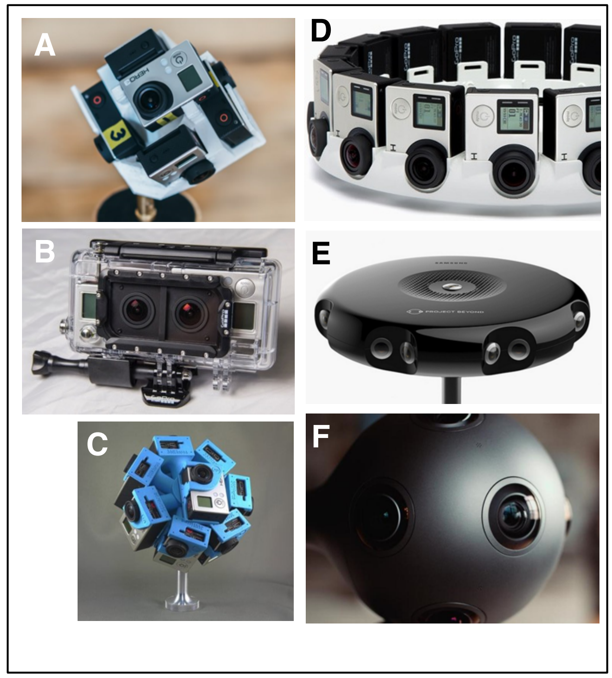
[G] http://www.feiyu-tech.com/products/5/ Accessed 6/9/2016.

commercially available video cameras. Furthermore, wide-angle cameras that capture large fields of view may have image distortion around the edges of the frame. This can become noticeable; as straight lines may appear curved around the edges of the video frame.

In order to record 360-degree videos, multi-camera configurations are becoming widely available. These range from customized camera mounts that allow multiple cameras to be used together to specialized cameras that record the complete spherical 360 degree images (Figure 2). In these cases, the video editing software must be able to 'stitch' or attach the videos together to create a seamless image. For example, if two 180-degree cameras are used to record a circumferential scene, the video editing software must be able to merge the two videos to create the full sphere (Figure 3).

One of the benefits of the multi-camera configurations is that it minimizes the angle distortions seen around the edges of video recordings with wide-angle camera lenses. However, these configurations are costly and require powerful computers with extensive hard drive capabilities to manage the large video files as well as video editing.

Figure 2 – Multi-camera mounts: (A) 3D-printed mount for 6 GoPro Hero 3 or Hero 4 camera models[H]; (B) Stereoscopic camera mount for two GoPro Hero 3 cameras, includes a synchronization cable to synchronize start/stop video timestamps[I]; (C) 3D-printed mount for 9 GoPro Hero 3 or Hero 4 camera models[J]; (D) Google's JUMP 3D-printed mount for 16 GoPro Hero 3 or Hero 4 camera models[K]; (E) Samsung project beyond virtual reality stereoscopic video camera[L]; (F) Nokia Ozo virtual reality camera[M].



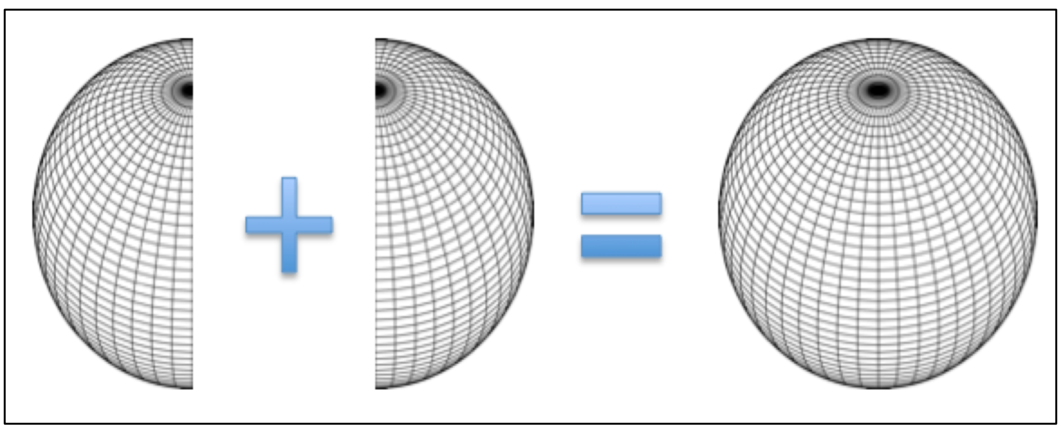


Figure 3 – Video footage from two or more cameras can be 'stitched' together to create a complete sphere. In this example, two hemi-spherical video recordings are combined to make a complete 360 scene.

[H] https://www.pinterest.com/pin/319755642269265358/ Accessed 6/9/2016.
[I] http://www.provideocoalition.com/gopro-dual-hero-3d/ Accessed 6/9/2016.
[J] http://2.bp.blogspot.com/-S7ov4CSUFqQ/VG7V6kbtNXI/AAAAAAAABXw/-FxldbtKmEg/s1600/360_heros_rig.jpg Accessed 6/9/2016.
[K] https://vr.google.com/jump/ Accessed 6/9/2016.
[L] http://thinktankteam.info/beyond/ Accessed 6/9/2016.
[M] https://ozo.nokia.com Accessed 6/9/2016

Video Editing

Video editing software has become widely available across device platforms. Smartphone devices on all platforms provide some options for video editing while more sophisticated video editing software is available as standard software packages on consumer desktop and laptop computers. Recordings performed with one camera that do not require stitching of two video-clips together to increase the field of view can be performed with a basic video editor. Professional video editing suites such as Adobe Premier (Adobe, San Jose, CA), Final Cut Pro (Apple, Cupertino, CA) offer more advanced options.

In order to stitch together videos from multiple cameras, specialized video editing software is required. Commercially available options provide free trials but limit the amount of video that can be edited. The software bundles range from approximately $700 and up. These video editors require powerful computers to perform the necessary processes to stitch together the video clips. As an alternative, Google's JUMP (Google, Mountain View, CA) platform is poised to revolutionize the field by compiling the video stitching if recorded with the custom JUMP camera mount (Figure 2D). The JUMP example uses only the central vertical strip of video from each camera to stitch together a smooth video with minimal distortion. Needless to say, multi-camera video editing requires a high level of organization and access to a high-performance fast hard drive, since high quality videos consume large amounts of hard drive space.

Further exploration of video editing software to create full 360-degree circumferential video was deferred due to cost and time constraints. All video editors available to achieve this required software licensing that was unavailable to the author at the time of the writing. Camera manufacturers introduce new video cameras that tailored to various consumer and professional 360-degree circumferential video.

Immersive Virtual Reality Video Players

Immersive virtual reality videos viewing options are becoming increasingly accessible on various platforms and the options listed in this capstone will likely be obsolete by the time of its publication. Video viewers can be used on personal computers or laptops, but viewing the videos on a traditional computer screen is not representative of an immersive virtual reality experience.

Current options to experience virtual reality content range from use of smartphones or tablets with viewing hardware such as Google Cardboard (Figure 4). Proprietary players such as the New York Times Virtual Reality video viewer provide a smooth virtual reality experience. It delivers content produced and/or curated by The New York Times and cannot be used to view video content not available through their service. Kolor Eyes™ (GoPro Inc, San Mateo, CA) provides a platform to display immersive virtual reality videos and is freely available for smartphones and computers.[N] Alternative platforms for viewing self-produced or acquired virtual

[N] http://www.kolor.com/kolor-eyes/ Accessed 6/9/2016.

reality video clips are emerging, including youtube.com (YouTube, San Bruno, CA) 360 degree videos and Total Cinema 360 to name a few.

While Kolor Eyes™ offers video-editing software specifically designed to stitch together videos, this software requires the purchase of a license. The viewer companion app, Kolor Eyes™ is freely available. The Kolor Eyes™ application desktop version can detect virtual reality viewers configured with the computer such as the Oculus Rift, and displays any video supplied to it in a stereoscopic format. The video player receives input from the virtual reality headset and adjusts the video displayed based on the "head movements" detected by the device. The smartphone version of Kolor Eyes™ can also be used with or without a virtual reality viewer such as the Google Cardboard.

The smartphone application can be configured to use the touchscreen to navigate the viewing direction, or to use the device's accelerometer and gyroscope sensors to adjust the viewing angle. Video files can be loaded directly onto the smartphone and made accessible "locally" to the application for development. The smartphone application performs well but may be affected by the hardware that it is used on. Installing the video locally on the device allows users to view it regardless of an Internet connection, but may still experience delays in loading the video files. The playback control performance may also vary across devices based on the hardware and software performance.

More sophisticated devices such as the Oculus Rift and Samsung VR use a combination of freestanding hardware or a computer workstation that can project the virtual reality video. The dedicated virtual reality viewers offer additional advantages such as ergonomic design, higher quality video and motion tracking technology and support more sophisticated virtual reality applications such as games and educational software.

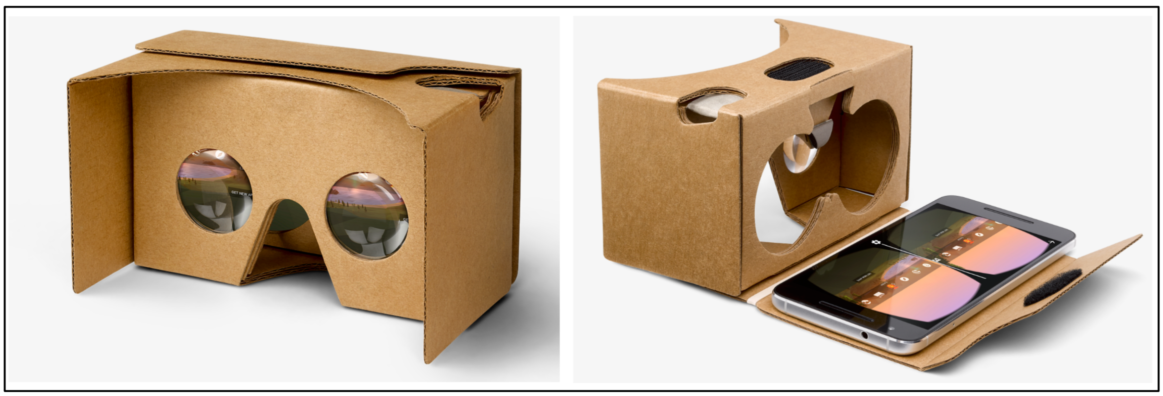


Figure 4 – Google cardboard sample[0] – Design specifications for the Google cardboard virtual reality viewer are freely available online. The device consists of two lenses and cardboard folded hold a smartphone as shown. The cardboard device can be used with a smartphone to create a simple virtual reality experience. The smartphone viewing software may use the device's accelerometer and gyroscope to adjust the viewer's perspective during the virtual reality experience. In other words, the viewer would be able to control the virtual viewing angle by turning and tilting their head while viewing the video.

Oculus Rift Configuration and Set Up

Setting up the Oculus Rift was reviewed with the Child Life specialist and individuals providing technical support. The instructions are attached in Appendix 2 – Oculus Rift Set Up Instructions. A dedicated space with a chair, desk, two wall power outlets, Oculus Rift and laptop computer with two USB ports and one video output

[0] https://goo.gl/BjDHzO Accessed 6/9/2016.

connection (HDMI, VGA or DVI). The computer should be either a windows PC or a Mac with legacy operating system (10.9.5) or earlier. The Oculus Rift drivers should be pre-installed in the computer. The Oculus Rift Drivers are available from the developer site https://developer.oculus.com/downloads/.

The Oculus Rift presents several challenges for implementation in a clinical setting. Specifically, it requires a dedicated computer working area. The space should include a chair for the user and be clear of objects that could injure the user during the virtual reality experience. There are multiple cables with complex configuration that requires time to set up. The Oculus Rift uses an infrared camera to provide a reference point for head movement tracking. If this camera moves during use, the user can experience unexpected movements in the virtual reality environment, which can lead to motion sickness. The Appendix focuses on the configuration with a Mac (Apple, Cupertino, CA) computer because that is the configuration available for use in our clinical environment.

Standalone players that rely on smartphones have the advantage of increased access and portability. There are abundant options for cardboard devices starting at a few dollars. These devices work with any smartphone or hand-held video player that fits within the device. The devices have two eye pieces and allow the user to experience a binocular view of a virtual reality environment. The Kolor Eyes™ video player functions well with this configuration despite a few limitations. The limitations are that sometimes the video takes a long time to load or stream. Users may experience delays or interruptions while watching the video.

The head-tracking features depend on the device's accelerometers. While these features work well, one limitation is that the device does not always point in the direction of interest in the video at the beginning. For example, the proton therapy tour was produced in 180-degree recording or less. As a result, the video is only displayed on half of the sphere, while the other half is a black background. When starting to view the virtual reality video in a smartphone Kolor Eyes™ viewer, the video may start pointing at the black screen rather than the area of interest. Users would have to manually adjust the viewing angle to view the video. If the head tracking feature is used, the user would have to turn their head around until they can see the video.

In terms of maintenance, dedicated viewers such as the Oculus Rift may be costly and require maintenance/updates to the software and hardware over time. In contrast, the smartphone players are generally compatible with most smartphones. The cost of the virtual reality viewers for smartphones is low enough that it can be acquired for each individual patient as a disposable device.

Financial Considerations

Although virtual reality viewers are becoming increasingly available in the consumer market, they are still expensive. Dedicated players such as the Oculus Rift and the HTC Vibe (HTC, Taoyuan, Taiwan) cost between $600 and $800. These devices require a dedicated computer with high performance graphics card which limits their portability. The Oculus Rift DK2 set up used for this case study was configured with a Macbook pro.

Smartphone devices are able to deliver a lower quality virtual reality experience at a more affordable price. Viewing adapters for smartphones rely on the design on Google cardboard and are available from a variety of retailers starting at $5. Smartphone applications to view virtual reality videos are either free or only cost a few dollars in the respective application stores. In a healthcare setting, the low cost of these viewers may facilitate adoption since each viewer may be used as a "single use" or single patient device.

Pediatric Healthcare Setting Implementation Requirements

Infection Control

The infection control specialist at The Children's Hospital of Philadelphia raised several concerns related to using virtual reality devices and presented recommendations for cleaning the devices. Foam pads that contact the face and elastic head straps on these devices pose the greatest infection risks. It is not possible to clean the foam pads with hospital approved disinfectant solutions. The specialist recommended obtaining an impermeable cover for the foam pads, such as a vinyl cover which could be cleaned before and after patient use. Regarding the elastic head straps, the specialist recommended not to use the head straps. The head straps can be folded back over the front of the device.

The complete set of cleaning recommendations provided are:

- Clean plastic surfaces with bleach-based, non-alcohol disinfectant wipes
- Clean lens surfaces with single-use alcohol and single-use microfiber cloths
- Cover the foam pads with a vinyl cover which can be cleaned with the bleach-based disinfectant wipes
- Do not use the elastic head bands on patients
- Do not use the device if the patient has healing wounds on the face or scalp
- Do not use the device if the patient is on isolation or contact precautions

Age Restrictions

One of the general limitations of Virtual Reality headsets in pediatrics is that children have smaller heads than adults. The distance between the eyes, also known as the interpupillary distance, is a key variable that can greatly affect the ability of an individual to experience the binocular visual display delivered through most virtual reality headsets. For example, the Oculus Rift has a fixed interpupillary distance of 63.5mm, and the device recommendations state that it should not be used by individuals younger than 13 years of age.

Summary of Implementation Requirements for Virtual Reality Applications in a Pediatric Healthcare Setting

The following section consists of two tables that outline the requirements for virtual reality applications in healthcare settings. Table 1 describes the hardware and configuration requirements that should be addressed when designing and implementing a virtual reality program for children in a pediatric healthcare setting. Table 2 summarizes the requirements for virtual reality video production. The production requirements describe video camera categories including benefits and limitations of each system.

Table 1 – Summary of Virtual Reality Display requirements in Pediatric Healthcare Setting

Requirement	Detail	Recommendation	Hardware/Software Used
Portable Virtual Reality Hardware	Hand-held devices ranging from cardboard viewing boxes to devices that integrate with certain smartphones	Portable devices are appealing, but in some cases may yield a lower quality experience.	Google Cardboard and iPhone 6 using Kolor Eyes™ software iTunes used to load video content directly into iPhone
Stationary Virtual Reality Hardware	Virtual reality goggles that depend on a separate computer or console to receive video input.	Dedicated devices may deliver a higher quality virtual reality experience but may require technical expertise and dedicated space to use.	Oculus Rift SDK 2 Computer (see Oculus Rift system requirements) 2 USB Connections 1 HDMI Connection 1 Power supply CPU: Intel i5-6400 / i5-4590 equivalent or greater Memory: 8GB RAM or more
Infection Control	Consider single v. Multi-use device. Single use devices include cardboard goggles that fit over smartphone. Multi-use devices may be challenging to clean, particularly if there are porous or hard to reach surfaces with sensitive electronic components.	Consult infection control specialist to establish cleaning recommendations. Cardboard may be corrugated and pose infection threat. Multi-use devices should be cleaned/disinfected per hospital's specific policies.	Single-use lint cloths to clean lens pieces on virtual reality viewer Alcohol (70%) wipes used to clean Oculus Rift plastic surfaces VR vinyl cover designed for Oculus Rift
Motion Sickness	Children in a healthcare setting may be more prone to nausea and vomiting. Consider using virtual reality videos and experiences that minimize motion sickness.	Reduce use of: Non-forward camera motion Acceleration Vection Yaw If appropriate, use a static frame of reference (cockpit, car dashboard, window frame)	Tripod GoPro articulating camera mounts VR video was recorded using a tripod. The only portion of the video with motion was recorded with a stabilizing gyroscopic gimbal.
Perspective	Camera placement and relation to the objects in a scene can affect the perspective. The height of the camera and size of the video on the projected screen can make objects appear larger or smaller than they are in real life.	Camera height was set around 4.5 feet above the floor, approximately the height of an adolescent. The viewing area was adjusted to minimize distortion of the objects in the scene.	Tripod mount was adjusted to approximately 4.5 feet. Video viewing frames were adjusted to minimize the distortion. The dimension settings were: Scale video to 49.1%; Center position on the following coordinates: X= -149.8px y= -0.3px
Age Restrictions	The interpupillary distance for children is typically smaller than adults. This may affect the ability to experience binocular video	Video recording with tripod is strongly encouraged. If motion is required, minimize sudden acceleration/deceleration or sudden changes in camera angle.	Institutional Review Protocol allowed use for patients older than 13 years.
Virtual Reality Video Viewer	Virtual reality video viewers project video display in pairs to allow users to view footage in a binocular format.	Video frames may be duplicate images or two distinct video frames that would allow depth perception or 3D effect.	Kolor Eyes ™ (http://www.kolor.com)was used to project the recorded videos on a virtual reality headset. The player is compatible with personal computers and smartphone devices.

Table 2 - Video Production Requirements

Requirement	Detail	Recommendation	Hardware/Software Used
360 Immersive Video Recording	360 degree videos allow a user to view an entire scene through a virtual reality viewer.	These videos are technically challenging to produce and may be more difficult to view because the field of view is not fixed. Points of interest may be missed if the user is "looking the other way." Image quality and distortion may be variable and are impacted by the camera configuration used. Multi-camera systems	Not implemented in this capstone. Require specialized equipment such as 360 degree cameras or multiple cameras with customizable mounts. Specialized software for video editing is necessary to link videos together into a single file. Software licenses are evolving and becoming increasingly accessible. Video recordings must be synchronized either at the time of recording or later at video editing. Tested recording video with 6 GoPro cameras on a custom mount (see below).
180 Immersive Video Recording	180 degree, or hemisphere, recordings allow the user to view half of a scene.	These videos may be recorded with specialized cameras with fisheye lenses. Image quality and distortion may be variable and are impacted by the camera configuration used. This can be achieved with a single camera.	Recorded video with Kodak Pixpro 360 camera
Less than 180 Immersive Video Recording	Video recordings allow the user to view a smaller portion of a scene.	These videos may be recorded using standard camera lenses. Wide angle lenses (small focal length) such as those available on GoPro cameras allow a wide field of view but may distort the image. Lenses with higher focal length have a smaller field of view but cause less image distortion. One advantage of this format is that it is compatible with non-Virtual Reality video players and displays.	Recorded video with GoPro Hero 3+ Black edition. May be viewed on any standard video player.
Stereoscopic Recording	Stereoscopic video allows depth perception, akin to 3D movies.	These videos must be recorded with specialized equipment. The minimum requirement is one pair of cameras pointing in the same direction.	Recorded test video with Dual GoPro 3D Hero System. Consists of a two-camera housing with a synchronization cable that allows user to start/stop recording simultaneously with both cameras.
Mounting Equipment	Various camera mounts used to stabilize and secure cameras in a fixed position	Tripods allow mounting of video cameras in a fixed position. This allows recording still videos without movement or camera shake. Custom camera mounts specific to GoPro cameras allow various mounting options for GoPro cameras.	We used a camera tripod (Dolica ProLine Aluminum Alloy Tripod and Ball Head AX620B100 62"). The tripod has a ball head that allows maximum flexibility to adjust camera angle. It also has a level to facilitate positioning. GoPro camera mounts shown in Figure 5, "The Frame", "Flex Clamp" and "Jaws" to attach the GoPro cameras (single and stereoscopic) to the Tripod. Multiple camera mounts were employed simultaneously to record the same scene with both camera configurations (Dual Hero system and Kodak Pixpro 360).
Stabilizing Equipment	When camera motion is necessary, the image can be stabilized mechanically with stabilizing gimbals (Figure 1) Alternatively, video footage may be stabilized at the video-editing stage with software filters (Final Cut Pro, Motion bundle).	Image stabilization is critical to ensure optimal user experience in virtual reality environments. Any camera shake or fast motion may result in discomfort or	Image stabilization was achieved with the FeiyuTech G3 Ultra gimbal using a single GoPro Hero 3 Camera.
Video Editing Software	Video editing suites for virtual reality videos are developing rapidly. Options include client-based applications such as Final Cut Pro, or web-based applications such as Google Jump (https://vr.google.com/jump/),	Video editing software suites allow managing video files and application of special effects such as image stabilization, cropping, transforming (re-sizing), adjusting soundtrack.	Video was edited with Final Cut Pro X (10.2.3) on a MacPro 3.5 GHz 6-Core Intel Xeon E5). All video recordings used consisted of single-camera feeds. Multi-camera feed video quality was equivalent to single-video and not included in the final video.

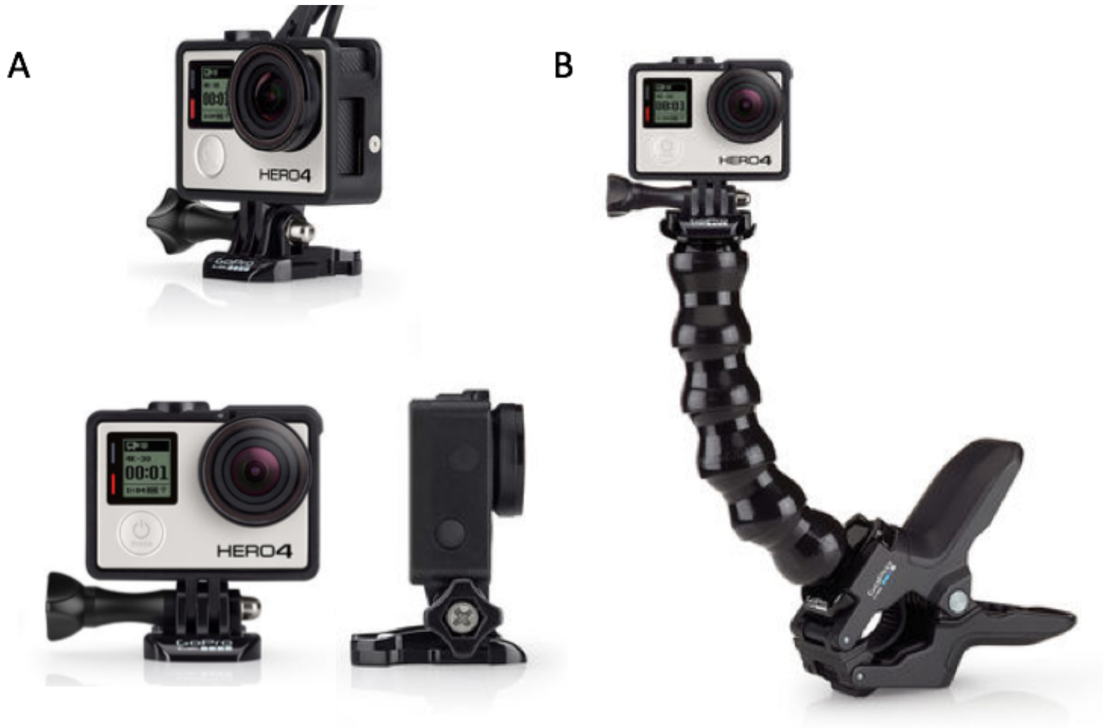


Figure 5 - GoPro camera mounts.[P] Panel A - GoPro "The Frame" mount for a single GoPro Hero 4 or Hero 3 camera mount. This mount is not waterproof and does not interfere with the built-in microphone. Panel B –GoPro "Jaws" and "Flex Clamp" mounts attach to any GoPro camera mount and allow the camera to be fixed to any stationary object that fits the "Jaws". The "Flex Clamp" is a series of interlocking ball joints that allow a range of adjustments of the camera's position.

Virtual Reality Project Case Study – Radiation Therapy Tour

The Children's Hospital of Philadelphia provides care for children and adolescents undergoing radiation therapy for a range of tumor types and locations. The process involves a multi-disciplinary approach to assist patients and their families with coping and managing the stress of treatment and its side effects. Individuals

[P] http://shop.gopro.com/mounts-accessories#prefn1=compatibility&prefv1=HERO4%20Black Accessed 6/9/2016.

specializing in child life therapy focus on assisting with developmentally appropriate coping techniques to assist throughout the course of treatment.

Once a patient receives a diagnosis and consents to undergoing radiation therapy, the child life therapist will engage the patient and their family to introduce the facility. The process begins with a tour of the entire facility, the waiting area and its resources, as well as the patient rooms, changing areas and radiation therapy rooms.

Video Recording

Permission to record video was obtained from the facility and staff volunteered to participate in recording and producing a video tour during off-hours. The video was recorded with assistance from two radiation therapists and a child life specialist from the Roberts Proton Therapy Center at the Perelman Center for Advanced Medicine. Video footage was recorded according to the script outline (Appendix 6). The video was recorded using the following equipment:

- GoPro Hero 3 silver and black edition
- Kodak Pixpro 360
- Tripod
- 3D-printed camera mount for 6 GoPro cameras
- Feiyu gyroscopic stabilizer gimbal for GoPro Hero 3 series cameras
- GoPro Dual Hero stereoscopic recording housing
- Assortment of GoPro camera mounts, clamps and housings.

Each scene was recorded with a stationary camera on either a tripod or mounted on a stationary device with accessory equipment. The clinical locations of interest involve either small space such as a patient waiting room to larger spaces with oversized medical equipment such as the Proton treatment room. Cameras with wide-angle lenses were chosen to capture the key elements of each room. In order to minimize image distortion, the key elements of interest in each scene was positioned near the center of the field of view. The scenes were recorded with the following camera configurations:

1. Single GoPro Hero3+ black edition
2. Dual GoPro Hero3+ black edition (stereoscopic)
3. Custom mount for 6 GoPro Hero3 (2 Black, 4 Silver) cameras (360-degree video footage)
4. Kodak Pixpro 360 camera

The scenes were all amenable to be recorded from a single perspective, typically by placing the cameras in a corner of the room, approximately at eye level. This would allow pointing the cameras to the areas of interest as shown in Figure 6, Figure 7, and Figure 8. The virtual reality video viewing software and viewing headsets provide a narrower field of view than that obtained by the camera as show in Figure 9, Figure 10 and Figure 11.

360-Degree Video Recording

The 360-degree video footage obtained with the custom mount for 6 GoPro cameras proved to be impractical. Setting up the cameras required securely mounting the cameras and synchronizing the video cameras to a single remote control to ensure that the video recordings had the same timestamps. The camera recording performance was not always optimal and required re-configuration during the recording sessions. Placing the camera in the rooms also proved to be challenging since the camera would be positioned on a tripod and the tripod would be visible in the field of view. As a result of these limitation on the video recording sessions, the use of the 360-degree custom mount was minimal.

Virtual Reality Viewing Environment Configuration

The virtual reality viewing environment was configured as shown in Appendix 2 – Oculus Rift Set Up Instructions. The environment consisted of a quiet room with a chair and a desk. A laptop (Macbook Pro, 2.3 GHz Intel Core i7; 16GB 1600 MHz DDR3 RAM) was configured with the Oculus Rift DK2 and both were connected to an external power supply. The Oculus Rift was fitted with a vinyl cover over the foam pads to allow cleaning between users. The user was sitting down in a comfortable chair with a backrest. The head straps were adjusted to fit the user's head comfortably. Users were instructed to put the device on with their eyes closed and to open one eye at a time while adjusting the device to ensure an adequate viewing experience. Once the device was adjusted, the video playback started. The users were allowed to watch the video in full.

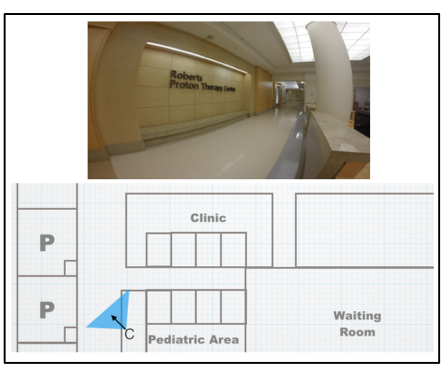


Figure 6 – Screenshot from Proton Therapy virtual reality tour (top panel) and schematic of the Proton Therapy center (bottom panel). The camera location is shown at point C, with a black arrow for the viewing direction. The blue triangle represents the field of view. The scene above shows the hallway outside the Proton treatment rooms.

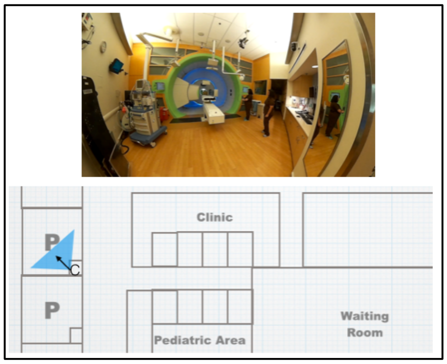


Figure 7 - Screenshot from Proton Therapy virtual reality tour (top panel) and schematic of the Proton Therapy center (bottom panel). The camera location is shown at point C, with a black arrow for the viewing direction. The blue triangle represents the field of view. The scene above shows the gantry of one of the Proton treatment rooms.

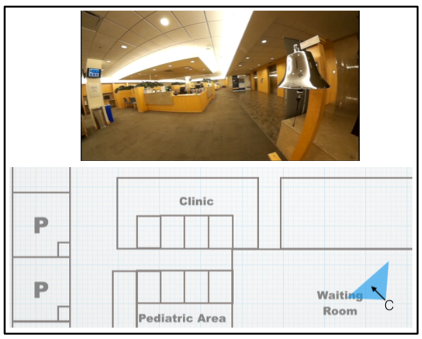


Figure 8 - Screenshot from Proton Therapy virtual reality tour (top panel) and schematic of the Proton Therapy center (bottom panel). The camera location is shown at point C, with a black arrow for the viewing direction. The blue triangle represents the field of view. The scene above shows main reception and patient waiting room. The bell shown on the picture is used by patients after completing the last radiation treatment sessions and symbolizes a milestone in each patient's experience.

Figure 9 – Video footage in the Proton treatment room recorded with a GoPro Hero 3 camera. The red line represents the field of view that is displayed on a virtual reality headset. Head tracking motion can be used to look around the surrounding scene.

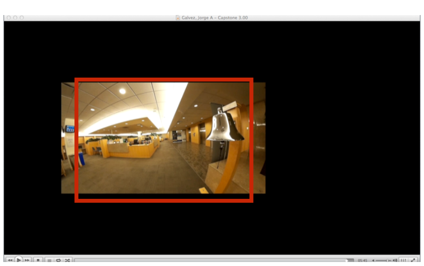


Figure 10 - Video footage in the patient reception and waiting room recorded with a GoPro Hero 3 camera. The red line represents the field of view that is displayed on a virtual reality headset. Head tracking motion can be used to look around the surrounding scene. The video was cropped as shown in order to minimize distortion to the apparent proportions to the viewer. If the video is displayed at full cropping, the objects will appear disproportionately larger than in real life. The settings for

image transformation on Final Cut Pro were: Scale 49.1%; Position on the following coordinates: x = -149.8px; y = -0.3px.

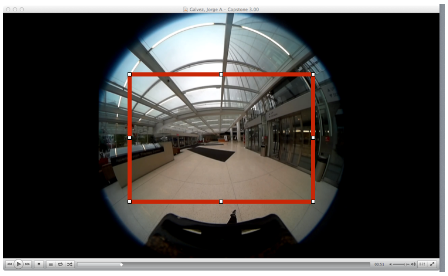


Figure 11 – Video footage in the main lobby for the Perelman Center for Advanced Medicine recorded with the Kodak Pixpro 360. The spherical edges fit within the rectangular video frame. The red line represents the field of view that is displayed on a virtual reality headset.

Results

Virtual Reality Video

The video produced in standard m4v format and is compatible with any media player. The immersive virtual reality experience is delivered via Kolor Eyes™ viewer on a computer configured with an Oculus Rift. Alternatively, the video can also be viewed on the Kolor Eyes™ mobile app in a smartphone or tablet. The immersive experience allows adjustments of the user's perspective with changing the position of the device (i.e. tilting or rotating the screen). For completely immersive experience, the video may be viewed with a virtual reality headset such as the Oculus Rift. The video was displayed the video on an Oculus Rift Development Kit 2 successfully using the configuration outlined in Appendix 2 – Oculus Rift Set Up Instructions. The wide-angle cameras allow capturing a large field of view and are particularly useful in clinical areas that have limited space. However, the image required cropping to allow accurate perspective of scale. The image resolution on the Oculus Rift Development kit is limited, thus affecting the readability of small font or distinguishing fine details in a room.

The virtual reality viewer will always display a spherical video, even if the actual content of the video does not fill the viewing area. The result is that the video produced here is displayed on one half of the sphere while the other half remains a black screen. This is a result of not using the 360-degree video cameras. When using the Oculus Rift with its tracking equipment, the video will always be displayed looking at the center of the screen. However, if the video is displayed with another device that does not have the ability to track the device's position in reference to a stationary object (i.e. a smartphone with the cardboard viewing goggles), the video may display the black screen first. When the user turns the device around to become oriented, the video footage will come into view.

All of the video cameras used had a range of wide-angle lenses. While the lenses provided the ability to record wide scenes, there was some image distortion along the edges of the frame as shown in Figure 6. However, this was tolerated well by individuals who experienced the virtual reality tour during its production.

Usability Feedback

Informal usability testing was conducted while producing the video. None of the users tested reported experiencing uncomfortable symptoms such as nausea, lightheadedness or motion sickness. The usability testing guided the selection of the scenes included in the final videos as well as the length of each section (approximately 15 seconds of video with 5 second transitions). Individuals commented on the comfort of wearing the Oculus Rift as well as any feelings of motion sickness. None of the users informally tested reported motion sickness or discomfort while wearing the Oculus Rift.

The video content was adjusted under the guidance of the Child Life therapists from the Proton Therapy Center to ensure it fit into their workflow. Specifically, two versions of the video were produced. One version included footage from outside of the building and transitioned into the lobby, elevator and waiting room. The second video was a shorter version that began in the pediatric area of the Proton Treatment facility.

Pre-Investigation Usability Testing

The following usability questionnaires were administered after conducting a demonstration of the virtual reality tour using the Oculus Rift in a controlled environment. The individuals had experience caring for patients in various capacities at the Perelman Center for Advanced Medicine, Roberts Proton Therapy Center and The Children's Hospital of Philadelphia:

Survey #1 – Child Life Therapist

1. Do you plan on incorporating the virtual reality video in your practice at the Proton Therapy Center?
   "Yes, I do. It is a more detailed preparation experience than using just pictures alone because the teenager gets to visually experience what it will be like to walk into the proton room and lay down on the table. The video is much closer to reality than just a picture. It is also easier to go into detail about each step of the procedure as the patient is looking around the room and watching the machine move."
2. Do you see any challenges incorporating it into your practice?
   "The only challenges I see are making sure I have the equipment easily available and the limitation of the age range (13 to 17). I believe this could benefit many more kids/teens/young adults if the age ranger were wider."
3. Do you feel comfortable setting up the virtual reality video device by yourself? (answer for each device)
   I don't have any experience doing it on my own yet so I think I would need another run through.
   a. Oculus Rift – *would prefer practice*
   b. smartphone with Google cardboard – *pretty comfortable*
4. Do you think that patient family members would benefit from experiencing the virtual reality proton therapy tour?
   "Absolutely. It would be a great introduction to the proton experience, especially for families who have a child getting general anesthesia. They don't have the ability to walk back to the proton machine with their child for treatment (they say goodbye to the child in the induction room). Many families

are curious about the machine and what it looks like. This video would be a neat learning experience for parents."

5. Are there any other clinical settings that may benefit from a virtual reality tour or distraction?
   "Yes! I think this would be beneficial to every procedure area of the hospital that kids experience (for example, interventional radiology). It is a more comprehensive preparation experience because the child can really imagine physically being in that room. I also think that for some kids, it would be beneficial to have a distraction video experience during procedures (when appropriate), like a blood draw or IV placement. For kids who want distraction and don't want to "look," this would be great."

Survey #2 – Pediatric Anesthesiologist

1. Did you have any discomfort while watching the virtual reality video?
   "No"
2. Having seen the virtual reality video and the actual proton therapy room, how do you think the two experiences compare?
   "I think the virtual reality version is a good representation of the actual proton therapy room."
3. Do you feel comfortable setting up the virtual reality video device by yourself? (answer for each device)
   a. Oculus Rift
      "No, have never done it"
   b. smartphone with Google cardboard
      "No, have never done it"
4. Do you think that patient family members would benefit from experiencing the virtual reality proton therapy tour?
   "Yes, I think it would be good especially as a web-downloaded option prior to ever coming to CHOP or HUP"
5. Are there any other clinical settings that may benefit from a virtual reality tour or distraction?
   "Autistic children"

Survey #3 – Research Assistant

1. Did you have any discomfort while watching the virtual reality video?
   "I had no discomfort."
2. Having seen the virtual reality video and the actual proton therapy room, how do you think the two experiences compare?
   "The only difference that I noted was the size of the actual room was smaller than what appeared on the VR. Perhaps that is due to the difficulty of imaging depth of the Oculus, but whatever the case, that was the only difference I could note."
3. Do you feel comfortable setting up the virtual reality video device by yourself? (answer for each device)

a. Oculus Rift
"I do."
b. Smartphone with google cardboard
"Familiar with the concept, but never performed. So, no."

4. Do you think that patient family members would benefit from experiencing the virtual reality proton therapy tour?
"I wondered if more can be done to make the tour unique. I am less familiar with the technology, but I think perhaps a video for the oculus might be of more use, which in my estimation would allow for the patient to better imagine themselves in the setting. The still images I think are only beneficial in looking around the proton room, but the other areas (lobby, prep room) seem to be too similar to a typical web page used in other settings. I know that motion sickness can be an issue, so my suggestion may not be feasible, but it is really the only feedback I can offer."
5. Are there any other clinical settings that may benefit from a virtual reality tour or distraction?
"So far my only thought is the various radiology spaces similar to Proton. I'm thinking also maybe for MRI including an audio recording that can prepare the patient for the noise."

Discussion

VR Tour discussion

The project completed the production of a virtual reality tour of the Proton Beam facility that is viewable on a smartphone, computer, or virtual reality headset. The image quality is adequate to provide a tour of the facility, but on certain devices it is quite pixelated and does not allow the user to read signs with small letters. The video is mostly stationary, thus allowing the users to passively experience the tour, or to move the device or their head to visually explore each part of the tour. In order to minimize motion sickness, we did not experiment with camera motion such as walking with the camera, or changing the camera angle within each scene. The proton therapy virtual reality tour described above was well tolerated by various individuals on informal usability testing. Users coached through the experience did not experience discomfort or nausea. This may be a result of the stationary nature of the scenes recorded. There was very little movement in each of the scenes, and most of the movement was slow and predictable.

The video was produced with the intention of delivering the content with any video player. This was intentionally done to maximize future use of the video regardless of access to specialized immersive virtual reality systems. As of the time of the writing, the video has been successfully delivered via smartphone based Kolor Eyes™ using a generic Google cardboard model (Figure 12) and the Oculus Rift as shown in Appendix 2 – Oculus Rift Set Up Instructions.

One advantage of the Google cardboard experience is the portability and ease of configuration. However, the cardboard is not as comfortable from an ergonomic standpoint. Furthermore, the corrugated cardboard poses an additional challenge for use in a healthcare setting, namely that there is a risk of biologic contamination from larva eggs within the corrugated folds (Figure 13). Non-corrugated cardboard boxes do not carry the same risk of infection. One advantage of the Google cardboard configuration is that it can be issued to the patient as a single-use item, thus does not require washing or sterilization in order to use it with another patient.

The Oculus Rift configuration does provide a more comfortable user experience because the device is ergonomically designed with foam pads for the forehead and effectively blocks external visual stimulation and light. The user is unable to see anything outside of the virtual reality headset. Therefore, the experience is truly immersive, in contrast with the Google cardboard configuration, which does not completely block out all light and views outside the headset. However, the Oculus Rift DK2 as tested does have several limitations.

First, setting up the device is time consuming and requires a clean working surface to configure all the necessary equipment. The set up process can take from 5 to 15 minutes or longer if the individual is not experienced with the steps. The Oculus Rift functions with a computer and requires two USB connections and one video connection such as HDMI, DVI or VGA. Since this project began, Oculus Rift withdrew ongoing support of Apple computers. For the purpose of this configuration, the Kolor Eyes™ program supports video output that is viewable on the Oculus Rift DK2 using the Macbook Pro computer described in the methods. However, the configuration is heavily dependent on legacy software versions and may not be stable. This co-dependence on high-end computers will continue to be a limitation for portable virtual reality applications that may be usable in a healthcare environment.

Second, in order to use the device in a clinical or research setting such as the Proton Radiation treatment facility, the device requires a thorough cleaning with hospital-approved disinfectant solutions. Commercial devices such as the Oculus Rift often present challenges for disinfection in healthcare settings. The Oculus Rift has a foam pad that contacts the face around the eyes, and two elastic straps that are placed around the head which cannot be easily cleaned or disinfected. Hospital infectious disease specialists recommended placing a waterproof cover over the foam pad which can be cleaned with hospital-grade disinfectant wipes.

An unexpected advantage of modifying the Oculus Rift head strap configuration for use was that that by avoiding use of the elastic head straps, the user is able to control exposure to the virtual environment by holding the headset to their eyes much like a pair of binoculars. If the user experiences any discomfort, they can promptly remove the headset from their face.

Third, the device specifications recommend that individuals 13 years or older use the device. This is due to the fixed position of the device eyepieces and limited range for interpupillary distance for adults.

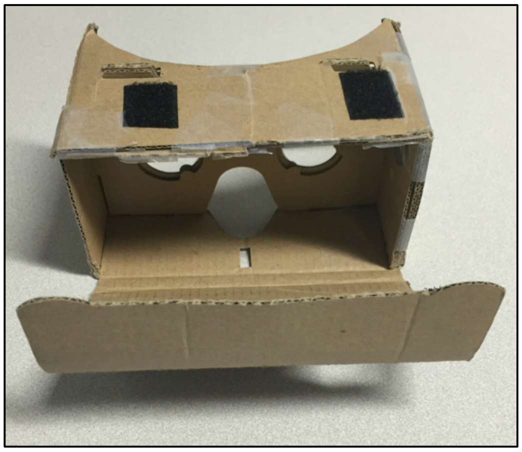


Figure 12 – Google cardboard model for initial smartphone-based Virtual Reality Testing.

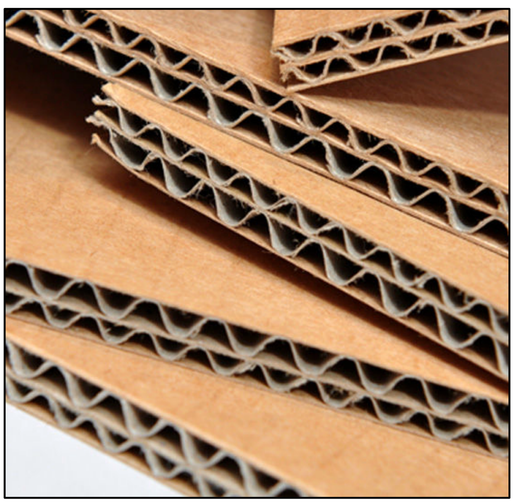


Figure 13 – Corrugated cardboard[Q] carries potential risk of infection due to the area within the corrugations. There is potential for larva and other insect contaminants to be present in the cardboard. This may not be appropriate for use in a clinical environment, particularly if patients are at risk of infection. This is more likely in an oncology environment where patients are receiving chemotherapy, radiation therapy and may even undergo bone marrow transplants.

Future work will explore with camera motion in an immersive virtual reality environment. Furthermore, current commercially available equipment for immersive virtual reality has limited screen resolution, thus affecting the ability to display fine details in the video. As this technology improves, so will the ability to

[Q] http://goo.gl/3Krj1g Accessed 6/9/2016.

create more detailed videos such as procedure videos in the operating room and throughout the hospital. We plan to implement the virtual reality tour as a research protocol at our institution and evaluate patient tolerability as well as logistics such as device maintenance and cleaning.

Challenges of Video Production for Virtual Reality

One of the main unexpected challenges in this project was in identifying the appropriate video cropping to achieve realistic proportion of objects in the virtual environment. The process required iterative approach of video editing and publishing to the virtual reality device. The problem can arise from the time of the recording, particularly if the camera is positioned too high or too low in relation to the desired perspective. For example, if the desired perspective is that of a child, the camera should be placed at the expected height of the child. Alternatively, if the adult perspective is desired, the camera should be positioned at a higher location. These effects can be exacerbated if the video is not cropped appropriately.

Multi-camera video editing can be even more challenging from a camera synchronization standpoint. It is important for all of the camera timestamps to be perfectly synchronized. Furthermore, managing the files and completing the video rendering require a very powerful computer, particularly if video from 12 cameras is pieced together.

The scenes in the proton virtual reality tour did not require circumferential 360 video recordings. The footage in the final production video was obtained from a single camera shooting in one direction. One advantage of this approach is that it forces the viewer to focus on the displayed field of view. When circumferential video is displayed, users may be busy exploring the scene and miss the key elements if they're looking the other way (i.e. behind instead of forwards).

Recommendations

Virtual Reality technology is becoming widely available for consumer use. This technology has great potential for various applications in healthcare, such as assisting healthcare providers to introduce patients to the hospital setting and therapy areas such as radiation therapy as described. There are various ways to deliver virtual reality content, some of which may not be applicable in a pediatric population. For example, devices that have fixed interpupillary distance and are designed for adults may not work appropriately when used by children.

Generating content to create an immersive virtual reality experience is feasible with consumer video cameras. While it is possible to obtain cameras to make 360-degree videos, it is possible to create an equivalent experience with less sophisticated equipment as described. Wide-angle video cameras may cause image distortion around the edges, which will be noticeable in buildings as the walls may appear to be curved. Use of tripods or stationary camera mounts should be used to minimize camera movement. Stationary video scenes minimize the likelihood that users will experience motion sickness.

Infection control is also an important consideration when introducing any device in a pediatric setting. Hospital guidelines regarding device disinfection should be reviewed and a protocol should be developed for any headset used. Single-use devices such as the cardboard virtual reality headsets are appealing because of their portability and no need to clean between patient use. Specific attention should be paid to the type of cardboard employed to make the device. If the cardboard is corrugated, there may be a risk of infection due to the presence of insect larva within the corrugated folds.

Future directions

The video produced for this capstone project will be studies at the Perelman Center for Advanced Medicine in the Roberts Proton Therapy Center. The pilot project will focus on acceptability and usability by adolescent patients using the Oculus Rift DK2. The study has been approved by the Institutional Review Boards from the Children's Hospital of Philadelphia, Hospital of the University of Pennsylvania and Oregon Health & Science University. The study is currently enrolling patients ages 13 to 17scheduled to receive proton therapy with counseling from the Child Life Therapy specialists.

Another group of individuals that may benefit from the virtual reality tour are the parents and caregivers of infants and children receiving proton therapy. These individuals often want to learn more about the machines that are helping their child, but may not have opportunities to tour the treatment rooms because of the high clinical demand on the treatment space. The virtual reality tour may offer the opportunity to learn about the facility in a more controlled environment without interrupting access to the proton treatment room from patients that need radiation therapy.

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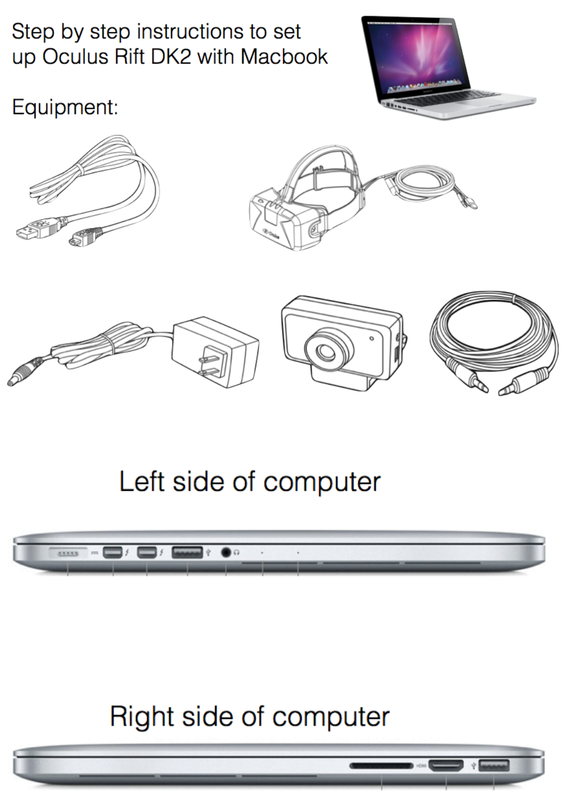
Appendices

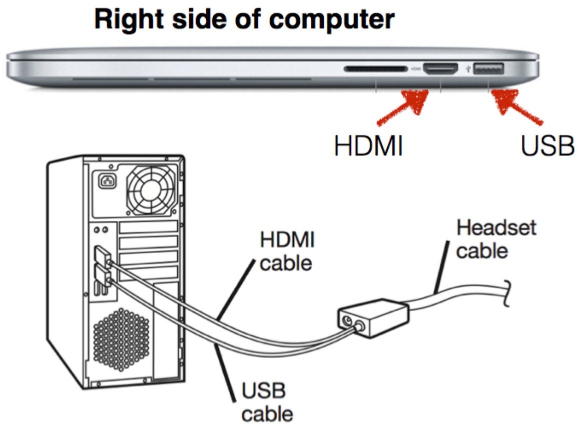
Appendix 1 – Proton Therapy Virtual Reality Tour

Title	Description	Link
Long Video Tour	Video tour starts outside of the building and progresses through the lobby, elevator into treatment areas. Designed for use at the main hospital and oncology clinics which are located outside of the radiation treatment facility.	https://vimeo.com/170681364 Password: chopvirtualreality
Short Video Tour	Video tour starts just outside of the consultation room where the tour is given. The first scene is the hallway with examination rooms. This is designed for demonstration at the radiation treatment facility.	https://vimeo.com/170681793 Passowrd: chopvirtualreality

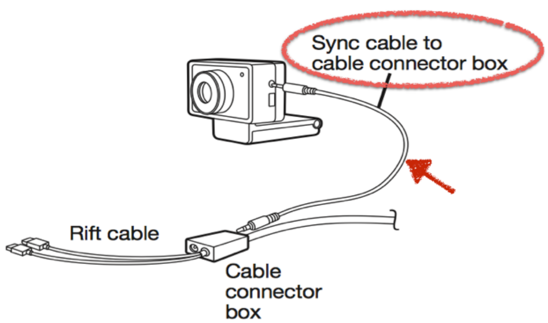
Appendix 2 – Oculus Rift Set Up Instructions



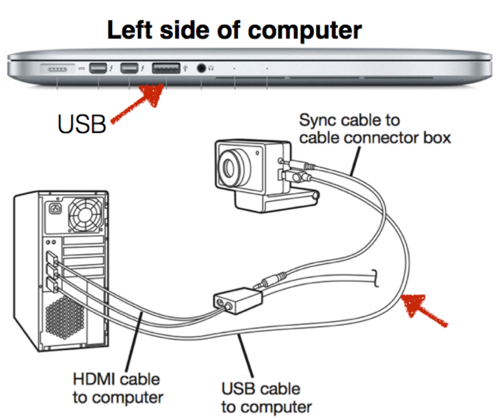
First, connect Oculus Rift cables to computer



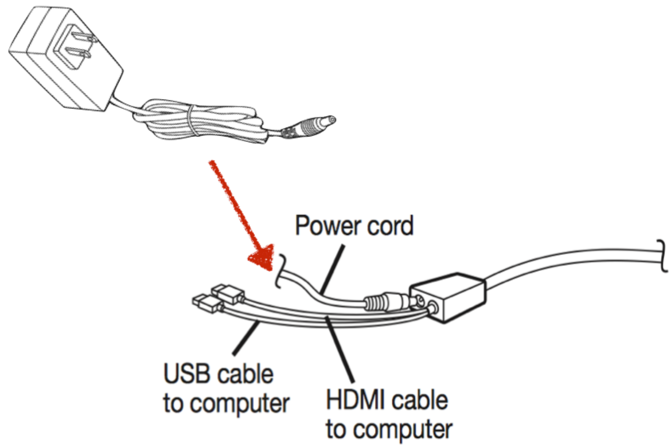
Connect sync cable to motion tracker



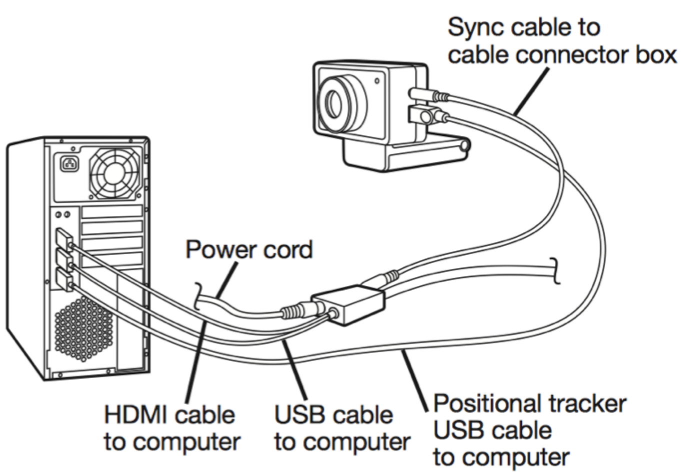
Connect USB cable from motion tracker to computer



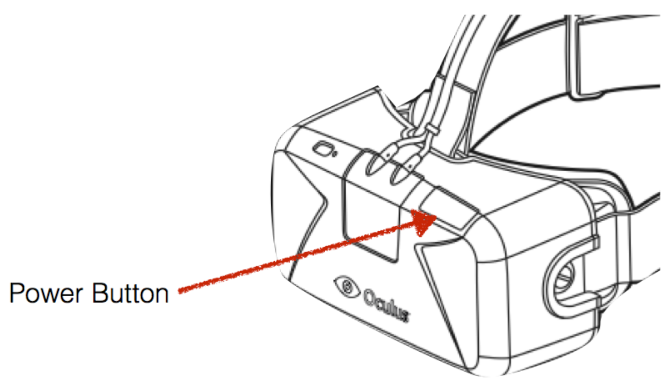
Connect Power supply to Oculus Connector



When the set up is completed,
it will look like this.

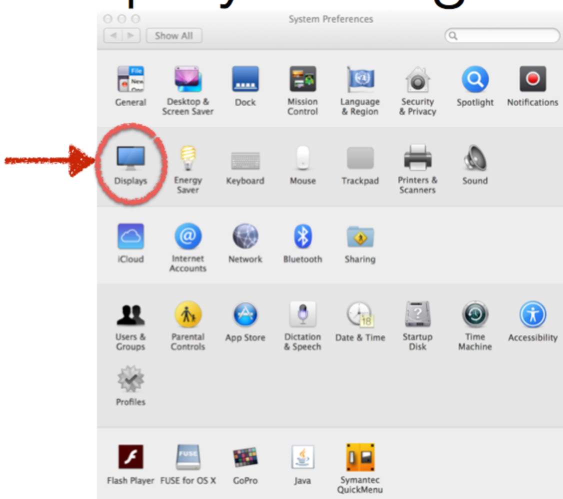


Turn Oculus Rift On

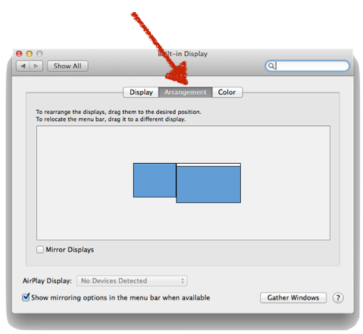


Once the Oculus Rift is powered on, go to the computer to adjust the display preferences as follows:

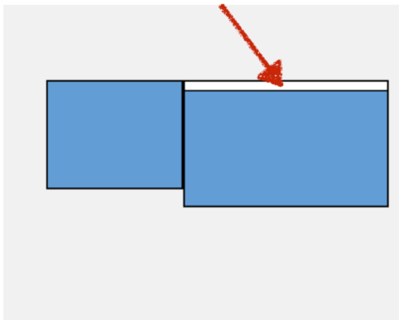
Display Arrangement



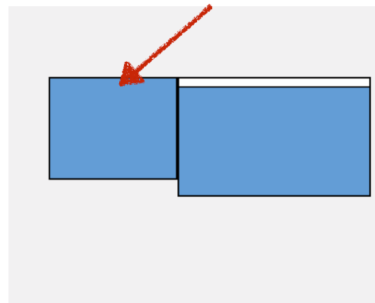
Display Arrangement



Move the menu bar from the Oculus Display to the mac display

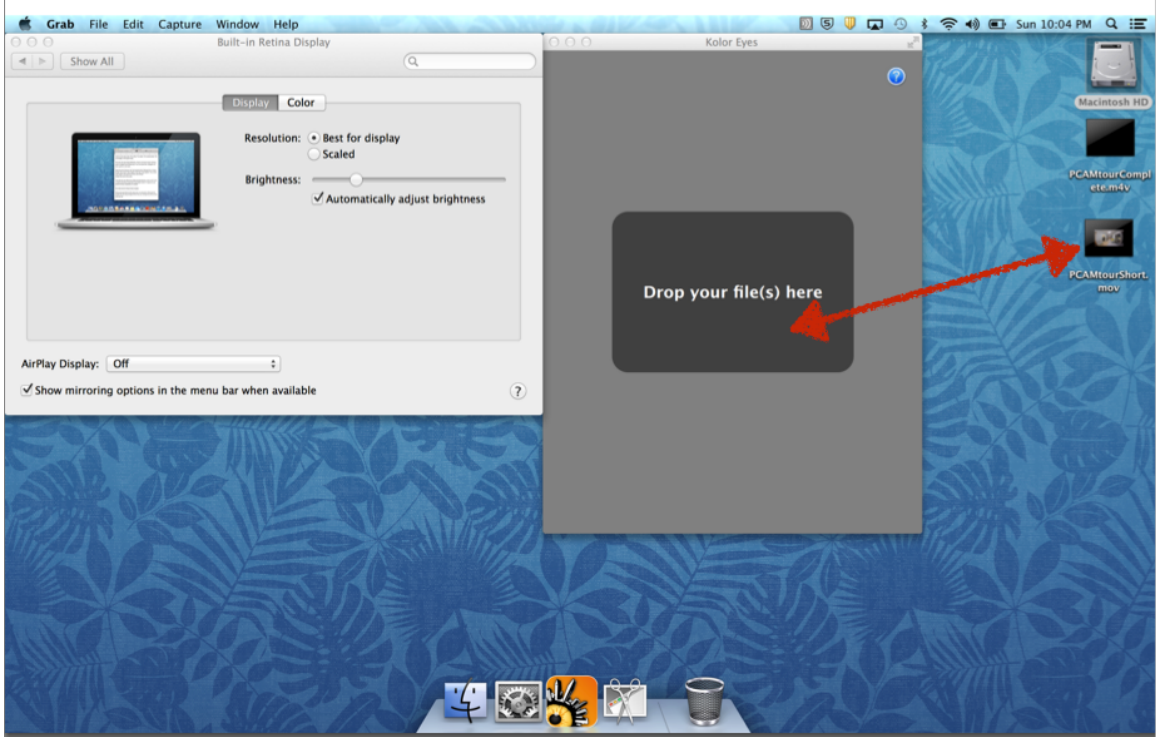


Move the menu bar from the Oculus Display to the mac display



Open Kolor Eyes

Drag the selected movie to the viewer



Appendix 3 – Proton Therapy Center Virtual Reality Tour Patient Questionnaire

1. How many times did you pause/stop the video? 0 / 1 / 2 / 3 Why?
____
2. How many times did you re-wind the video? 0 / 1 / 2 / 3 Why?
____
3. Did you complete the VRT? Yes / No If no, why not?
____
4. Do you think the VRT might help you to prepare to go through proton therapy?

   Yes / No / Not sure

5. Was there any part of the virtual reality tour that was really helpful? Yes / No If yes, explain
   ____
6. Was there any part of the virtual reality tour that was not helpful? Yes / No If yes, explain
   ____
7. Did you have any other questions about the Proton Therapy center after watching the VRT?
   Yes / No If yes, what are they?
   ____
8. Did you have any discomfort while watching the VRT? Yes / No If yes, what type of discomfort?
   ____
   If Yes, did you continue watching? Yes / No

   What did you do to improve your comfort?

   Nothing / Adjust headset / pause and resume watching VRT / Stopped / ?”
   [circle all that apply]

9. Would you like to watch a VRT that is similar to this one for other areas or procedures in the hospital?

   Yes / Might / No / I don’t know

   Other areas or procedures you would suggest:
____
10. Would you recommend that others watch the VRT? Yes / Not sure / No
____

Appendix 4 - Oculus Rift Developer Center Documentation and Software Development Kit (SDK)
https://www.oculus.com/en-us/dk2/

Documentation

INTRO TO VR

- **Oculus Best Practices**
  - **Introduction to Best Practices**
  - Binocular Vision, Stereoscopic Imaging and Depth Cues
  - Field of View and Scale
  - Rendering Techniques
  - Motion
  - Tracking
  - Simulator Sickness
  - User Interface
  - User Input and Navigation
  - Closing Thoughts
  - Health and Safety Warnings
- Frequently Asked Questions
- Public Displays and Activations
- Oculus Glossary

PC SDK

Introduction to Best Practices

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VR is an immersive medium. It creates the sensation of being entirely transported into a virtual (or real, but digitally reproduced) three-dimensional world, and it can provide a far more visceral experience than screen-based media. Enabling the mind's continual suspension of disbelief requires particular attention to detail. It can be compared to the difference between looking through a framed window into a room, versus walking through the door into the room and freely moving around.

Overview

If VR experiences ignore fundamental best practices, they can lead to simulator sickness—a combination of symptoms clustered around eyestrain, disorientation, and nausea. Historically, many of these problems have been attributed to sub-optimal VR hardware variables, such as system latency. The Oculus Rift represents a new generation of VR devices, one that resolves many issues of earlier systems. But even with a flawless hardware implementation, improperly designed content can still lead to an uncomfortable experience.

Because VR has been a fairly esoteric and specialized discipline, there are still aspects of it that haven't been studied enough for us to make authoritative statements. In these cases, we put forward informed theories and observations and indicate them as such. User testing is absolutely crucial for designing engaging, comfortable experiences; VR as a popular medium is still too young to have established conventions on which we can rely. Although our researchers have testing underway, there is only so much they can study at a time. We count on you, the community of Oculus Rift developers, to provide feedback and help us mature these evolving VR best practices and principles.

Note: As with any medium, excessive use without breaks is not recommended developers, end-users, or the device.

Rendering

- Use the Oculus VR distortion shaders. Approximating your own distortion solution, even when it "looks about right," is often discomforting for users.
- Get the projection matrix exactly right and use of the default Oculus head model. Any deviation from the optical flow that accompanies real world head movement creates oculomotor issues and bodily discomfort.
- Maintain VR immersion from start to finish—don't affix an image in front of the user (such as a full-field splash screen that does not respond to head movements), as this can be disorienting.
- The images presented to each eye should differ only in terms of viewpoint; post-processing effects (e.g., light distortion, bloom) must be applied to both eyes consistently as well as rendered in z-depth correctly to create a properly fused image.
- Consider supersampling and/or anti-aliasing to remedy low apparent resolution, which will appear worst at the center of each eye's screen.

Minimizing Latency

- Your code should run at a frame rate equal to or greater than the Rift display refresh rate, v-synced and unbuffered. Lag and dropped frames produce judder which is discomforting in VR.
- Ideally, target 20ms or less motion-to-photon latency (measurable with the Rift's built-in latency tester). Organise your code to minimize the time from sensor fusion (reading the Rift sensors) to rendering.

- Game loop latency is not a single constant and varies over time. The SDK uses some tricks (e.g., predictive tracking, TimeWarp) to shield the user from the effects of latency, but do everything you can to minimize *variability* in latency across an experience.
- Use the SDK's predictive tracking, making sure you feed in an accurate time parameter into the function call. The predictive tracking value varies based on application latency and must be tuned per application.
- Consult the OculusRoomTiny source code as an example for minimizing latency and applying proper rendering techniques in your code.

Optimization

- Decrease eye-render buffer resolution to save video memory and increase frame rate.
- Although dropping display resolution can seem like a good method for improving performance, the resulting benefit comes primarily from its effect on eye-render buffer resolution. Dropping the eye-render buffer resolution while maintaining display resolution can improve performance with less of an effect on visual quality than doing both.

Head-tracking and Viewpoint

- Avoid visuals that upset the user's sense of stability in their environment. Rotating or moving the horizon line or other large components of the user's environment in conflict with the user's real-world self-motion (or lack thereof) can be discomforting.
- The display should respond to the user's movements at all times, without exception. Even in menus, when the game is paused, or during cutscenes, users should be able to look around.
- Use the SDK's position tracking and head model to ensure the virtual cameras rotate and move in a manner consistent with head and body movements; discrepancies are discomforting.

Positional Tracking

- The rendered image must correspond directly with the user's physical movements; do not manipulate the gain of the virtual camera's movements. A single global scale on

the entire head model is fine (e.g. to convert feet to meters, or to shrink or grow the player), but do not scale head motion independent of interpupillary distance (IPD).
- With positional tracking, users can now move their viewpoint to look places you might have not expected them to, such as under objects, over ledges, and around corners. Consider your approach to culling and backface rendering, etc..
- Under certain circumstances, users might be able to use positional tracking to clip through the virtual environment (e.g., put their head through a wall or inside objects). Our observation is that users tend to avoid putting their heads through objects once they realize it is possible, unless they realize an opportunity to exploit game design by doing so. Regardless, developers should plan for how to handle the cameras clipping through geometry. One approach to the problem is to trigger a message telling them they have left the camera's tracking volume (though they technically may still be in the camera frustum).
- Provide the user with warnings as they approach (but well before they reach) the edges of the position camera's tracking volume as well as feedback for how they can re-position themselves to avoid losing tracking.
- We recommend you do not leave the virtual environment displayed on the Rift screen if the user leaves the camera's tracking volume, where positional tracking is disabled. It is far less discomforting to have the scene fade to black or otherwise attenuate the image (such as dropping brightness and/or contrast) before tracking is lost. Be sure to provide the user with feedback that indicates what has happened and how to fix it.
- Augmenting or disabling position tracking is discomforting. Avoid doing so whenever possible, and darken the screen or at least retain orientation tracking using the SDK head model when position tracking is lost.

Accelerations

- Acceleration creates a mismatch among your visual, vestibular, and proprioceptive senses; minimize the duration and frequency of such conflicts. Make accelerations as short (preferably instantaneous) and infrequent as you can.
- Remember that "acceleration" does not just mean speeding up while going forward; it refers to *any change in the motion of the user*. Slowing down or stopping, turning while moving or standing still, and stepping or getting pushed sideways are all forms of acceleration.
- Have accelerations initiated and controlled by the user whenever possible. Shaking, jerking, or bobbing the camera will be uncomfortable for the player.

Movement Speed

- Viewing the environment from a stationary position is most comfortable in VR; however, when movement through the environment is required, users are most comfortable moving through virtual environments at a constant velocity. Real-world speeds will be comfortable for longer—for reference, humans walk at an average rate of 1.4 m/s.
- Teleporting between two points instead of walking between them is worth experimenting with in some cases, but can also be disorienting. If using teleportation, provide adequate visual cues so users can maintain their bearings, and preserve their original orientation if possible.
- Movement in one direction while looking in another direction can be disorienting. Minimize the necessity for the user to look away from the direction of travel, particularly when moving faster than a walking pace.
- Avoid vertical linear oscillations, which are most discomforting at 0.2 Hz, and off-vertical-axis rotation, which are most discomforting at 0.3 Hz.

Cameras

- Zooming in or out with the camera can induce or exacerbate simulator sickness, particularly if they cause head and camera movements to fall out of 1-to-1 correspondence with each other. We advise against using “zoom” effects until further research and development finds a comfortable and user-friendly implementation..
- For third-person content, be aware that the guidelines for accelerations and movements still apply to the camera regardless of what the avatar is doing. Furthermore, users must always have the freedom to look all around the environment, which can add new requirements to the design of your content.
- Avoid using Euler angles whenever possible; quaternions are preferable. Try looking straight up and straight down to test your camera; it should always be stable and consistent with your head orientation.
- Do not use “head bobbing” camera effects; they create a series of small but uncomfortable accelerations.

Managing and Testing Simulator Sickness

- Test your content with a variety of un-biased users to ensure it is comfortable to a broader audience. As a developer, you are the worst test subject. Repeated exposure to and familiarity with the Rift and your content makes you less susceptible to simulator sickness or content distaste than a new user.
- People's responses and tolerance to sickness vary, and visually induced motion sickness occurs more readily in virtual reality headsets than with computer or TV screens. Your audience will not "muscle through" an overly intense experience, nor should they be expected to do so.
- Consider implementing mechanisms that allow users to adjust the intensity of the visual experience. This will be content-specific, but adjustments might include movement speed, the size of accelerations, or the breadth of the displayed FOV. Any such settings should default to the lowest-intensity experience.
- For all user-adjustable settings related to simulator sickness management, users may want to change them on-the-fly (for example, as they become accustomed to VR or become fatigued). Whenever possible, allow users to change these settings in-game without restarting.
- An independent visual background that matches the player's real-world inertial reference frame (such as a skybox that does not move in response to controller input but can be scanned with head movements) can reduce visual conflict with the vestibular system and increase comfort (see Tracking).
- High spatial frequency imagery (e.g., stripes, fine textures) can enhance the perception of motion in the virtual environment, leading to discomfort. Use—or offer the option of—flatter textures in the environment (such as solid-colored rather than patterned surfaces) to provide a more comfortable experience to sensitive users.

Degree of Stereoscopic Depth ("3D-ness")

- For individualized realism and a correctly scaled world, use the middle-to-eye separation vectors supplied by the SDK from the user's profile.
- Be aware that depth perception from stereopsis is sensitive up close, but quickly diminishes with distance. Two mountains miles apart in the distance will provide the same sense of depth as two pens inches apart on your desk.
- Although increasing the distance between the virtual cameras can enhance the sense of depth from stereopsis, beware of unintended side effects. First, this will force users to converge their eyes more than usual, which could lead to eye strain if you do not move objects farther away from the cameras accordingly. Second, it can give rise to perceptual anomalies and discomfort if you fail to scale head motion equally with eye

separation.

User Interface

- UIs should be a 3D part of the virtual world and sit approximately 2-3 meters away from the viewer—even if it's simply drawn onto a floating flat polygon, cylinder or sphere that floats in front of the user.
- Don't require the user to swivel their eyes in their sockets to see the UI. Ideally, your UI should fit inside the middle 1/3rd of the user's viewing area; otherwise, they should be able to examine it with head movements.
- Use caution for UI elements that move or scale with head movements (e.g., a long menu that scrolls or moves as you move your head to read it). Ensure they respond accurately to the user's movements and are easily readable without creating distracting motion or discomfort.
- Strive to integrate your interface elements as intuitive and immersive parts of the 3D world. For example, ammo count might be visible on the user's weapon rather than in a floating HUD.
- Draw any crosshair, reticle, or cursor at the same depth as the object it is targeting; otherwise, it can appear as a doubled image when it is not at the plane of depth on which the eyes are converged.

Controlling the Avatar

- User input devices can't be seen while wearing the Rift. Allow the use of familiar controllers as the default input method. If a keyboard is absolutely required, keep in mind that users will have to rely on tactile feedback (or trying keys) to find controls.
- Consider using head movement itself as a direct control or as a way of introducing context sensitivity into your control scheme.

Sound

- When designing audio, keep in mind that the output source follows the user's head movements when they wear headphones, but not when they use speakers. Allow users to choose their output device in game settings, and make sure in-game sounds appear to emanate from the correct locations by accounting for head position

relative to the output device.
- Presenting NPC (non-player character) speech over a central audio channel or left and right channels equally is a common practice, but can break immersion in VR. Spatializing audio, even roughly, can enhance the user's experience.
- Keep positional tracking in mind with audio design; for example, sounds should get louder as the user leans towards their source, even if the avatar is otherwise stationary.

Content

- For recommendations related to distance, one meter in the real world corresponds roughly to one unit of distance in Unity.
- The optics of the DK2 Rift make it most comfortable to view objects that fall within a range of 0.75 to 3.5 meters from the user's eyes. Although your full environment may occupy any range of depths, objects at which users will look for extended periods of time (such as menus and avatars) should fall in that range.
- Converging the eyes on objects closer than the comfortable distance range above can cause the lenses of the eyes to misfocus, making clearly rendered objects appear blurry as well as lead to eyestrain.
- Bright images, particularly in the periphery, can create noticeable display flicker for sensitive users; if possible, use darker colors to prevent discomfort.
- A virtual avatar representing the user's body in VR can have pros and cons. On the one hand, it can increase immersion and help ground the user in the VR experience, when contrasted to representing the player as a disembodied entity. On the other hand, discrepancies between what the user's real-world and virtual bodies are doing can lead to unusual sensations (for example, looking down and seeing a walking avatar body while the user is sitting still in a chair). Consider these factors in designing your content.
- Consider the size and texture of your artwork as you would with any system where visual resolution and texture aliasing is an issue (e.g. avoid very thin objects).
- Unexpected vertical accelerations, like those that accompany traveling over uneven or undulating terrain, can create discomfort. Consider flattening these surfaces or steadying the user's viewpoint when traversing such terrain.
- Be aware that your user has an unprecedented level of immersion, and frightening or shocking content can have a profound effect on users (particularly sensitive ones) in a way past media could not. Make sure players receive warning of such content in advance so they can decide whether or not they wish to experience it.

- Don't rely entirely on the stereoscopic 3D effect to provide depth to your content; lighting, texture, parallax (the way objects appear to move in relation to each other when the user moves), and other visual features are equally (if not more) important to conveying depth and space to the user. These depth cues should be consistent with the direction and magnitude of the stereoscopic effect.
- Design environments and interactions to minimize the need for strafing, back-stepping, or spinning, which can be uncomfortable in VR.
- People will typically move their heads/bodies if they have to shift their gaze and hold it on a point farther than 15-20° of visual angle away from where they are currently looking. Avoid forcing the user to make such large shifts to prevent muscle fatigue and discomfort.
- Don't forget that the user is likely to look in any direction at any time; make sure they will not see anything that breaks their sense of immersion (such as technical cheats in rendering the environment).

Avatar Appearance

- When creating an experience, you might choose to have the player experience it as a ghost (no physical presence) or in a body that is very different from his or her own. For example, you might have a player interact with your experience as a historical figure, a fictional character, a cartoon, a dragon, a giant, an orc, an amoeba, or any other of a multitude of possibilities. Any such avatars should not create issues for users as long as you adhere to best practices guidelines for comfort and provide users with intuitive controls.
- When the avatar is meant to represent the players themselves inside the virtual environment, it can detract from immersion if the player looks down and sees a body or hands that are very different than his or her own. For example, a woman's sense of immersion might be broken if she looks down and sees a man's hands or body. If you are able to allow players to customize their hands and bodies, this can dramatically improve immersion. If this adds too much cost or complexity to your project, you can still take measures to minimize contradictions between VR and reality. For example, avoid overtly masculine or feminine bodily features in visible parts of the avatar. Gloves and unisex clothing that fit in the theme of your content can also serve to maintain ambiguity in aspects of the avatar's identity, such as gender, body type, and skin color.

Health and Safety

- Carefully read and implement the warnings that accompany the Rift (see Health and Safety Warnings) to ensure the health and safety of both you, the developer, and your users.
- Refrain from using any high-contrast flashing or alternating colors that change with a frequency in the 1-30 hz range. This can trigger seizures in individuals with photosensitive epilepsy.
- Avoid high-contrast, high-spatial-frequency gratings (e.g., fine, black-and-white stripes), as they can also trigger epileptic seizures.

Documentation

INTRO TO VR

- Oculus Best Practices
- Frequently Asked Questions
- **Public Displays and Activations**
- Oculus Glossary

PC SDK

MOBILE SDK

AUDIO SDK

GAME ENGINES

PUBLISHING

Public Displays and Activations

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Many developers, agencies, and institutions have been interested in using

Oculus products to help share their VR ideas and experiences with the general public. This interest often manifests itself in the form of public displays and activations.

At the outset, it's important to note that both of our products, the Oculus Rift Developer Kit 2 and the Samsung Gear VR Innovator Edition, are not industrial-grade devices nor are they fully-fledged consumer products. They are development kits aimed at developers and enthusiasts making the first wave of consumer content.

However, there are still interesting ways that our current products can be used for public displays and activations. So here we'll provide some guidance and recommendations to that end.

Keep It Short and Sweet

Activations should only last a matter of days and be relatively modest in scope. We also suggest that there be no more than four to six devices in use. These limits make it significantly easier to effectively manage the activation, and the constrained scope allows you to innovate and experiment. Note: it is recommended that you have at least one backup for each device in use.

Make It Free

You shouldn't be directly or indirectly charging users. Both the Oculus Terms of Service and the Oculus Rift Development Kit 2 Terms and Conditions prohibit commercial use, so your public activation must be provided free of charge. In the future we may have a program for commercializing public activations, but we're not there yet.

People First

User safety and comfort is extremely important to us because we want everyone's first experience with virtual reality to be great. We've published the Oculus Best Practices Guide to help you. Make sure to read through it before starting development, and apply the recommendations to your activation. Please pay extra attention to the following aspects of the Best Practice Guide:

- Users should be 13 years or older
- Users should be seated and safe
- Users should be and feel comfortable

Because you will need to move people through the experience, help them take the device on and off, and prepare the device for each new user, you will need individual, trained staff for each user. The headset should be cleaned between each use with skin-friendly antibacterial wipes (particularly the lenses) and dried with a microfiber cloth.

Similar to what you might find at amusement parks, health and safety signage should also be properly displayed. Applicable Health and Safety Warnings for Oculus hardware can be found here in our online Developer Documentation. These are minimum recommended requirements. Each activation, however, is unique and the responsibility of the developer, so please tailor your messaging accordingly.

Appendix 6 - Proton therapy virtual reality video tour script outline.

Storyline:

(9-12 seconds per scene to approach 3-4 minute video)

1. Outside CHOP
2. Cross street
3. PCAM lobby
4. PCAM elevator
5. Main waiting room
6. CHOP waiting room
7. Walkway to locker area
8. Locker area, look at gowns
9. Hallway to Protons
10. Entryway to gantry
11. Gantry spins
12. X-rays come out
13. Therapist control area
14. Approach table
15. Lay down on table
16. Therapists stand next to head of bed
17. X-ray panels come out and back
18. Gantry moves around
19. Get up and leave
20. Focus on Bell
21. End-of-therapy party room decoration(s)

CHOP-Street View

Exit CHOP building and cross street toward the Proton Therapy Center

Consideration: PCAM Parking area

PCAM Street view

PCAM Valet area view

PCAM Lobby

Look around lobby. Will focus on elevators, art displays and a small replica of the proton therapy center. Note, this display is very high and is often missed by short children. Also, some children enter the building through a different entrance if coming from CHOP and may not see the display.

Elevator ride down

as we come of out elevators, look around lobby. Focus on bell (see description below).

CHOP waiting area

Check in with front desk, greet personnel.

Look at toys/ activities

Go to proton area and receive a gown

Proton hallway

Changing area

Proton Room

Proton doorway

Watch therapists move the machine

Watch the x-ray panels come out from the wall

Look at therapist work area

Lay down on table

See therapists standing next to you while laying down on treatment table

Look at x-ray plates come out and go back

See gantry move a little bit

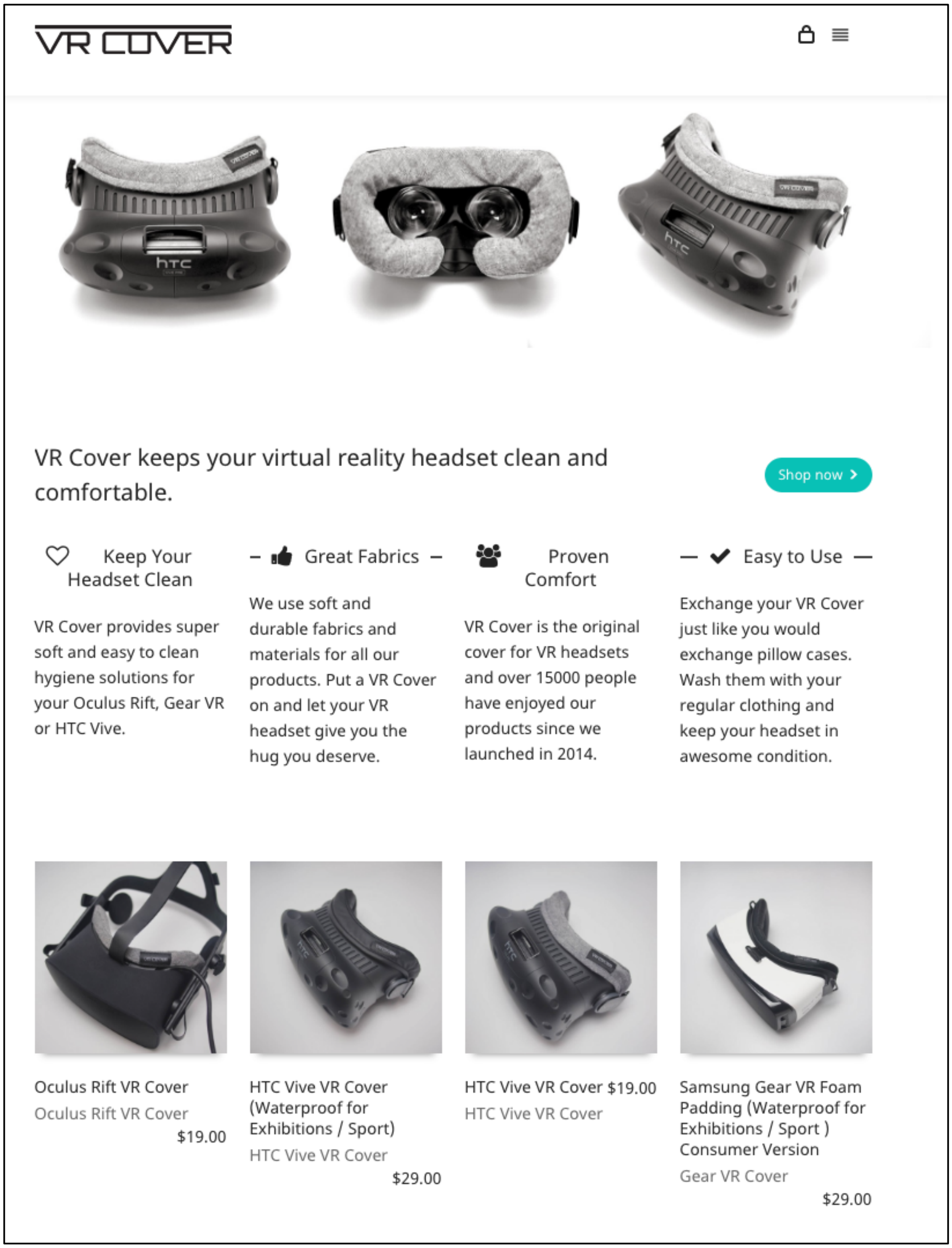
Put a mask on the camera *(may not be included in final video)*

Get up from table

Walk out to changing area

Ring the bell? ** may not be included in the video, consider showing the bells)

Appendix 7 - Oculus rift vinyl cover[18]



18 https://vrcover.com Accessed 6/9/2016

Appendix 8 – Oculus Rift Product Warnings

Inability to tolerate virtual reality head mount

It is possible that subjects will not tolerate the virtual reality environment well. As listed in the manufacturer pamphlet for the Oculus Rift Developer Kit 2 –

- Seizures: Some people (about 1 in 4000) may have severe dizziness, seizures, epileptic seizures or blackouts triggered by light flashes or patterns, and this may occur while they are watching TV, playing video games or experiencing virtual reality, even if they have never had a seizure or blackout before or have no history of seizures or epilepsy. Anyone who has had a seizure, loss of awareness, or other symptom linked to an epileptic condition should see a doctor before using the headset.
- Use only in a safe environment: The headset produces an immersive virtual reality experience that distracts you from and completely blocks your view of your actual surroundings. Always be aware of your surroundings when using the headset. Remain seated whenever possible, and take special care to ensure that you are not near other people, objects, stairs, balconies, windows, furniture, or other items that you can trip over, bump into, or knock down when using, or immediately after using, the headset. Do not handle sharp or otherwise dangerous objects while using the headset. Never wear the headset in situations that require attention, such as walking, bicycling, or driving.
- Ease into the use of the headset to allow your body to adjust; use only for a few minutes at a time at first, and only increase the amount of time using the headset gradually as you grow accustomed to virtual reality.
- Do not use the headset when you are tired, need sleep, are under the influence of alcohol or drugs, as this can increase your susceptibility to adverse symptoms.
- Immediately discontinue if the subject experiences any following discomfort or experiencing: seizures, loss of awareness, eye or muscle twitching, involuntary movements; altered, blurred, or double vision; feeling detached from your body or from reality; dizziness; disorientation; disrupted balance; nausea; lightheadedness; discomfort or pain in the head or eyes; drowsiness; fatigue; or any symptoms similar to motion sickness.