

CMPT 371 – TEAM 3 Health Risk Report

Virtual Reality Medical Imaging Software with Luxsonic Technologies Inc.

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1. Introduction

The purpose of this document is to outline the various risks involved when dealing with virtual reality. Since the current medium of virtual reality is relatively new, health risks are still being researched and documented. The risks that are currently documented and understood will be described in detail, along with factors that contribute to them and how to reduce both the effects and risk. Currently, the adverse effects of virtual reality can be broken down into four main groups: motion sickness, eyestrain, physical fatigue, and latency problems. None of these effects are guaranteed, with some individuals never experiencing side effects from virtual reality use. Others seem more susceptible to these effects. All these contributing factors will be discussed in more detail below.

2. Motion Sickness

Motion Sickness is one of the primary side effects of virtual reality usage. It is characterized as condition where the body's vestibular sense of movement does not match the visual sense of movement. In relation to virtual reality, this is also known as 'cyber sickness'. There are numerous symptoms associated with motion sickness that include, but are not limited to, nausea, dizziness, disorientation, headaches, vertigo, general discomfort, and vomiting. There are two types of motion that can cause sickness.

The first is intentional scene motion, where the user has to navigate the world around them. Vection is heavily used here to give the illusion of movement. While vection involving constant velocity have not generally caused motion sickness, it becomes a problem when acceleration is simulated. Our project will not involve any intentional scene motion, but it is important to be aware of.

The second motion is unintentional scene motion, which is the greater concern for our project. With unintentional scene motion, motion sickness is caused by technology shortcomings and program bugs. These bugs are more specific to the flow of the program and include things like incorrect calibration, tracking errors, latency in actions performed, and speed of the headset to register changes in head movement. Most of these issues can be resolved by better optimizing the code. However, problems such latency in camera movement and visual display can persist when the problem lies with the technology. In these instances, users will have to be aware of the inherent risks of using a technology with these issues.

3. Eye Strain

Perhaps the most obvious health concern associated with virtual reality are those associated with visual stimuli. While motion sickness is more associated with moving objects, visual risks have more to do with the eyes focusing on stationary virtual images. Such risks include Accommodation-Vergence and Binocular-Occlusion conflicts.

3.1 Distance Conflicts

Within reality, we rely on our eyes to be able to focus on objects at different distances. We can visually determine the distance of an object and have our eyes adjust to bring it into focus. Virtual reality takes care of focusing, and sometimes this puts strain on our eyes which we still expect to do the focusing. This Accommodation-Vergence conflict can result in eye fatigue and discomfort. These same risks are shared when there is Binocular-Occlusion conflicts as well.

The best example is when text from a distance actually appears clearer than objects closer up. This is generally an uncomfortable experience for VR users, and one that has already been of concern for our project. Unity, by default, allows 3D text to show through objects that are in front of it, which gives an uncomfortable and confusing experience. While easily solved, it is something that we must constantly consider.

3.2 Flicker

Flicker is a broad term that applies not only virtual reality but any electronic display. It refers to the refresh and/or change of a display. It can also include the constant flashing of lights. For our project, only the former will be of concern to us. Flickers can be known to cause eye fatigue, nausea, dizziness, headaches, and in rare cases can cause seizures. Since the exact frequency of flickering that causes seizures is unknown, it is best to minimize flickers as much as possible. While they cannot be completely eliminated from our program, the best way to reduce them would be to provide smoother transitions between changes in the applications' state. While less than one hundredth of the population are susceptible to seizures, it would be best if anyone who is prone to or has had an epileptic episode not use virtual reality.

3.3 Aftereffects

While not fully understood or characterized, there are certain side effects to using virtual reality that occur after the user leaves the virtual world. The most common after-effects experienced by users are disorientation, perceptual instability, and flashbacks. According to [reference], these after-effects are experienced by roughly ten percent of users. The users in these instances are those that typically experience motion-sickness. Research has been done in comparing balancing and posture of individuals that were immediately exposed to VR and those

that were intoxicated. The results have shown that some individuals had balance impairments similar to those that were intoxicated. Because of this, many businesses that provide virtual reality experiences suggest that individuals wait an hour before driving or physically exerting themselves.

Many of these after effects can be caused by adaptation to inconsistencies in the virtual environment. Situations that involve the user adjusting to shortcomings within the virtual environment would carry on after in reality. For example, to see a distorted image in virtual reality, the user might have to squint or look indirectly at the object. Over a period of time the user may get used to doing this, and after VR use the user may continue to do this for a time. They have to readapt to looking at objects normally, which does not typically take long.

4. Physical Challenges of Hardware

4.1 Headset

While significant changes to hardware have been developed since the early nineties, there is still physical risk from the hardware that must be considered. The headset itself can cause strain to the user if used improperly. In general, the headsets' center of gravity relies on how the user adjusts it. Ideally we would want it centered in line with the user. Having the headset adjusted incorrectly can result in the center of gravity being too far forward which means the user will be using their neck more to support the weight of the headset. While the nature of the headset will have a tendency to pull the user's head forward, this impact can be minimized by properly adjusting the headset. Some strain will remain, so it is advised that individuals with severe neck or back problems refrain from using virtual reality equipment for long periods of time.

In addition to weight concerns of the headset, it is important for straps to be secure and snug. Having the straps of the head set too tight can cut off circulation and put too much pressure on the skin. Having the headset too loose can cause the straps to rub against the skin causing skin irritation. Before use, it is best to consult the manual on how to properly adjust the headset for each user.

4.2 Controllers

For the Oculus Rift, controllers have been adapted to achieve a 'natural feel' where the user can pick them up and feel comfortable using them with little to no experience. That said, the use of controllers in virtual reality requires the user to sometimes have their arms above their waist for extended periods of time. This can cause what is known as 'Gorilla arm', which is arm fatigue caused from extended use of hand gestures without rest. Since the weight of controllers is generally quite small, the fatigue caused by them is generally not too serious. Any fatigue that is experienced can be easily treated by taking a ten minute break.

4.3 Physical Trauma

Physical trauma are injuries that can occur due to extreme physical exertion within the virtual environment. Of note, the user should ensure that their surroundings are clear of objects. Since real world objects cannot be seen in the virtual world, the user can easily trip on objects causing injury to themselves or damage the equipment. The user can also unknowingly leave the virtual environment and begin interacting with and damaging real world objects. The cords from the headsets can pull away from the computer and damage equipment and injure the user. Virtual reality environments do have warning systems that tell the user when they are leaving the observable environment. However, these systems are not always effective.

Repetitive strain injuries can also occur due to repeated carpal and metacarpal activities. These injuries can damage the musculoskeletal and nervous systems leading to injuries like carpal tunnel syndrome, tendonitis, and torn ligaments. While these injuries are more common in the traditional mouse and keyboard setting, they still pose a risk to users.

4.2 Sanitation

Generally overlooked in many computer science environments, hygiene become important when using devices worn by multiple users. Both the headset and controllers of the Oculus Rift can become an agent for transmitting pathogens. The best practise is to wipe down the devices with alcohol and apply a microfiber cloth to the lenses.

5. Latency

Latency refers to the time a system takes to respond to a user's input. Latency is measured by the delay between the user's action and movement of corresponding pixel. Today's VR applications provide unstable scenes due to latency. The technology also plays a huge role with the varying rise and fall times. Prediction and warping are a few examples of what can be used to reduce latency and create stable scenes

5.1 Negative Effects

Users are not able to perceive low latencies (below 100ms) but still feel the consequences of it. For example virtual static scenes may seem unstable when users move their head around. Latency in VR systems causes visual cues to lag behind other perceptual cues which leads to sensory conflict. With latency the virtual scene may have a delay when recording head movements, which could result in major usability consequences. Latency is the leading cause of motion sickness and eye strain in virtual reality programs. Latency in VR can cause degraded vision. Scenes still moving while the head stops may result in degraded visual acuity and motion

blur. Latency can also cause scenes to move in a way that is not consistent with head movement which can lead to the user being distracted.

5.2 Latency Thresholds

There is still not a defined requirement of what latency should be. Ideally, the latency should be low enough that the user is not able to perceive the scene motion. Latency also often increases with quicker head movement. Different scenes ranging from single simple objects to complex rendered environments had no effect on latency thresholds. Users are also just as sensitive to lower latencies as they are to higher ones. It is also important to maintain consistent latency even if it is high.

5.3 Sources of Delay

System delay is the sum of delays from tracking, application, rendering, display and synchronization among components. Tracking delay is the time between when a motion occurs and when it is tracked by the system. Application delay is the time from when the motion is received to when it is sent to render. The rendering delay includes the time between the data entering the graphics pipeline to when the data is completely drawn. Rendering delays depends on the complexity of the scene, the desired quality of the image and the performance of the hardware/software. Display delay is the time from when a processed image leaves the graphics card and is displayed in VR. It is important that we keep the system delay as low as possible to reduce latency.

6. Contributing Factors

During the 1990s, VR systems resulted in 80%-95% of users reporting motion sickness, with as many as 5%-30% of users discontinuing the use of the VR headset because of severe sickness. Fortunately, drastic cases of vomiting is low in comparison to real-world motion sickness with only a 1% chance.

Understanding the contributing factors will allow the creation of the most comfortable VR experiences. Many of these contributing factors may not affect a user until it is combined with other issues. These contributing factors are divided into categories: system factors, individual user factors, and application design factors. Removing one of these categories results in no adverse effects, as each one of these are important contributors to VR sickness.

6.1 System Factors

This section outlines the technical weak points that will continually be improved through engineering. Each factor is listed with decreasing importance.

Latency

Latency is the greatest cause for error in VR, it is discussed above in section 5.

Calibration

Incorrect calibration is a large cause for motion sickness, especially concerning head movement. Accurate tracker offsets, mismatched field-of-view parameters, misalignment optics, incorrect distortion parameters, etc. are important calibration aspects to consider.

Tracking Accuracy

If the accuracy is low, it may result in the user seeing the the environment from the incorrect viewpoint. On the other hand, incorrect tracking of the hands does not induce motion sickness but may decrease usability.

Tracking Precision

If precision is low, it may cause a **jitter**, to the user this may appear as if the world is shaking.

Field of View

A large field of view may cause motion sickness due to the illusion of the user moving with the environment being stationary, the scene moving over a large portion of the eyes, and scene motion.

Refresh Rate

High refresh rates decrease latency, judder, and flicker. Because of this, refresh rates should be as fast as possible.

Judder

Judder is the appearance that the display is jerky or indicates irregular visual motion.

Display Response Time and Persistence

Response time is the time it takes for a pixel to reach its intended intensity, with persistence being the time that the pixel stays in its intended state. These timings along with judder, motion smear/blur, flicker, and latency can cause problems and should be considered in regards to hardware.

Flicker

When light is unsteady, it can be distracting, cause eye fatigue, and seizures. As the intensity of light increases, more flicker is perceived. Displays that have longer response times can reduce flicker but at a cost of increased motion blur, latency, and/or judder.

Vergence/accommodation conflict

Accommodation refers to the changes in optical power to focus on objects at different distances, while vergence is the movement of both eyes in opposite directions to maintain a single binocular vision. For common Head-mounted displays (HMDs), accommodation remains constant while vergence does not. Visuals generally should not be placed close to the eyes, and if they are, only for short periods of time. This is to reduce strain on the eyes.

Binocular Images

For HMDs, images can be presented in multiple ways. This includes: one image for a single eye, the same image for both eyes, or different images for each eye to provide a sense of depth. If the images presented are incorrect, it may cause double images and/or eye strain.

Eye Separation

The inner-image distance, inter-lens distance, and interpupillary distance are frequently in conflict with each other. This may cause discomfort and muscle imbalances in the user's eyes.

Real-World Peripheral Vision

HMDs that allow the user to see the real-world in the peripheral vision can reduce the illusion of the user moving in a stationary environment. Although this is not necessary for a perfectly calibrated HMD.

Headset Fit

Headsets that do not fit properly can cause discomfort and pressure, leading to headaches. For users who wear glasses, the headset may push up against the glasses causing discomfort. Ill-fitted headsets may also slip, causing unintended scene motion.

Weight and Center of Mass

Heavy HMDs can cause neck strain and lead to headaches. This may also alter the way that distance and self-motion are recognized by the user.

Temperature

An increase in temperature around the eyes can cause discomfort, this increase of temperature can be due to lack of ventilation.

Dirty Screens

If the display is not clean, it may cause eye-strain because the user cannot see clearly.

6.2 Individual User Factors

The most considerable component of motion sickness is the individual themselves. The user's sensitivity to VR sickness is determined to the user's polygenes. The range in which user's experience sickness varies greatly. Some people exhibit many signs immediately during use, others only exhibit a few signs after an extent of time, and there are some who do not exhibit any sickness after being exposed to extreme conditions.

User's are affected differently, one user may be affected by lateral motions while this may not affect another individual who is susceptible to sickness from other motions. New users are commonly more susceptible to motion in comparison to those who are more experienced with VR. Since there are so many factors that may attribute to each individual, the best option is to provide options for users to choose a setting best fitting their needs.

There are three factors that play a major role in how much an individual gets motion sick, these include:

- Sensitivity to provocative motion
- Rate of adaptation
- The time it takes to eliminate symptoms

The following section demonstrates distinct factors that attribute to VR sickness in decreasing importance.

Prior History of Motion Sickness

If the user has exhibited motion sickness in the past, it is a good indicator that they will experience sickness in VR.

Health

If the user is not in their conventional health state, they should avoid using the VR as this can contribute motion sickness. There are several health factors that may contribute to sickness, including: hangovers, the flu, respiratory illness, head colds, ear infections, ear blockage, upset stomach, emotional stress, fatigue, dehydration, and sleep deprivation. Additionally, VR is not suitable for those who are under the influence of drugs or alcohol.

VR Experience

The more that a user is experienced with VR, the less likely they will experience symptoms of motion sickness.

Thinking About Sickness

Suggesting to users that they may experience motion sickness will more likely cause the user to get sick. Warning the user provokes them to dwell on the fact that they might experience

motion sickness. On the other hand, if the user is not informed at all, they might not be able to make the right choices to lessen the chance of experiencing sickness. It is best to inform the user that there could be some sort of discomfort without putting emphasis on sickness.

Gender

VR sickness is three times more likely to occur in females than males. Contributing factors could include hormonal differences, difference in field-of-view (females have a larger field-of-view), and/or data reported by the individual (males tend to under-report symptoms).

Age

People aged from 2-12 are more susceptible to physically induced motion sickness, this decreases dramatically from the ages of 12-21 and continues to decrease slowly. On the other hand, VR sickness still increases with age. The reasons are still not apparent for why there are difference between physically induced sickness versus VR sickness but this could be due experience in similar situations.

Mental model/expectations

If the user's expectations do not match what they actually see, it can cause sickness. If navigation does not match the viewing direction, their mental model may come apart and bring about confusion.

Interpupillary distance

The distance between an adult's eyes ranges from 45mm to 80mm. The VR system should be calibrated to each individual.

Not Knowing what looks Correct

A user who is a beginner may not know how the headset should fit and what they should see. Educating the user on how to put on the headset and make adjustments to ensure the image is clear and until they feel comfortable can reduce negative effects.

Sense of Balance

Motion sickness can be correlated to the user's pre-VR sense of balance.

Flicker-fusion frequency threshold

The flicker-fusion frequency threshold is the frequency in which the flicker can be noticed by the user. This frequency varies greatly across individuals, and within individuals (time of day, etc.).

Real-world Task Experience

Those who have experience in a real-world setting of the application may more likely be susceptible to motion sickness because they have the experience of how the real-world should function in regards to the task.

Migraine History

Those who have a history of migraines are more likely to be susceptible to VR sickness.

There are many other possible factors that contribute to VR sickness but not enough research has been done to conclude any results.

6.3 Application Design Factors

Although all technical issues may be solved, content can still cause sickness. This is due to the fact that human physiological hardware differs from human-made hardware. Factors that can be considered during the design are presented below.

Frame Rate

Latency issues can be contributed to slow frame rates. Frame rates can be affected by how complex an application is and software optimizations. An inconsistent frame rate can be worse than a low frame rate.

Physical Head Motion

If a system has issues with latency and inaccurate calibration, sickness can be reduced considerably if there is no head movement. It is best to design the application with minimal to no head movements if latency is greater than ~30ms.

Duration

With the increase of time experiencing VR, motion sickness increased. It is best to design the application for short uses with options for breaks.

Virtual Rotation

“Virtual rotations of one’s viewpoint can result in motion sickness.”

Gorilla Arm

Arm tiredness can result from user interfaces with extended above-the-waist gestures without rest.

Rest Frames

Humans are inclined to prefer stationary environments, because of this it is best to include visual cues that are consistent with the user's vestibular system.

Standing/Walking vs. Sitting

"VR sickness rates are greater for standing users vs. sitting users which correlates with postural stability."

Since users cannot hear nor see the outside world, there is a larger chance of injury due to falling and collision with objects. Standing may also cause fatigue to the user for longer periods.

Height Above the Ground

Positioning the user at a different height than their real-world physical height may induce sickness.

Excessive-Binocular Disparity

If images are placed too close to the eyes, double images may occur because the eyes are not able to fuse the left and right images seen.

VR Entrance and Exit

When the user is putting on or removing the headset, the screen should be blank. Any visual stimuli should not be displayed to the user during transition.

Luminance

Systems with less light may result in less problems with flicker and low refresh rate.

Repetitive Strain

Prolonged repetitive activities can cause strain.

7. Methods Of Health Risk Reduction

7.1 Optimize Adaptation

Dual adaptation can reduce sickness, this can be done because visual and perceptual-motor systems are modifiable. Generally speaking, most people can adapt to VR, the more that one adapts, the likelihood of getting sick is reduced. The speed of adapting varies by person, someone who may adapt quickly may not experience any sickness at all. On the other hand someone who takes a long time to adapt may give up beforehand. An effective way to reduce motion sickness is to increase exposure as time goes on. These exposures should occur 2-5 days apart. Those who are new to VR should be advised verbally and textually to use slow head

movements. Also, to reduce the chances of adaptation being temporary, latency should be kept consistent.

7.2 Real-World Stabilized Cues

When visual cues imply that there is no movement but the vestibular system is stimulated as if there is movement, motion sickness often occurs. This may also happen in the inverse situation where visual movement occurs but the vestibular cues is not stimulated. Either way, the visual and vestibular system are in conflict.

Matching both the visual and vestibular cues will eliminate the conflict, dramatically reducing motion sickness. The same will happen in the inverse situation, adding stable visual cues to virtual environments will act as a rest frame.

7.3 Delay Compensation

Virtual Reality will constantly have a delay since computations are not instantaneous. Using techniques to compensate for delays will the harmful effects of system delays. These techniques are described in the following sections.

7.3.1 Prediction

A technique that is usually used for head-mounted displays is head-motion prediction. This type of prediction will result in acceptable results for slow head movements and low system delays. On the other hand, prediction may result in sensor noise being amplified and the increase in motion overshoot.

7.4 Reducing Gorilla Arm

The use of VR devices can become exhausting after long use because of continuously holding the controllers out in front of the user. To decrease the strain, designing interactions that allow the user to keep arms in a relaxed position will permit the user to interact for longer hours.

7.5 Medication

While various medications can have widely different effects and symptoms, the use of medication in virtual reality is generally not well researched. These effects could greatly increase the chances of motion sickness depending on the medication used by the user. For safety reasons, use of serious medication (particularly those for migraines) is strongly discouraged when using virtual reality.

8. References

Jerald, J. (2016). The VR Book: Human-Centered Design for Virtual Reality (pg. 159-221). IL: Morgan and Claymore.