VR Headset for Endoscopy and Microsurgery

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ABSTRACT

Despite the presence of VR headsets in variable healthcare settings, such wearable technologies have not yet reached their full potential in the operating room where large monitors are still predominantly used to display endoscopic surgeries. While existing medical VR headsets offer physicians an immersive image and reduce bodily strain caused my staring at a monitor during procedures, they limit the healthcare professional's ability to see the world surrounding them when deemed necessary. The objective of this project to to build upon existing VR technologies and add a functionality that enables surgeons to seamlessly transition between endoscopic and environmental (real-world) view at their own discretion. There were two main approaches to develop such a product: either building a novel device from scratch or modifying an existing chassis to fulfill the aforementioned goal. After meeting with our client and advisor to determine which direction was most fitting, and by discussing preliminary designs and evaluating the designs with a design matrix, we elected to pursue a modified HTC Vive design. Using the Unity game engine we will develop a software solution that allows our client to switch between an endoscopic view and environmental view streamed from the front facing camera on the headset. We will make concurrent modifications to address comfort requirements that accompany a lengthy surgical procedure.

I. INTRODUCTION

1.1: Motive, Current Methods, and Problem Statement

The virtual reality market has grown exponentially over the last couple years, and not just in the gaming industry. As the technology has increased, so have the potential applications. One area in particular that virtual reality has taken root is in the healthcare industry. In fact, according to estimations, the VR health market could reach $641 million by 2018 and $ 3.8 billion by 2020 [12]. The majority of this market share is from systems that use VR to train surgeons, reduce neck strain, or stream procedures; however, the market for VR assisted Endoscopic procedures is currently untapped and could prove fruitful [4].

[Figure 1] A physician performing a procedure aided by endoscopy [9]. The monitor, pictured on the right, demands the physician's utmost attention and places her head at a stressful angle.

Traditionally, large monitors have been used to display images from surgical tools, however, these are bulky and don't provide as immersive of an experience as other methods do. This problem has been partially addressed by using virtual reality headsets. VR headsets have allowed the healthcare field to make massive strides in reducing physician discomfort and chronic pain, however they limit the surgeon to see anything outside of the operative view. In order to see his or her surroundings to grab a tool, the healthcare professional is required to physically remove the headset, wasting time, threatening sterility, and interfering with their tool positioning in vivo. The goal of this project is to design a VR headset that would allow the surgeon to transition from the operative view (what the endoscope displays) to environmental view (normal visual field) without the use of the surgeon's hands. Not only would this device give endoscopic surgeons a more immersive view, but it would potentially decrease occupational hazards by allowing them to keep their necks at natural positions rather than bent forward looking at a monitor. The standing and arching for a better view certainly contributes to perform forced and overloading musculoskeletal system body positions [3]. Eventually, all monitor based surgeries could use this technique and even adopt a seated position to minimize the strain on the operator [1].

There are no current products on the market that address this problem. There are many virtual reality headsets currently on the market however, that could be modified to suit our purposes. Because the time frame for this project is only one semester, a VR headset will be purchased and modified rather than built from scratch. Additionally, it makes sense to use a proven product that has been designed and developed for years rather than restart from square one. The specific products that were considered for modification are discussed later in the preliminary designs section.

II. BACKGROUND

2.1: Relevant Physiology and Biology

Current endonasal procedures take advantage of the use of endoscopic technologies that primarily focus on the use of a display such as a television screen. Often, surgeons will have to lean in very close to the televisions screen during these long procedures to see accurate details [7]. However, when people have screens "much closer than they normally would printed material, that puts an extra demand on the eyes" [5]. Along with this added demand, inadequate screen resolution can cause procedures to be difficult and lead to even more eye strain [7]. Further yet, these procedures are conducted in a dark room [7]. This compounds the negative impact of screens as "when using a computer [monitor,] ambient lighting should be about half as bright as that typically found in most offices" [7]. Additionally, "the constant exposure to technology results in symptoms of digital eye strain leaving our eyes dry, irritated, causing eye fatigue, blurred vision, headaches, neck and back pain" [7]. As expected, many surgeons also report issues involving muscle fatigue and strain. In fact one study found that "site-specific pain included pain in the back (50%), neck (48%), and arm or shoulder (43%). Fatigue was reported by 71% of surgeons, numbness by 37%, and stiffness by 45%" [3].

Furthermore, when the "strain experienced by surgeons performing open surgery, [surgeons completing] minimally invasive surgery (MIS) were significantly more likely to experience pain in the neck (OR 2.77 [95% CI 1.30–5.93]), arm or shoulder (OR 4.59

[2.19–9.61]), hands (OR 2.99 [1.33–6.71], and legs (OR 12.34 [5.43–28.06]) and experience higher odds of fatigue (8.09 [5.60–11.70]) and numbness" [3]. Thus, surgeons utilizing endoscopy equipment to complete endonasal procedures are much more likely to experience negative effects due to their career requirements.

By replacing the surgeon's monitor with a VR headset, new factors are introduced. In addition to eye strain, a rather unique concern is that of VR sickness. When using a VR device, the brain demands that the image "be good enough to adequately fool our senses, but not have a level of quality that is well beyond the limits of our receptors" [6]. If these conditions are not met, the brain will process the offset as visual confusion and a painful headache will result. Numerous aspects impact this phenomenon, including pixel density and retinal image slip. Most VR headsets use magnification to provide an immersive view of the screen; however, by bringing the screen closer to the eyes, the pixel requirements of the screen are far greater and beyond the capabilities that current headsets are able to provide [6]. Another issue that can arise with VR headsets and vision is that "retinal image slip due to VR artifacts can not match the retinal image slip encountered in the real world" [6]. In other words, there is a necessity for headsets to live stream video feed without lag in order for the image that the user is seeing to match the real world that the user is feeling. Deficiencies in either of these categories may cripple a headset's effectiveness in a lengthy surgical procedure.

2.2: Fabrication Research

We will be using Unity to construct our code for the HTC vive modifications. This platform will allow us to incorporate the endoscopic image into a Vive-compatible format. Additionally, it will allow us to create a trigger that will switch the view from operative to environmental using internal sensors within the vive. Unity as a platform has a large community of users, which gives us many great resources to aid in our design. Additionally, Taylor Waddell, a Virtual Reality Maintenance & Operation Manager at the Makerspace is very knowledgeable with the platform. Kevin Ponto, a professor at the School of Human Ecology here on campus is also a great resource our group will be able to utilize.

2.3: Client Information

Our client, Azam Ahmed, MD, is affiliated with the University of Wisconsin School of Medicine and Public Health. Dr. Ahmed is a neurosurgeon seeking a novel surgical VR headset to assist him in performing endoscopic surgeries.

2.4: Product Design Specifications

The ultimate goal of this project is to build upon the existing technological standard for VR headsets and add functionality that allows the user to seamlessly transition between a surgical (endoscopic) and environmental view at his own discretion. Our client specified that the headset should run virtual reality (VR) as opposed to augmented reality (AR) which superimposes images onto the user's surroundings. The final product must be more immersive and offer a more expansive view than a operating-room monitor while delivering a reliable 1080p HD image. In order to perform this task, it is necessary that the product be compatible with the endoscope's BNC, coaxial cable output. Any mechanism programmed to switch the device between views should be hands free and intuitive. In addition, it is important that our product does not inhibit or radically change the current surgical procedure.

Since the device will be used frequently in high-risk procedures, the health of both the physician and patient are paramount. To ensure the safety of the patient, it is essential that the headset be wireless and provide a live feed of the endoscopic camera, with laging latency exceeding no more than 30 ms. One of the client's largest complaints regarding the current mode of endoscopic surgery revolved around physician discomfort. To help remedy this issue in this project, the headset should remain within 10 degrees of $55 \circ F$ throughout its operational use to assure the operator is not burned or uncomfortable [11]. Plenty of ventilation should be factored into the design to reduce moisture in the eye chamber. Similarly, in an ideal situation, the product's weight (in the range of 400-900 g) will be evenly dispersed throughout its volume to reduce neck strain on the surgeon [2].

Modern day headsets are manufactured from a mix of fabrics and polymers and fit a profile of roughly 225x185x140mm [2]. Plastics often form the structural chassis of the device whereas fabric is used to prevent fluids from soiling electrical components and to pad the headset's interface with the user. Materials for the headset's exterior should be chosen on the basis of how well they prevent chemical penetration and how easily they can be sterilized. For a full review of design specifications, refer to the PDS located in the Appendix (Section 7.1).

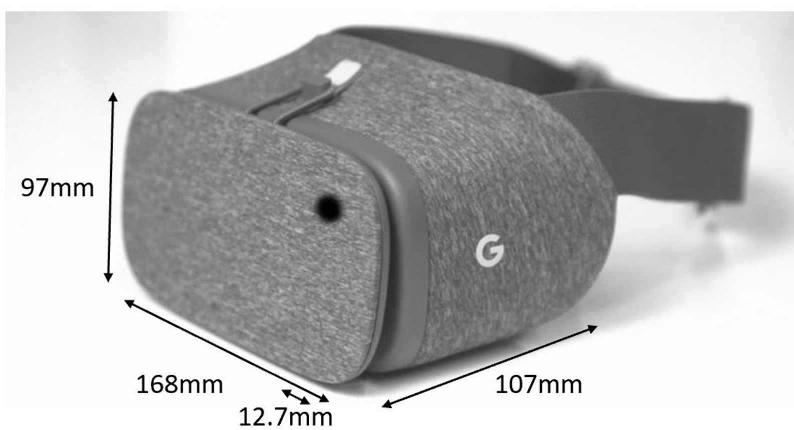
III. PRELIMINARY DESIGNS

3.1: Choosing a Starting Point

To best address our client's design needs, we will be reviewing various system design solutions. Our group considered making our own headset to display the endoscopic view, however we felt this would not be the most effective way to create a comfortable and immersive experience. Designing our own headset would turn the emphasis of the project to assembling a working electrical circuit. With this focus, we would not be able to devote the necessary time to address the primary needs, immersiveness and ergonomics. We will instead approach the situation by evaluating existing VR headsets on the market and the system that would be required for integration into the endoscopic procedure.

The three preliminary designs that will be considered are the Google Daydream/Nexus, HTC Vive, and Dell Visor. Each design contains respective modifications in order to satisfy the requested functions of our client. Listed below are the detailed descriptions of each design.

3.2: Google Daydream and Google Nexus



[Figure 2] A schematic of the Google Daydream's dimensions. The image was retrieved from [13].

This first design is the only two-component design in consideration. It is composed of both a Google Daydream VR headset frame and a Google Nexus phone that is to be inserted into the frame. Despite the separate parts, it is the lightest, most cost effective, and simplest of the three design options. This headset will provide environmental and endoscopic view via the camera of the Nexus phone which will capture the environmental perspective. Furthermore, when the Nexus is not displaying the endoscopic video input, it will be displaying the view from its camera while it is in the headset to give a user an external viewpoint. This transition will be triggered via a hands-free gesture.

For this headset to be of practical surgical use, there are some modifications that must be added onto this system. The addition of a latitudinal head strap running across a user's head would compliment the horizontal elastic strap that comes stock with the Daydream frame to provide comfort and support. This addition would not only improve fit for a surgeon, but it would improve the safety of the design by ensuring that the headset does not slip from Dr. Ahmed's face during a procedure. Another minor modification would be the cutting of a hole in the the frame flap that holds the Nexus phone within the headset frame. This hole would correspond to the Nexus camera simply so that the camera can view the external environment.

Design Specifications:

- Price: $290 ($235 Google Nexus + $55 Daydream frame)
- System Requirements: Nexus phone, Google Daydream headset frame, hardware connectors between headset and computer intermediate (transfers video from endoscope to Nexus)
- Weight: 19.2 oz. (10 oz. Nexus phone + 9.2 oz. Daydream frame)
- Development Environment: Android Mobile OS
- Connectivity: USB-C for video input and power

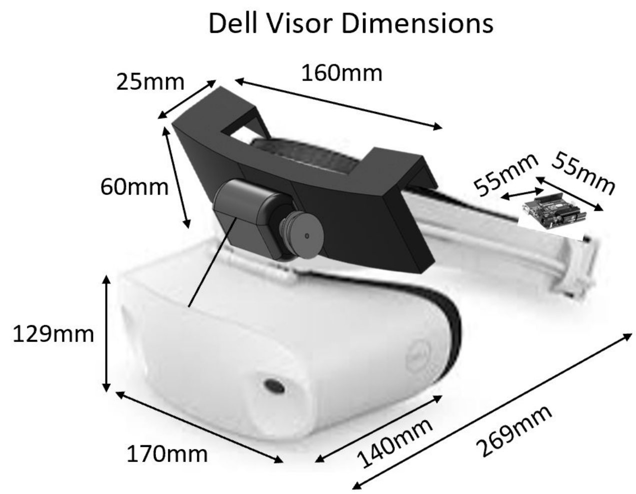
Advantages:

One of the main advantages of this design will be that it has limited ear obstruction because there is only a singular horizontal elastic strap wrapping around the sides of a user's head. In the event that our client needs to hear something during an operation, nothing will be in the way to hinder his hearing ability. Another benefit of this design option is that there is already an existing community of programmers familiar with operation of Android systems, so software modifications will be coherent, and there is an abundance of resources if necessary.

Disadvantages:

Because this design contains multiple pieces (phone and headset), there is a possibility that use of this design in the operating room could be unsafe if loose parts become disassembled during a procedure. This is not likely with designed fasteners, but it is a possible disadvantage of the practicality of this design. There are also complications regarding the use of a phone as the display source and environmental view retriever. Within the headset, the Nexus will not provide as immersive of an experience as other design options with internal displays, and the environmental view could be skewed when viewed through the VR headset. This is due to the offset camera of the Google Nexus: it is on the upper corner of the phone, so either skewed to the right or left of Dr. Ahmed's vision field. Moreover, the transition from endoscopic view to environmental may provide a confusing and shifted perspective for Dr. Ahmed that depletes the practicality of this design.

3.3: Dell Visor



[Figure 3] A schematic of the Dell Visor's dimensions. The image was retrieved from [8].

The Dell Visor is the second design in consideration for this project. The Visor includes a solid, adjustable headband that provides one of the most even weight distributions of any VR headset on the market today. For this reason, the Visor and comfort go hand in hand. The display of this headset is hinged and gives a user the option to flip the display up and out of the field of vision for temporary eye relief and environmental vision. This design option will include a hands-free mechanical feature that flips the display up when our client wishes to view his environment. This process will be facilitated with a wire, miniature winch motor, arduino, and interactive foot pedal. Moreover, when our client wishes to raise the endoscopic display, he steps on a foot pedal with an arduino on it that is hardwired to the winch motor and signals which way to wind the motor, subsequently raising or dropping the display.

The only modifications necessary for this design are the addition of a motor, wire, and hardwiring to the foot pedal and arduino. No software modifications will be required for transitions between endoscopic and environmental views due to the mechanical nature of this design option.

Design Specifications:

- Price: $540 ($450 Headset + $70 Mechanical Modifications)
- System Requirements: Dell Visor, miniature winch motor, wire, arduino, hardwire, foot pedal
- Weight: 20.81 oz.
- Development Environment: No development necessary
- Connectivity: HDMI 2.0 (video) and USB 3.0 A-Type (Data/Power)

Advantages

The advantages of the Dell Visor revolve around the even weight distribution, simplicity, and clarity of both perspective views. With the even weight distribution, Dr. Ahmed will be able to wear the headset for extensive periods of time during an operation without feeling neck strain from a front loaded display. Additionally, by flipping the display up, our client will be able to relieve his eyes of continuously staring at a display, and having an enclosed set of goggles over his face. Both of these performance factors will allow the design to be used with continuity and comfort. Because of this designs mechanical simplicity, there will also be no time spent programming or working with a foreign development environment: a time consuming activity.

Disadvantages

Due to the mechanical nature and multiple different components of this design, there is the possibility of mechanical failure. This is a major drawback of this design because a malfunction in the headset's ability to raise the display could prove detrimental to an operation's progress. Additionally, if our client wishes to move about the operating table/around the patient, he will have to be cognisant of the foot pedal that is hardwired to the headset. This could be a major inconvenience and could hinder the safety of the operation.

3.4: HTC Vive

[Figure 4] A schematic of the HTC Vive's dimensions. The image was retrieved from [10].

The HTC Vive is one of the most popular VR headsets on the entry level consumer market today. The headset is best known for its immersive VR experience and is widely used in the gamer community. The Vive requires an external computer to run the device, but has an option for a wireless connection to stream the display. While the headset is relatively light, it is front heavy and not known for its comfort. Similar to the Google Daydream design, switching between endoscopic and environmental view will be implemented with software and the existing Vive front camera. A hands-free gesture performed by the surgeon will switch the endoscopic stream to a live camera view of the environment. Once finished with an environmental view need, the surgeon may switch back to the endoscopic view with another hands-free gesture. With a live connection to a computer and numerous sensors integrated into the headset, this design has the ability to collect data on each operation for later analysis.

Design Specifications:

- Price: $500
- System Requirements: HTC Vive headset, Vive to computer cable, computer, computer to endoscope cable
- Weight: 16.58 oz
- Development Environment: Unity game engine
- Connectivity: HDMI (video) and USB (data) and DCIN (power)

Advantages:

The strength of the HTC design lies in its immersiveness and ease of software development. The Vive is known as one of the best virtual reality experiences due to its display quality and isolation from external environment. When used in endoscopy, the Vive would be a notable improvement over conventional monitor displays, allowing for full attention of surgeon to be directed towards the procedure. Additionally, the Vive software can be developed using the popular Unity game engine. The Unity game engine has a strong user community and is known for being an easy to learn introductory engine. With a camera already included in the headset, no additional modifications would need to be made to the Vive in order to create a software solution to switch between environmental and endoscopic views.

Disadvantages:

The HTC Vive has an awkward weight distribution that may be uncomfortable to wear for long periods of time. Since the device may be worn for approximately ten hours, this discomfort could be a serious problem for the viability of the headset. Modification may have to be made in order to better distribute the weight of the device around the head.

IV. PRELIMINARY DESIGN EVALUATION

4.1: Explanation of Design Matrix:

[Refer to the Final Design Matrix and Design Criteria located in the Appendix, Section 7.2 and 7.3, respectively] The HTC Vive and Dell Visor both received the highest score for immersiveness. Both headsets were intentionally built for a high fidelity virtual reality experience. This is comprised of a high resolution display, lense adjustments for sharpness of vision, and a contoured frontal design that isolates the user from the external device. On the contrary, the Nexus with Daydream was adapted to VR but not designed intentionally for it. The headset does not feature the same adjustments and contouring of the other two designs.

Equally weighted with immersiveness, comfort was the next criteria for evaluating the preliminary designs. The Dell Visor was the strongest design in this category (4/5), with the most balanced distribution of weight and most comfortable cushioned headband. The Vive and Daydream fell short of the visor with front heavy designs and awkward headbands.

For programmability, the Dell Visor again scored the highest with a perfect score. The Visor does not require any special software implementation to switch between endoscopic and environmental view since it uses a mechanical transition (5/5). While scoring the best for programmability, the Visor scores the worst for physical modifications (1/5). The Visor requires an extensive mechanical component to be built and attached in order to raise and lower the headset. The fabrication of this would be much more difficult than the simple modifications that are needed to be made to the Daydream to expose the camera (4/5). Ultimately, the Vive scores highest, with no external modifications necessary for proper view transitioning (5/5).

For the final categories, the designation was relatively straightforward. The Daydream was the cheapest option and scored (5/5). As for Safety and Sensors, the Vive won both these categories having the fewest separate components that could cause accidents and the most sensors available for data collection.

4.2: Proposed Final Design:

The final design will consist of the HTC Vive because of its modifiable ergonomics, high quality resolution, and most importantly its fully immersive experience. If needed, we can work with the client to modify the headset so that comfort is guaranteed throughout long surgeries. The design will feature a feed switching mechanism that will be triggered by a head motion of the client's choosing such as a jerk upward or to the side. We will code the switching mechanism with the help of two sources mentioned above. We will continue to display the feed of the endoscope through the monitor in the operating room so that the nurses can be prepared, but we will increase the lighting of the room so that the camera of the headset can appropriately display the environmental view.

V. CONCLUSION

Through this design process we strive to create a more immersive endoscopy experience for our client. The current monitor display does not allow for full focus on the procedure, and our client believes that a VR headset would be the ideal way to view the procedure. However, a VR headset may also obstruct the normal workflows of an operation when the surgeon needs to be able to view the surrounding environment to interact with other staff. To address this problem we came up with three potential solutions. Two of these solutions use a software implementation that switch from an endoscopic view to an environmental view by live streaming a camera input on the front of the headset. The third design, uses a drawbridge type mechanism that mechanically raises and lowers the headset allowing the surgeon to see the environment. After considering the strengths and weaknesses of each design in a decision matrix, we have decided to move forward with a software implementation using the HTC Vive. The Vive's immersive experience, front facing camera, and popular development environment, make it the ideal platform for addressing our clients needs. Our two primary next steps are to start developing the software application that allows for the switch between views and to start addressing the problem of discomfort with the Vive headset. We will accomplish proof of concept for the software using the Makerspace's free available resources. Ultimately, as we move forward with the HTC Vive design we will continue to be in contact with the client to ensure we are adequately addressing his needs.

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VII. APPENDIX

7.1: Product Design Specifications (PDS)

VR Headset for Endoscopy and Microsurgery

Product Design Specifications

September 21, 2018

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Function:

Dr. Azem Ahmed from the neurosurgery department of the University of Wisconsin - Madison School of Medicine and Public Health presented this team with the task to improve surgeon visualization during endoscopic procedures. Endoscopic surgeries have become increasingly prevalent in the operating room along with the visualization techniques used to perform them [2]. Traditionally, large monitors have been used to display the images from the surgical tools (endoscopic view), however, these are bulky and do not provide as immersive of an experience for the surgeon as other methods do. This problem has been partially addressed by using virtual reality (VR) headsets. One major limitation of these, however, is that they do not allow the surgeon to see anything outside of the endoscopic view. This is a problem as the surgeon will have to remove the headset everytime he or she has to change instruments, or perform an action requiring a clear line of sight (environmental view). This team's goal is to create a VR headset that would allow the surgeon to transition from the endoscopic view to the environmental view without the use of the surgeon's hands, all the while presenting a continuous, non-interfering, and immersive experience for the surgeon.

Client Requirements:

- Create a more immersive view for performing endoscopy.
  - Endoscopic surgery is currently performed with the use of large display monitors stationed above the head of the patient. The monitors occupy a small field of view for the surgeon and result in a suboptimal and potentially distracting means of viewing the procedure.
  - The client would like a wide field of view display that allows for fewer distractions. The more immersive viewing experience will make anatomical visualization easier and facilitate more effective endoscopy.
- Maintain smooth workflow of endoscopic procedures in operating room.
  - The client must be able to conduct surgery unobstructed by the new display platform. Any kind of immersive display must allow for an easily

accessible environmental view. Cords or accessories to the display must not hinder movements of the surgeon or others in the operating room.

- Create an ergonomic platform for the surgeon using a new interface.
    - The surgeon will be using the display for long periods of time. The display must therefore be comfortable to wear and intuitive to interact with.

Design Requirements:

1. Physical and Operational Characteristics

a. *Performance requirements:*

The designed VR headset must comfortably sit upon the surgeon's head for the duration of an endoscopic surgery, which averages about 10 to 12 hours according to Dr. Ahmed. Moreover, the VR headset should produce minimal additional strain on the surgeon aside from inevitable operating pains [3]. In terms of technical performance, the headset must reliably deliver 1080p, standard HD display to the user throughout the course of an endoscopic surgery. This display must be a continuous feed from the endoscopic camera communicated through hardwire or bluetooth. Any source of video lag could be detrimental to the surgery. Additionally, the VR headset should be able to effectively switch from the endoscopic view to the environmental view through hands-free command at various times during the course of the operation.

b. *Safety:*

There are two main safety requirements for the device. The first concerns the surgeon and the second concerns the patient. Since the duration of the surgeries being conducted are so long, the headset has to be comfortable and ergonomically friendly enough so that the surgeon doesn't fatigue. If the surgeon is not performing to the highest level possible, the health of the patient is at risk. Additionally, the device has to provide a continuous and clear, immersive experience for the surgeon otherwise the health of the patient is once again at risk. The most frequent major complication of endonasal skull base surgery (the kind performed by Dr. Ahmed) is a cerebrospinal fluid (CSF) leak [5]. This results from accidental tissue damage. Any lag or deficiency in visualization by the surgeon will increase the risk of CSF leaks and other complications.

c. *Accuracy and Reliability:*

The VR headset must administer a reliable communicative feed between the endoscopic camera and the display. For seamless streaming, the laging latency should not exceed 30 ms between the video input and output [4].

d. *Life in Service:*

The device must function with perfect accuracy during all operations with a projected lifespan of five years based on technological trends and development of VR technology. It must also withstand regular use without deformation or breakdown due to standard sterilization procedures.

e. *Shelf Life:*

The device must be able to be stored in a stable environment without having contamination issues involving sterilization. Along with sterilization, batteries must be self-contained with no issues involving the spilling of harmful contaminants.

f. Operating Environment:

The device will be initially used in neurosurgical operating rooms. These operating rooms are dark environments with focused light on the patient. The OR contains both sterile and non-sterile fields that must be maintained through proper workflows. A variable number of monitors are in the OR which may be utilized for external displays of the endoscopy view.

g. Ergonomics:

The VR headset will be worn for 10-12 hours during surgery and must fit comfortably on the surgeon's head with optimal comfort. The VR headset must also be balanced very well and fit snugly to the head to avoid any tipping or movement of the device during regular use. Along with a comfortable fit, the design must not cause any strain or pain in the head, neck, or spinal regions due to sustained use. The design must focus on easing the view of detailed information pertinent to the procedure that will minimize strain on the body. Within the design, any cords or wires used must be contained and controlled to ensure no entanglement between body parts and cords occurs.

h. Size:

The current oculars used by surgeons cover the eyes and part of the front of the face. This is comparable to current VR headsets which vary in size and are approximately 225x185x140mm. These dimensions will serve as a general baseline for the sizing of our VR headset.

i. Weight:

The weight of the top six major VR headsets range in weight from around 453 grams to 610 grams. The average of these is 501 grams [6]. As of now the oculars used by neurologists now range from about 453 grams to 906 grams.

j. Materials:

The base of the VR headset will be the main material needed since the plan is to modify an existing product. In addition to the headset, cameras will be needed to view the operating room during surgery. The headset could end up being connected to the endoscopic tower via bluetooth but if not we will need to acquire an HDMI cable or USB cable to connect the headset. Depending on what headset is chosen, the design would require the separate purchase of a smartphone to display surgery.

k. *Aesthetics, Appearance, and Finish:*

The headset will be set on the face of the operator and should fit comfortably for long surgeries. It will have appropriate weight distribution and have small cords connected to the back of the headset. The outside of the headset itself will most likely be unmodified and look similar to the factory versions of the product.

2. Production Characteristics

l. *Quantity:*

For this project, only one prototype will be constructed. The one prototype will prove whether it will be necessary to continue production and whether it would be feasible to create more on a larger scale for mass distribution. If the prototype excels while being used in a surgical setting, creation of more could be reality and will be pursued.

m. *Target Product Cost:*

This product is seeking to compete with current television display screens that are approximately forty inches if not larger. The televisions like what Dr. Ahmed is using likely are priced at approximately $500 and may be even more expensive. Therefore, we are seeking to make a product that costs approximately $500. This price point also fits the higher-level virtual reality devices on the market right now. This price would likely involve the entire assembly along with software expenses and any other incurred costs. Though this may increase throughout the development of the device.

3. Miscellaneous

n. *Standards and Specifications:*

VR headsets of display monitors for surgical procedures fall under the Class I Medical Device FDA regulation [1]. Currently, the FDA sets the requirement of going through the 510(k) acceptance process for all new medical devices that are seeking to be offered in the future medical device market. These applications must be sent at least 90 days before individuals intend to market a device and go through a very thorough investigation.

o. Customer:

The client, Dr. Azam Ahmed mentioned that he would prefer focusing on VR devices over other technologies such as AR. He also communicated that he would prefer if the device can be wireless so that there is not tangling of cords that can occur. Additionally, Dr. Azam iterated that this product cannot stall as a lag in video timing or quality would be detrimental to his patients health. Last, Dr. Ahmed has warned that lighter and lighter designs would be best as they will decrease the strain put on surgeons during these extensive procedures.

p. User-related concerns:

The client's main concern for the device is maintaining a smooth workflow. While the immersive view allows for more effective endoscopy, a potential side effect may be preventing environmental views or adding obstacles to the surgeon or team. Our solution must be cognizant of the activity in the OR as well as the motions required of the surgeon during operation. This may be accomplished by offering a product with a seamless transition between endoscopic and environmental views, and potentially through the addition of voice commands by allowing the surgeon to change views without the need to move his hands.

q. Competition:

Currently, the client uses a large monitor to display the output by the endoscope, similar to that created by Synaptive Medical. This technology presents a wide image that capable of ideal image quality, but lacks the immersiveness of a VR headset and required the surgeon to crane their neck to one side and away from the patient during procedures. Other competing technologies include all VR headsets currently on the market that could be adapted to be used in the OR. Many of these existing products appeal to a recreational audience, and are not adapted to the OR desipite their use of bluetooth, 360° POV angles, and sleek designs. Similarly, AR is another type of competing technology applicable to endoscopic procedures.

Works Cited:

4. PDS References

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7.2: Final Design Matrix

Criteria (weight)	Designs					
	HTC Vive		Daydream		Dell Visor	
	Score	Weighted	Score	Weighted	Score	Weighted
Immersiveness (20)	5/5	20	3/5	12	5/5	20
Comfort/Ergonomics (20)	3/5	12	3/5	12	4/5	16
Programmability (15)	3/5	9	3/5	9	5/5	15
Physical Modifications (15)	5/5	15	4/5	12	1/5	3
Price (10)	3/5	6	5/5	10	3/5	6
Sensing Capabilities (10)	5/5	10	3/5	6	4/5	8
Safety (10)	4/5	8	3/5	6	3/5	6
TOTAL (100)		80		67		74

[Figure 5] The VR for Endoscopy Design Matrix. Green indicates which design scored highest in each category. The final row indicates the overall score of each design. Scores were obtained by taking each design's individual score out of 5 and then multiplying that score by the weight of each category. Final scores were obtained by adding all of the weighted scores of each design.

7.3: Design Criteria

Immersiveness (20): *The ultimate goal of the project is to create a more immersive view of endoscopy. Device experience evaluates the experience of viewing the endoscopy. This includes field of view, quality of display, and vision adjustments for reducing eye strain.*

Comfort/ergonomics (20): *The device must be used for long periods of time. Comfort evaluates the experience of wearing the headset. Factors affecting this score include weight, distribution of weight, shape of headset, etc..*

Programmability (15): *The hands-free switches between environmental view and endoscopic view must be created with software. Programmability refers to the ease and flexibility of the development environment for the headset. This includes community/documentation of the development environment as well as the relative power and capabilities of the platform.*

Physical modifications (15): *Some of the devices selected for the design matrix would require physical modifications to the project. This would increase the complexity and the work required, and could potentially ruin the device itself.*

Price (10): *While the client didn't specify the amount of money he was willing to allocate towards the project, it is safe to assume that minimizing the cost of the design is always a goal. Additionally, some devices are more expensive because they have additional capabilities that are not relevant to this project.*

Sensing Capabilities (10): *The project requires us to have a hands free trigger to switch between the environmental and endoscopic view. Sensors of some sort will be needed in order to accomplish this. The greater the sensing capabilities of the headset, the more options we will have in order to accomplish this task*

Safety (10): *This is a criteria for any project. The design we choose should minimize any risk associated with it for both the patient and the doctor. The main factor to consider with this is reliability. If the device stops working mid surgery, there could be drastic consequences.*

7.4: Materials and Costs

At this moment, there have been no purchases. Our client has provided us an open-ended budget.