Spatial guiding through haptic cues in omnidirectional video

Joona Kinnunen

University of Tampere
School of Information Sciences
Interactive Technology
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Supervisor: Roope Raisamo
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ABSTRACT

Omnidirectional video's extensive amount of visual information challenges the users to find and stay focused on the essential parts of the video. I examined how user experience was affected when haptic cues in the head area are used to guide the viewer's gaze towards the essential parts of omnidirectional video. User experiences with different omnidirectional video types combined with haptic guiding were compared and analyzed. Other part of the research was aimed to find out how haptic and auditory modalities and their combination affected the user experience. The participants used an Oculus Rift headset to watch omnidirectional video material and two actuators were placed on their forehead to indicate if the essential part located in the left or right direction. The results of the questionnaires and the comments showed that haptic guiding was useful and effective, though it was not experienced as a necessary feature during easy to follow and slow-paced videos. The combination of haptic guiding and audio was rated the most positive use of modalities. This feature has a lot of potential to enhance user experience of omnidirectional videos. Further studies on the long-term usage of the feature are required to eliminate the novelty effect and gain a more accurate understanding of the users' needs.

Keywords: Spatial guiding, Gaze guidance, Haptic feedback, omnidirectional video, head-mounted display

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Joona Kinnunen
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Tampere

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1. Introduction

Omnidirectional video (ODV), also known as 360˚ video, immersive video and spherical video are video recordings with a 360-degree field of view. ODV covers visually almost the entire sphere depending on the capture device. It can be displayed in multiple ways. The video can be projected into a cave-like room, viewed through a head-mounted display or displayed through a 2D screen which can be interacted with multiple interaction techniques.

In 2015 omnidirectional cameras were released on the market for regular users and social media services such as Youtube and Facebook added support for ODV. The 360-degree video content has ever since been slowly increasing. This format is often used when creating panoramic art. Omnidirectional cameras can create high quality panoramic art efficiently without the need for manual post processing. Omnidirectional panoramic art is very immersive, while it captures the whole scenery and can be viewed in a way which blocks all the outside distractions.

Social service's popular 360-degree videos often feature unique experiences, which may be too extreme to experience in real life. These experiences consist of bungee jumps, rollercoaster rides, base jumps and other suspenseful experiences. Sharing and watching such thrilling events through ODV comes closer to duplicating the real thing than any media content so far. The volume of immersion is one of the most important selling points for ODV.

360-degree video data is also utilized in robotics, computer vision, tracking and surveillance. Omnidirectional cameras record more extensive amounts of data, which enhances the use of video. In surveillance it lessens the number of required cameras and in robotics omnidirectional cameras are frequently used for visual odometry and to solve the simultaneous localization and mapping problems visually.

The release of high resolution head-mounted displays to the regular consumer has made researching virtual environments and ODVs more popular. Research has been done combining various forms of interaction with the spherical video. The combination of head-mounted displays and gesture recognition has been recognized as a compatible couple of input and output methods [Benko, Li, Rovelo]. The compatibility can also be seen how the virtual reality (VR) headset manufacturers have brought new gesture input controllers to the market and are sold along with the VR headsets such as Oculus Rift and HTC Vive.

Studies have also focused on new virtual environments which could challenge the traditional two dimensional desktop environments. One interesting study by Neng and Chambel [2010] researched if hyperlinks could be used as a navigation technique in an ODV environment. They added hyperlinks into ODV which took users to other related hypermedia. This was created to provide users extra information about all the important visuals that were present. The results show that early hypertext users got lost in the hyperspace and that hypervideo players should be as clear as possible about how a user should interact with it.

Imitating the input methods of the real world makes it more intuitive for users to learn to use certain actions. For example, grasping is one of the basic human actions and it can also be used in virtual spaces as a fast to learn interaction method to manipulate virtual objects. Controlling and interacting with virtual objects with our physical hands has the potential to improve the quality of our interaction. Using our physical hands can also improve our spatial understanding and self perception in the virtual environment. Output methods such as VR headsets also create a more immersive experience by co-operating more intuitively with our physiology.

The more immersive experience does not come without challenges. ODV contains extensive amounts of visual data from which the majority is not in the user’s field of view. This might make it challenging for the user to find the essential parts of the video. Haptic feedback can be used to influence our interactions and could be a functional method to guide the user’s gaze towards these essential parts in ODV.

The study addresses the following questions: Can haptic cues in the head area be applicable to guide user’s gaze towards essential parts of an ODV? How does this feature affect the user experience (UX)? Does the ODV content affect the UX of the feature? How?

The aim of this study is to research if ODV can be efficiently combined with haptic cues on the head area to guide the user’s gaze towards the essential part of the video. The study will research how haptic guiding affects the user experience when watching different ODV types which have a diverse pace and where the essential information is transitioned differently. UX with different combinations of auditory and haptic modalities is also analyzed to gain knowledge of the value this feature could offer. Knowing how applicable this feature is, might enhance the future ODV experiences.

My hypothesis is that the gaze guidance feature will be functional for its purpose and users will find it helpful. The UX on the other hand might be affected in both negative and positive ways depending on the user. The ODV types will most likely have varying user experiences.

These questions are researched by analyzing existing research on topics related to ODV, UX and haptic feedback, and by conducting user tests to gain comparable information about the UX. The results of the existing research and UX tests are cross examined and deduced to a conclusion.

2. Background

As there are many variables which affect the UX, other research and background information about immersion, ODV, VR devices, human attention and haptics needs to be introduced. These topics will be summarized and discussed to understand the basis of this study. The background information on the topic will partly explain the research' motivation and the chosen research methods.

2.1. Immersion

Immersion can be said to be a state of consciousness during which a person focuses on an artificial world, perceives to be present in that world and momentary has little to none awareness of the real physical world around him. In Brown and Cairns study [2004], gamers described immersion shortly as: "you feel like you're there".

Immersion is often studied because it is an important part of UX. It has been studied in various contexts such as gaming, engineering, architectural design and education. Immersive virtual environments can be used to enhance the design process through assimilating the sense of depth, scale, and spatial awareness. Using virtual environments for design can also save time and money. A study by Kleiss [2010] concluded that using immersive engineering did not only save money, but it also improved customer satisfaction and product quality.

Cruz-Neira et al. [1992] made a virtual environment called the CAVE, which consisted of a room whose walls, ceiling and floor were projected with images. This was an immersive environment which was not constrained by the issue in field of view, visual acuity and lack of intrusion. The virtual environment of the CAVE can be used for product development, panoramic exhibitions, collaborative planning, research and simulations. The biggest advantage against other virtual environments is that it allows multiple users to interact with the data displayed.

Immersion is one of the primary reasons why VR headsets are interesting to the public. VR headsets isolate the user's audio and visual perception which decreases the amount of distractions outside the virtual experience. The isolation helps the user to achieve immersion more efficiently due to minimized amount of physical world's distractions.

Studies by Jennet et al., [2008] and Ravaja et al., [2005] suggest that immersion can be measured subjectively through questionnaires and objectively for example by comparing task completion times or measuring eye movement. Björk and Holopainen [2004] have categorized immersion into four separate types: sensory-motoric immersion, cognitive immersion, emotional immersion and spatial immersion. Sensory-motoric immersion is experienced when performing tactile operations that use skill, whereas cognitive immersion is associated with mentally challenging tasks. Emotional immersion occurs when users become invested in the narrative and the spatial immersion is experienced when the simulated environment is perceptually convincing.

In this study I am most interested in the cognitive and emotional immersion. Watching ODVs with head-mounted displays completely copies the interaction which the sensory-motoric skills use in the real world for looking around, by using head movement and eye movement. Spatial immersion is also replicated to be almost identical to the actual experience. This makes it irrelevant to focus on immersion types which already work well. Narrative immersion might require long-term studies with longer duration ODVs, in which the user has the time to become invested in the narrative.

VR headsets offer a natural way of looking around which enhances sensory-motoric and emotional immersion, when the tasks do not require adapting to a new way of interaction. The natural interaction and the decreased amount of outer distractions of head-mounted displays create a more immersion friendly way to submerge into the virtual environment. Adding haptic feedback into the ODV experience creates a risk of disrupting immersion, but if cognitive and emotional immersion are already suffering it might be worth the risk.

2.2. Omnidirectional video

ODV enables an immersive surround video viewing experience. ODV can be recorded using an omnidirectional camera or using a collection of multiple cameras which can film all angles simultaneously. ODV can also be a recording of a virtual environment or an animation.

ODV can be viewed monoscopic or stereoscopic. The stereoscopic view creates an illusion of depth and it is created by directing two distinct images individually to each eye. Stereoscopic viewing can only be played by certain devices such as VR headsets and the method does not work unless both eyes have their own display.

The viewing of a 360-degree video can happen through head-mounted displays, regular monitors, smartphones or immersive virtual environments such as the CAVE [Cruz-Neira et al., 1992]. The controlling of the viewing angle depends on the display device and can for example be interacted with simple mouse drag interaction or linking the position angle of the device with the video’s viewing angle.

ODV has been used in education, journalism and time-lapses, and the technology has evolved to a point where one can live broadcast in ODV format. These 360-degree live streams can be watched in real time using mobile devices, desktop computers or VR headsets. This connects people in a more immersive way and enables better real-time co-experiencing.

Using ODV one can better present the big picture compared to regular video. The panoramic and immersive visuals can create more emotionally attractive experiences. This moderately new way of recording and receiving information has a lot of potential, but the use of it also represents challenges.

2.2.1. Prospects of VR and ODV

The arrival of VR headsets does not just benefit the movie and gaming industry. The depth of immersion and the massive amount of visual data offers new and more efficient methods to use technology for learning and experiencing. VR simulations and ODV can help people to visualize certain concepts. For example, members of MIT Game Lab [2012] created a first-person experience that exhibited special relativity by slowing down the speed of light. Space exploration and virtual tourism through panoramic pictures or ODV is another new way of providing information to people who cannot experience these places on the spot. These tours and exploratory ventures can be educational and motivational to students.

ODV and virtual reality can also convey a bigger emotional response to the user. The field of journalism has used virtual reality as an intermediate of emotions. USC School of Cinematic Arts has created a virtual experience called Project Syria which places viewers at the scene of a bombing, then allows them to explore a refugee camp [Project Syria, 2014].

University of Louisville Physicians have used virtual reality experiences to treat anxiety disorders and related problems [2013]. This method of placing patients in a virtual reality with their fears has been proven to be a highly effective treatment.

The utilization of VR and ODV is only at the beginning and it has shown to have great potential. It already enables some enhancements in journalism, teaching, health care and entertainment, and there most likely will be many more fields which are going to benefit from the use of ODV and VR technology.

2.2.2. Challenges of ODV

ODV features a large amount of visual information when compared to regular video with a locked angle. While all this data provides a more immersive experience, the extra information also creates a challenge to the viewer. It can be challenging to direct one’s attention towards the essential parts of the video. The field of view (FOV) of an average person is around 170-180 degrees, whereas playing on a monitor offers an average of 100 degrees FOV. A head-mounted displays such as Oculus Rift and HTC Vive have a 110 degrees FOV. This degree of FOV results in 69,4% loss of visual information. See calculations of visual information loss below.

$$(360^{o}-110^{o})/360\,^{o} = 69{,}4\%$$

Equation 1. The total loss of visual information with a 110 degrees FOV device

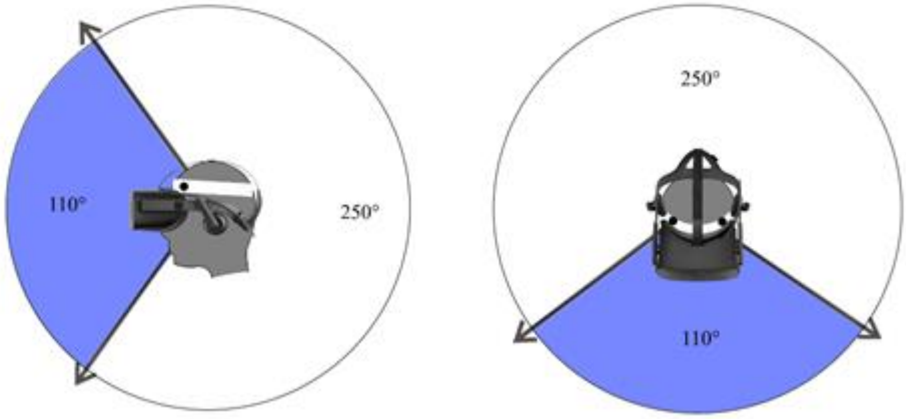


Figure 1. The field of vision presented from two perspectives

Bleumers et al. [2012] studied how ODV would work as a new format for TV viewers by researching what the users’ perspective was on televised ODV. The study showed that participants enjoyed the ODV experience, but were skeptical, if it was mainly the cause of the novelty effect. Users were also concerned about the information load whether it would threaten the viewing experience as a relaxing experience and if their narrative processing would suffer by losing the essence of the program. Participants were also worried that ODV could compromise the social concept of watching television together on a single screen.

Bleumers’ [2012] study listed matters which should be taken into account to improve the ease of use. The most interesting part in regards of this research was that viewers should be enabled to jump between different points of interest. The participants of this study used a laptop for viewing and a computer mouse to change their viewing angle, which is definitely more burdensome than using head gestures with a head-mounted display. Dragging with a mouse to change the viewing angle may need the ability to jump quickly from one point of interest to another. When the navigation is linked in with the direction the user is looking at the users may not need a quick jump feature, but it still might be useful when a video has many points of interest which are far apart from each other.

Due to the extensive quantity of visual information and the amount of hidden visual information, ODV material seems to need some kind of navigational guidance in cases which the video has for example narratively essential information in some locations. The need for navigational guidance in ODV is one of the major parts why researching the practicality and user-friendliness of haptic cues for navigational purposes is important. This could enhance the ODV experience and create an efficient feature to help viewers follow the essential information in a visually massive environment.

2.3. Human attention

Future narrative ODV movies and series will need more efficient ways to capture the viewer’s attention due to the extensive amount of visual information and the challenges of free spatial navigation. The challenge of free navigation has already surfaced in gaming after 3-dimensional environments emerged in the gaming world. For the game designers to offer the experience they want the players to have, they have to create a way to guide the users’ attention and actions. To understand how gaze could be guided with haptic feedback, we need to first understand how attention can be directed.

Attention is a neurobiological function which allows us to continually and dynamically select the most appealing stimuli so that greater neural processing resources can be directed for their analysis. When humans direct their attention towards something all their senses focus on the target. Attention capture has thus been a good method to guide gaze. In order to make a certain stimulus more important than the others, movie directors and game designers have exploited human functions which raise their priority, attention vice. Raising the attention priority of something basically means directing and focusing the selective attention towards a certain part of the medium.

One of the most natural attention capture methods is using sudden visual changes. This happens for example when a new object that appears or moves on the screen. Yantis and Jonides [1996] have shown that an object appearing abruptly in a previously blank location is efficiently detected in visual search when it is embedded in an array of objects without abrupt onset. Humans and animals have evolved and gained this function which makes the brain detect these so called abrupt-onset events. The skill which originally functioned as a survival mechanism to spot and recognize possible threats is nowadays utilized in various entertainment contents.

Capturing attention can also happen by making the target pop out of the environment, by manipulating the characteristics of the target. For example, by manipulating the shape or the color of the target into a distinct one will make the target easier to spot. Attention can also be directed using the gaze-shift in another individual. For example, if the viewer notices a person on the screen to suddenly look at a certain direction, the observer’s attention will be also directed into that direction.

When experiencing multisensory stimulation, attention tends to be directed at certain stimulus in one modality and the potentially distracting stimuli in another modality are blocked out. “Tuning off” a certain modality is called intermodal attention. Supramodal attention on the other hand consists of processes which are linked by other modalities, for example spatial auditory processing is often directed at the same direction as the visual stimuli. Tan et al. studies [2003, 2009] concluded that valid haptic cues can significantly speed-up visual detection. This supports the use of haptic cues as a guidance mechanism in a visual environment. DiFranco et al. [1997] study also suggests that coupling audio and haptics could help with perceiving the solidity, shape, location, and proximity.

If pairing haptics with other modalities is a functional method to guide the users' attention with visual and auditory data, the only question is how haptics can be used effectively with ODV, when most of the visual data is not present. ODV can use spatial audio for the users to hear the direction of the essential data, but for now most ODV content does not use spatial audio. The fact that all the vital information does not always make a sound supports the use of other modalities than audio for localization of events. Crossmodal pairing of visual and haptic stimuli can direct the user's attention, though presenting the distance and the precise direction with haptic cues can be challenging.

2.4. Haptic feedback research

Vibrotactile displays are arrays of vibrating actuators that can transfer information about the environment through the actuators' amplitude, waveform, frequency or signal duration. Haptic feedback is now commonly used in controllers and mobile devices to enhance the UX. Information that touch gives can make the experience more natural, intuitive, expansive and immersive. Other sources of information such as visual and auditory cannot alone replicate real life experiences, also these sources are often overloaded with information. The sense of touch can support other senses and can be utilized in multimodal interfaces. Some of the uses for haptic output will be introduced and it is explained how haptic feedback could be beneficial when paired with omnidirectional video.

Philips Research's tactile jacket was created by Lemmens et al. [2004] to study how movies and tactile feedback work together. The jacket consists of 64 embedded vibration motors which can be independently controlled. The purpose of the research was not merely to reproduce the physical sensation from the film, but to determine what sort of emotional responses touch can elicit viewers.

Figure 2. Philips's tactile jacket. [Body-pixel.com, 2011]

This area of research is called affective haptics. Affective haptics studies designs, systems or devices that can elicit, enhance or influence the emotional state of the user by using haptic feedback. Disney Research [2010,2011, 2012] also studied affective haptics by enriching various experiences with tactile feedback from haptic surfaces. These studies have shown that haptic feedback adds another dimension to perceptual experiences.

Usually haptic feedback is synced with auditory or visual cues to strengthen the overall experience or to improve the performance of certain tasks. It was shown by Kangas et al. [2014] that gaze gesture performance can be improved when using haptic feedback. McAdam and Brewster [2009] concluded in their research that haptic feedback sped up the speed of writing on tabletop computers. These studies support the use of haptics to improve performance.

Head tactile communication is a method which uses tactile signals to communicate with users. Myles and Kalb [2010] studied a silent head-mounted communication system, which can be used for example by soldiers as a guiding system or threat indication system. The guiding system was meant for situations where audio or visual feedback could result in the detection of the user, making haptic feedback a stealthy method for conceiving information. No results have been released but the idea seems promising.

The tactile stimuli itself in the head area has been demonstrated to be functional. Myles and Kalb [2009] research and Weber's study [1978] show that most sensitive areas of the head are the crown, temples and the back head. Dobrzynski et al. [2012] studied the effectiveness of head attached vibrotactile displays and identified three major design factors for them. First, the strength of tactile stimulation should be estimated to be around a comfort amplitude and it should be preferred over minimally detectable strength due to its insensitivity to hysteresis effects and variation in strength perception in various regions of the head. Second, the study results on multipoint stimulation suggest to avoid using multiple motors at the same time, because the precision in detecting the correct number of active motors is drastically decreased in contrast to a single active motor. Third, perceiving the location of the stimuli was always constant. The difficulty to detect multiple active actuators also occurred in Rantala et al. [2014] study which introduced eyeglasses that present haptic feedback when using gaze gestures for input.

Rantala et al. study [2014] envisioned three different main types of use scenarios for combining gaze gestures and haptic feedback. First type was interacting with objects in the physical environment without a visual display. Interaction would happen by using smart eyewear to recognize objects and using fixated gaze for example to control lamps on the ceiling. The second scenario Rantala et al. introduced was interacting with public displays such as information walls and for example browse timetables in a train station or bus stop by only using gaze. In the final envisioned scenario, the user would have a near-eye display attached with the eyewear (e.g., Google Glass). In the example, the user could browse through messages from friends only using eye gestures and receive haptic feedback.

A more recent study by Rantala et al. published in 2017 showed that there is potential in using vibrotactile cueing of gaze direction. A headband with six actuators on the forehead region proved to be accurately effective of directing gaze to the width of two to three fingers at arm's length. The study deduced that haptic cues for directing visual attention and providing navigational cues with wearable gadgets such as head-mounted displays, VR headsets, and headbands can be useful.

Previously referenced research results from Dobrzynski’s et al. [2012] and Rantala’s et al. [2014, 2017] studies clarified that the head area can quite accurately perceive the direction of the vibrotactile stimuli. An omnidirectional video has the 360 degrees sphere like environment and in order to guide the gaze as efficiently as possible, the vibrotactile stimuli should be located in the exact same direction as the occurrence. Unfortunately, human head area does not provide good actuator locations all over the surface for example the area beneath the eyes. If the actuators are not located near the skull and they are placed against muscle tissue the sensation of the sound wave can be irritating. This study will not use spherical area of vibrotactile stimuli because actuators cannot be comfortably attached all around the head.

A natural and a functional stimulus to indicate a target located in an up or down direction will be hard to create. Irritation is the first problem, as previously mentioned, vibrotactile stimuli anywhere close to muscle tissue and away from the skull can create irritation. The second problem surfaces when the actuator is placed on the chest or somewhere else than the head. The location of the actuator will interfere with the alignment of the vibrotactile stimuli and the visual information. This study will exclude the use of actuators which would indicate the users to look up or down because the human head surface does not provide intuitive and comfortable locations for these actuators.

Multiple active actuators were hard to detect in Dobrzynski's study [2012] which is a reason, why future studies should only use a single active actuator at a time. This study will continue with the same approach and examine if simple left and right vibrotactile cues on the temple area are efficient enough for the user to convert the gaze towards the essential data. In the experiment the users will have a 100 degrees FOV in the vertical direction. The results of this study should also show if users can scan the non-visible areas without the help of vertical vibrotactile guidance.

Tactile sensing variations do not only happen in different body surfaces, but there are also individual differences. The differences can be caused by impairments of haptic sensitivity such as neuropathies or skin injuries. Stevens et al. [2003] concluded his study that age declines the tactile acuity. Gender is also one factor which can affect tactile perception [Peters et al., 2009]. Individual preferences towards certain haptic stimuli can variate, which is why the haptic feedback strength should be adjustable.

As the previously introduced research demonstrated, haptics can be used in many scenarios varying from navigation to affirming interaction and to affective haptics to enhance narrative storytelling. With the arrival of various head-mounted displays on the market the competition has become more aggressive. The VR companies will need to stand out for example by releasing new interaction techniques or new output methods such as haptic feedback in the head area. Combining haptic feedback with head-mounted displays might be the future especially when it has been acknowledged as an effective way to convey information.

Haptic actuators in the head area could be a natural and an efficient way of perceiving tactile information when guiding the user's gaze without distracting the user with additional visual or auditory information. Haptic guidance can at worst diminish the overall emotional experience by distracting cognitive processes or irritating the user. One of the goals of this study is to examine if haptic feedback in the head area has any of these downsides.

2.5. VR headsets

Virtual reality headsets are head-mounted displays which transmit an immersive VR experience. These devices project stereoscopic visuals, meaning that the device provides separate images for each eye. This technique creates the illusion of 3D depth in images and videos.

VR headsets are used for computer games and ODV experiences, such as 3D-simulations. The user's head movements are tracked with gyroscopes, accelerometers and structured light system tracking sensors. Head tracking information can be synced in with the virtual reality and the user can change his direction of view, his head location and position accordingly inside the virtual environment. Some VR headsets include eye tracking sensors, headphones and controllers. The perception of depth, head tracking and the isolating effect of the headset enhance immersion by supporting and simulating human behavior and processes. The isolation increases immersion by removing outside distractions.

The first VR head-mounted system is considered to be the Sword of Damocles, created in 1968 by computer scientist Ivan Sutherland and his student Bob Sproull [Sutherland, 1968]. The device tracked the user's head position and rendered a simple wireframe 3D environment based on their simulated field of view. The head-mounted display was attached to a mechanical arm suspended from the ceiling of the lab. The mechanical arms enabled the device to track the user’s head movement and helped the user to wear the heavy device.

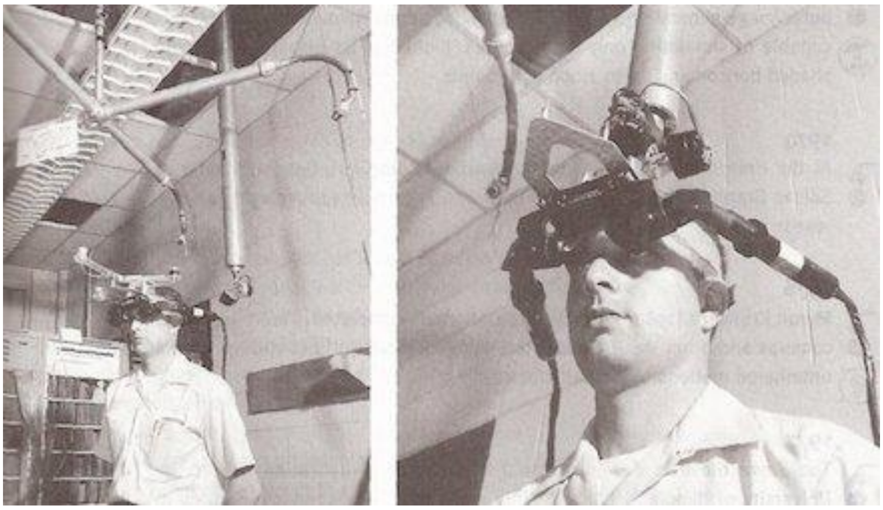


Figure 3. The Sword of Damocles. [The CCCU Psychology Programme Blog, 2017]

The first commercially available virtual headsets were introduced back in 1990’s. Forte VFX1 was one of the headsets which stood out the most by being one of the best VR headsets in 1995 [Figure 4]. Virtual I-O i-glasses and Cybermaxx were the other two VR headsets which tried to compete in the VR market. Sony also tried to join the VR headset market by releasing Glasstron in 1997. VR did not hit it off with the consumers partly due to several reasons. An article from VRrelated.com [2015] explains that the devices retailed around 700$ to 1000$, which at the time was a high price to pay for such a feature. The headsets were also considered uncomfortable and heavy. Using these devices with eyeglasses was unpleasant if not impossible. The picture quality and the resolution were poor compared to the displays used at that time. Briefly put, the technology had not advanced far enough for VR headsets to be consumer friendly.

Figure 4. Forte VFX1. [Wikimedia]

In 2012 plans for Oculus Rift were announced and the VR-headsets resurfaced to the consumer’s awareness. After a while Sony, Samsung and HTC appeared as competitors in the VR headset manufacturing area and released their own products in 2016, the same year as Oculus. Samsung focused their VR headsets for mobile platforms, while Sony’s headset was compatible only with Playstation 4. HTC and Oculus targeted their devices for the PC gaming market.

Figure 5. From left to right: Playstation VR, HTC Vive and Oculus Rift.

The 21st century VR headsets have improved a lot when compared to the 90s headsets. The field of view has doubled and the resolution of the devices has increased from 263x230 to 1080x1200 pixels per eye. Dome.fi article [2016] explained that the weight of the older devices was a big issue, whereas the newer devices weigh from 380 to 610 grams and have been reviewed comfortable. Newer devices have increased the refresh rate of the on-screen images from the old 50-72 Hz to 90-120 Hz to counter VR sickness and to provide a smoother experience. New technology has improved many aspects of VR headsets and even the price is more consumer friendly. These enhancements have made the VR headsets successful and they have not flopped like the 90s VR devices. According to an article in canalys.com published in November of 2017, more than a million VR headsets were sold during 2017. In 2018, HTC Vive released a new wireless version of their device and Oculus released a mobile version.

These new headset releases and the 2017 sale numbers implicate that the VR headset market is thriving and the user base is growing. If VR headsets become more common, it will be important to research new possible uses and features for these devices. One of the potential features is haptic feedback in the head area. This feature can be moderately easily adapted into the headset and it could be used for multiple purposes, one of them being gaze guidance.

2.6. User experience

The international standard on ergonomics of human system interaction [2009] defines UX shortly as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". Hassenzahl and Tractinsky [2006] divided UX into three major factors: the system, user and the context of use. The system factor is affected by multiple variables such as the complexity, functionality and usability of the system. The user’s internal state such as expectations, mood, motivation and needs resonate with the system and the context of use, which in consequence makes up the UX. See figure 6.

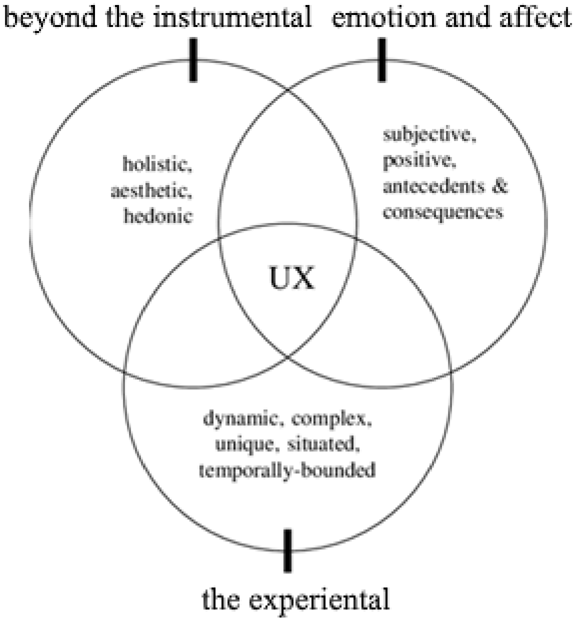


Figure 6. Three facets of UX [Hassenzahl and Tractinsky, 2006]

The field of human-computer interaction (HCI) has been interested in UX since it offers means and variables for evaluation. UX evaluation can include methods to evaluate holistic perspective and usability. The evaluations mostly focus on the user’s positive feelings and the performance. Evaluation time span can vary from long-term to task oriented use depending on the evaluated target.

There is no certain method which will work the best for UX evaluation. Roto et al., [2009] recommended to have mixed methods, also called method triangulation. This means using two or more evaluations methods to gather data. The gathered data can be observations, interviews, questionnaires. which offer qualitative or quantitative data. This data can be used to cross verify the results. Using method triangulation can result in more reliable, holistic and better understanding of a phenomenon. The downsides of combining methods is the strain it can put on the participant, if one is required to go through more tasks, and it will be harder to deduce conclusions from more extensive amount of data.

This study will use questionnaires, observations and short interviews as evaluation methods. The questionnaire will be derived from Attrakdiff using a set of scales of opposite adjectives. Each set of adjective items is rated into a scale. The purpose is to understand both the pragmatic and the hedonic side of the UX while using haptic cues in spatial guiding in ODV.

3. Research methods

The aim of the study was to answer the following questions: Are haptic cues in the head area applicable to guide user’s gaze towards essential parts of an ODV? How does this feature affect the UX? Does the ODV content affect the UX when this feature is used? To answer these questions, at least two distinct UX tests were required. First one to study how the gaze guiding feature affects the UX by comparing UX test results with haptic feature and without it. Second study to compare experiences with different ODV types. After the tests it was possible for the users to judge and answer if the feature was usable for the intended purpose.

3.1. The procedure

To carry out the UX tests, required hardware and ODV material was gathered. Each ODV clip used in the test was downloaded from Youtube and made into a software with Unity. In these software targets were marked into the video and they acted as the essential parts in which direction the users gaze was guided to. The software detected and informed the user if the targets were not in the user’s field of view in the horizontal angle. The participants used an Oculus Rift headset and had a headband with small actuators located in the left and right forehead area. Multiple active actuators were hard to detect in Dobrzynski’s study [2012] which is why in this approach only two actuators were used, and only one of them can vibrate at a time.

Figure 7. Two vibrotactile actuators fixed into a headband

These actuators vibrated once every half second if the relevant information was not located in the horizontal angle where the user was watching. A vibration on the right side meant that the target information was located to the right side and a left vibration to indicate that the target was located to the left side. There were no indicators if the target was not in the field of view and located directly above or under the current field of view. Design guidelines by Myles and Kalb studies [2010, 2013] suggest that the actuators would be most comfortable in the head area if the signal frequency did not exceed 150 Hz. During testing the frequencies, the best vibration was noticed to be at the 150 Hz limit, making the vibration noticeable and comfortable.

Figure 8. User wearing Oculus Rift and the headband.

Before the tests the participants were asked to sign an informed consent form and fill out a background information form. This query asked about the participants age, gender and previous experiences with ODV and VR devices. The purpose of the test and the guidance system was also explained to the participants.

The participants were seated into a rotating chair where they would sit through all the tests. The wires of the actuators restricted rotation movement on the test chair and it was not possible to rotate more than two times around the axis before the wires started to tighten around the user. The traction of the wires was always reset after watching a video. It was noticed that the participants did not rotate more than one cycle around the chair during the testing period and the restrictiveness of the wires was not an issue.

To diminish the learning and the novelty effect, each participant was given some time to familiarize themselves with Oculus Rift and the haptic guidance by viewing a test ODV clip combined with haptic guidance. This test video included seven target directions which triggered the actuators when the target was not displayed in the participants horizontal range of the field of view. The test ODV was a beach videoclip [Youtube 1]. Balls were edited into the clip and they appeared and disappeared in seven different locations. The target ball was visible from 5,5 seconds to 10 seconds. The test video lasted for 1 minute and 5 seconds and it was used to confirm that the user understood the functionality of the gaze guidance through haptic cues feature. It was noticed that the haptic feedback suffered if the headband was too tight or if Oculus Rift was pressing on to it. This test was also important to guarantee that the headband position and tightness were exactly right so that the haptic feedback would not be too weak. A screenshot of the beach ODV with the target ball can be seen in figure 9.

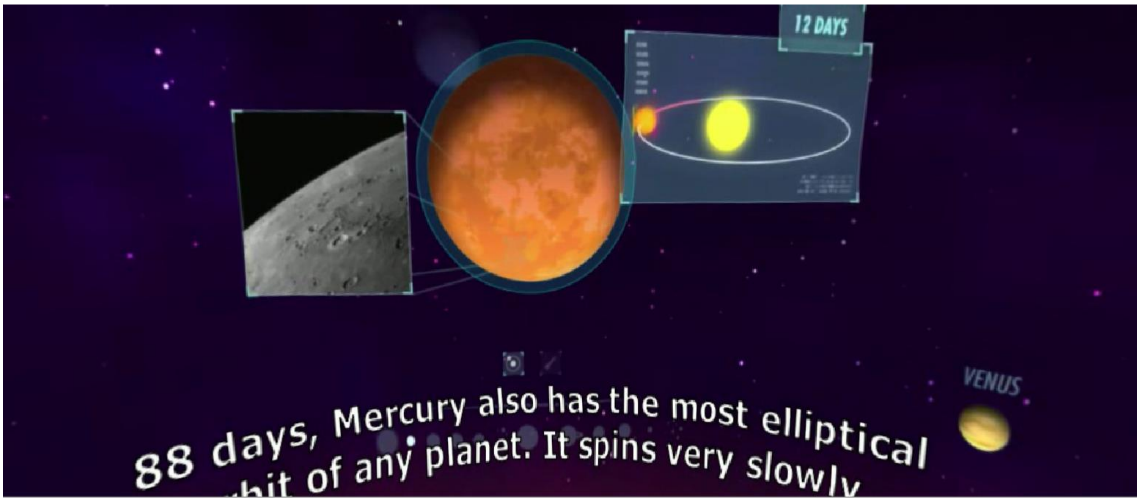
Figure 9. Screenshot of the beach tutorial ODV with a ball as the target.

After the warm up there were two big tests. One tested how audio and haptic modalities affected UX and the other tested how haptic guidance was experienced with three different types of ODV. The order of these tests was counterbalanced.

In the first test the participant watched a 3 minutes long ODV [Youtube 4]. This video was a tour of our solar system and the spoken audio was subtitled. The tour was a short informative animation and it introduced the sun and all the planets in the solar system. In figure 10 one can see how the subtitles are positioned. The animation presented a few interesting facts about the main objects in our solar system. These objects were the essential target information of the test.

The video could be categorized as an easy to follow omnidirectional video with smooth transitions of the targets, while the essential parts appeared in a left to right order and the subtitles were fixed below the essential parts. The essential parts changed location after 14 to 28 seconds.

This video had been cut into three equally long parts. These parts were: a part with sound, but without haptic guidance. A part without sound, but with haptic guidance, and a part with the combination of haptic guidance and audio. Before the test the participant was reported in which order he would experience the parts. Before each part changed the participant was informed by the tester which part was about to begin. The order in which the different modalities and their combination appeared was counterbalanced to decrease the potential effect of the order. The participant was asked to review these three distinct experiences individually by filling out questionnaires and giving comments.



88 days, Mercury also has the most elliptical
bit of any planet. It spins very slowly

Figure 10. Screenshot of the modality test ODV.

In the other test, the participant was asked to view three videos which were categorized as: a video with a smooth transition of the target, a video with a pop-up transition of the target and a chaotic transition of the target. The moving transition and pop-up transition types were picked out because they seem to be basic means for visually attention-grabbing events. The chaotic transition consisted of targets with both of these transition types and in addition included other distracting elements. The targets were the parts with the most essential information of the ODV clip.

The smooth transition ODV was a short Teenage Mutant Ninja Turtles animation [Youtube 5]. It was a trailer made to promote the 2016 Teenage Mutant Ninja Turtles: Out of the Shadows movie. In the test video a pizza box was passed on from left to right between the turtles in the sewer. See the screenshot in figure 11. The test's targeted essential information was the pizza box which slowly circled one cycle around the spectator. The clip was 58 seconds long.

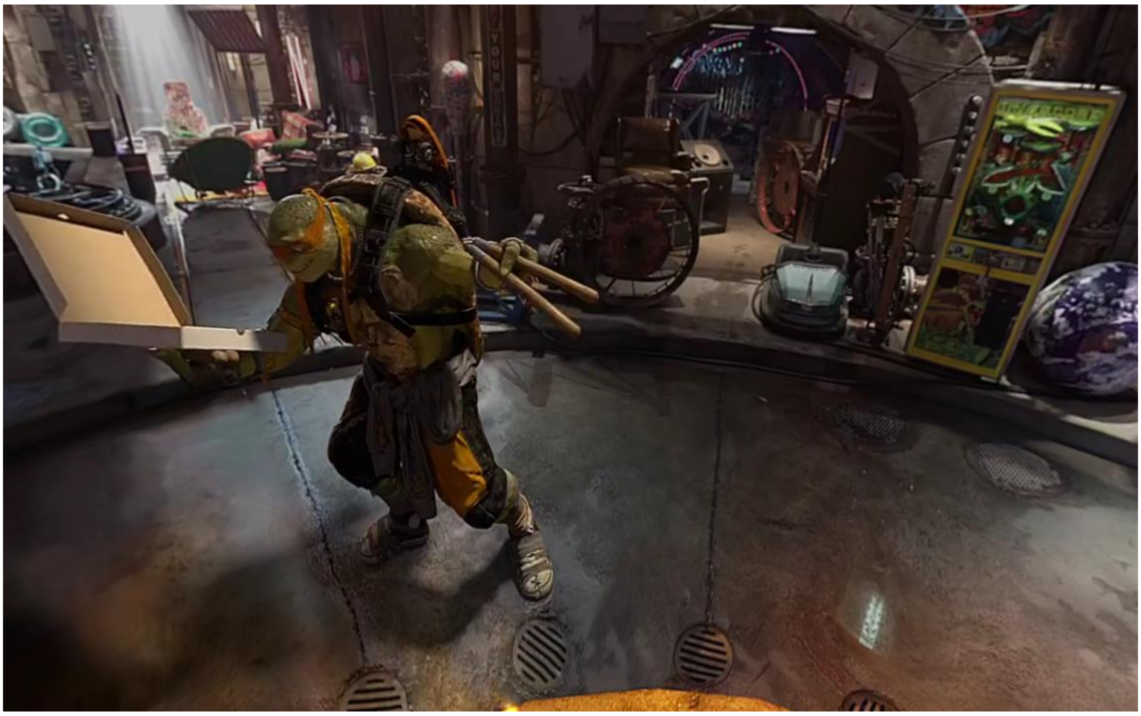


Figure 11. Screenshot of the smooth transition ODV.

The jumping transition video was a Pokémon ODV, in which a task was given to find all five Pokémon [Youtube 3]. The targeted essential parts in this video were the guiding intro text “Find Pokémon” and the five Pokémon. These Pokémon popped in certain places of a plaza where people are walking. Each target was active for gaze guiding for 8 seconds starting from the Pokémon’s first appearance. This clip was 1 minute and 46 seconds long, which made it the longest video out of the three in the ODV type test. The uneventful 35 second intro where the target Pokémon are introduced prolonged the clip a bit, but the active searching for the Pokémon part lasted approximately for the same duration as the other videos’ active parts. A screenshot of the intro can be seen in figure 12.

Figure 12. Screenshot of the pop-up transition ODV.

The chaotic transition video was a Clash of Clans ODV [Youtube 2] in which something was simultaneously happening all around the spectator, but the gaze was still only guided towards certain events. In the video giants, hot-air balloon bombers, a dragon and a pack of hog riders invade a castle which the viewers troops try to defend. During each targeted event something else was occurring elsewhere. The targets I selected as essential information, were the directions in which a side character was focusing on. She was located close to the spectator. This video had 6 targeted events which were active from 4 to 10 seconds in which time the gaze was guided if needed. The clip lasted for 1 minute and 23 seconds. A screenshot of the clip in figure 13 shows a giant approaching the spectator.

Figure 13. Screenshot of the chaotic transition ODV.

After each video the participant was asked to review the experience by filling out a questionnaire. The order in which these omnidirectional videos were viewed was counterbalanced to decrease any effect of the viewing order. At the end of the user test, the participant was asked to leave comments on the whole experience with the haptic guidance in omnidirectional video.

The experiment was conducted in a controlled environment to reduce the number of stimuli to as few as possible. No additional stimuli were used to affect the experiment situation. If any unwanted stimuli were noticed to affect the experiment, then current test video was cancelled and started from beginning to ensure acquisition of comparable results.

3.2. Variables

As I was interested in how different modalities and the transition type of the targets affect UX, the test was divided into two parts. The first part studied the three different modality combinations: ODV with sound, ODV without sound, but with haptic guidance and ODV with sound and haptic guidance. The second part of the study researched how haptic guidance was experienced when the targets transitioned in different ways. These ODV clips were categorized as smooth, pop-up and chaotic type.

An efficient way to evaluate the usability and the attractiveness of haptic guiding was to use AttrakDiff based longitudinal questionnaires. The set of scales of the opposite adjectives could be rated from 1 to 7. The questionnaires included a comment section part, which made it possible to accurately point out the user needs. A short interview was performed based on the comments, to further define the comments and get any new remarks on the subject. These results were put together and cross verified.

Immersion was measured by rating the experience between distracting and nonintrusive and being unpleasant or comfortable. Even though the ODV clips were not long enough for the participants to easily reach an immersive state of mind, these variables account for the possible immersion. Usability was measured with the rating of effectiveness, difficulty and usefulness. Lastly the emotional attractiveness was measured with rating the excitement and quality levels of the experiences. These attributes were used in the evaluation to gain an overall picture of the pragmatic and hedonic quality of haptic guiding in ODV using actuators in the head area. The set of used adjectives for evaluation can be seen in table 1.

Immersion	**Usability**	**Emotional attractiveness**
Unpleasent - Comfortable	Useless - Useful	Poor Quality - Good Quality
Distracting - Nonintrusive	Difficult - Effortless	Boring - Exciting
	Ineffective - Effective	

Table 1. The UX variables used in the questionnaires

3.3. Participants

The UX tests were made with 12 Participants, from which 25% were female and 75% were male. The participants were between 25 and 38 years old. 92% of the participants watched movies and series daily or at least a few times a week. 67% of the participants actively played games in a weekly basis. 50% had no previous experience with omnidirectional videos and 33% had never used a head-mounted display. Only one participant frequently used head-mounted displays and regularly watched omnidirectional videos.

3.4. Stimuli and technical setup

During the experiment a desktop PC with a Geforce Gtx 1080 GPU, 17-4770K 3,50 GHz processor and 16 GB RAM and with a 64-bit Windows 10 Pro version 1709 was used. The VR-headset was an Oculus Rift CV1 model. The headband had two small actuators which were located 11 centimeters apart. See figure 7. The headband was a velcro tape which made it possible to adjust it according to the heads circumference. The actuators were amplified with a Yamaha RX-V630RDS amplifier. The output of the actuators was a 150 Hz sound which transformed into vibration when it was conducted through the actuator. The vibration lasted for 0,02 seconds and repeated every 0,5 seconds when the target was not in the field of view. The test software were run in 1920 x 1080 pixel resolution and audio was produced with an external ProCaster BHS-06 speaker system through a laptop.

The test software was developed for the experimental purposes with Unity version 5.6.1f1. All the ODV clips used in the test software were downloaded from Youtube [Youtube 1-5] and were stitched into a 3D sphere in Unity. The ODV frame height and width also known as video resolution varied from 3840x1980, 3840x2160 to 2048x1024 pixels. The essential events in the video were edited into targets and marked with a timestamp, duration and a location. Subtitles were also edited into the modalities test video to assure that the absence of audio did not affect the narrative storytelling and the UX results.

4. Results

The research was focused on studying the UX of ODV combined with the haptic cue gaze navigation feature. The purpose was to find out how different modalities and their combinations affect UX. I was also interested in how different ODVs with different target transition types and pace affected UX with the haptic gaze guiding. The questionnaire results, comments and different observations made during the experiment were put together. This information was cross examined to make accurate conclusions.

4.1. Modality combinations in ODV test

The results were quite clear in the experiment where the users watched an ODV with three combinations of modalities; haptic guiding, audio and haptic guiding combined with audio. The part where the participant only had haptic guiding and no audio was rated more negative than the other combinations. Still the rating with only using the haptic feedback was more neutral than negative being rated 4 or above in all the experience scales. The best experience was delivered with the combined haptic and auditory experience. This combination had the highest mean rating in all the measured experience scales. The audio exclusive experience was not rated that far behind the audio and haptic combination, but there was a clear difference in the rating of the effectiveness of the experience. In this case the audio being rated at 4,4 and the combination of audio and haptics being a 5,5 out of 7. See figure 14.

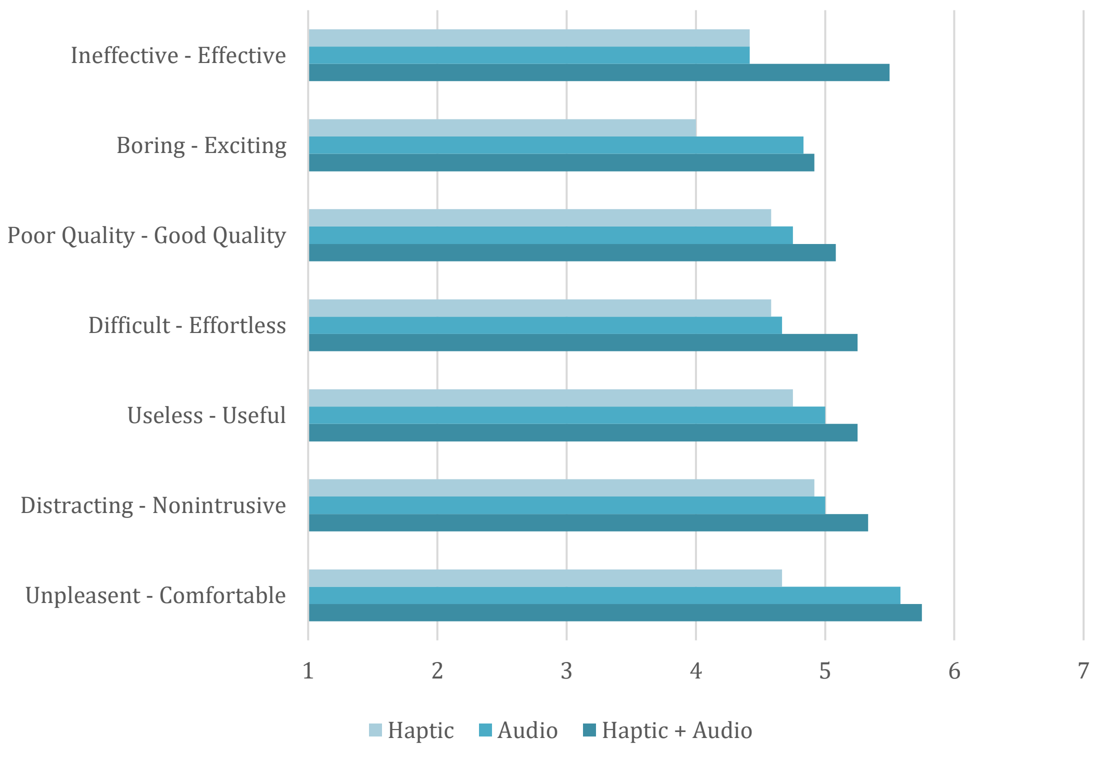


Figure 14. ODV UX rating means with different modality combinations.

Participants commented that the ODV in this experiment was already easy to follow so the haptic guiding was not necessary, but it made it easy to find the targets if their gaze was lost. The fact that essential information transitioned smoothly from left to right and the subtitles were fixed below the essential parts made finding the target locations easy. A few participants found the haptic guiding irritating while they wanted to explore the ODV. One participant commented “The feedback made you more inclined to turn around” and another one commented on the haptic feedback “Sometimes restricts to look around”.

The study’s aim was to find out how UX was affected by gaze guidance using haptic cues in the head area while watching ODVs. In conclusion we can say that the haptic feedback did add positive value to the experience, but in some cases, it felt constraining. The low ratings of using only haptic feedback made it clear that it does not overwrite the need of audio.

4.2. ODV types test

In the ODV type comparison experiment the participants rated the experience with the haptic guiding system with three different type of ODVs. Comparing the experience ratings in the ODV haptic guidance experience means in figure 15, one can see that the most negative ratings were given to the smooth transition type.

The smooth transition ODV ratings were the poorest, but it was rated better in the exciting and the quality section against the pop-up transition type, which had its own problems with the resolution of the video. The smooth transition type was also considered more effortless than the chaotic transition type. One user commented about the smooth transition ODV after watching all the three types of ODV: “Compared to the previous videos, I felt that it was not as useful or needed”.

The pop-up transition experience with haptic guiding was rated the most effortless and non-intrusive. It also gained a high rating in being useful, comfortable and it tied with being as effective as in the chaotic video. The poor rating of the quality might be the result of the poor resolution of the video compared to the other two ODVs. Some users were having problems deciding if they had to turn left or right when the target was right behind them.

The chaotic transition experience with the haptic guiding was rated the most exciting, useful and comfortable. It was also rated to have the best quality. One participant did comment on the chaotic transition ODV that: ”Sound takes attention away from the haptic feedback”, and explained that there was so much going on that he did not really pay much attention to the haptic feedback. The overload of visual and auditory information must have blocked out the perception of haptic feedback.

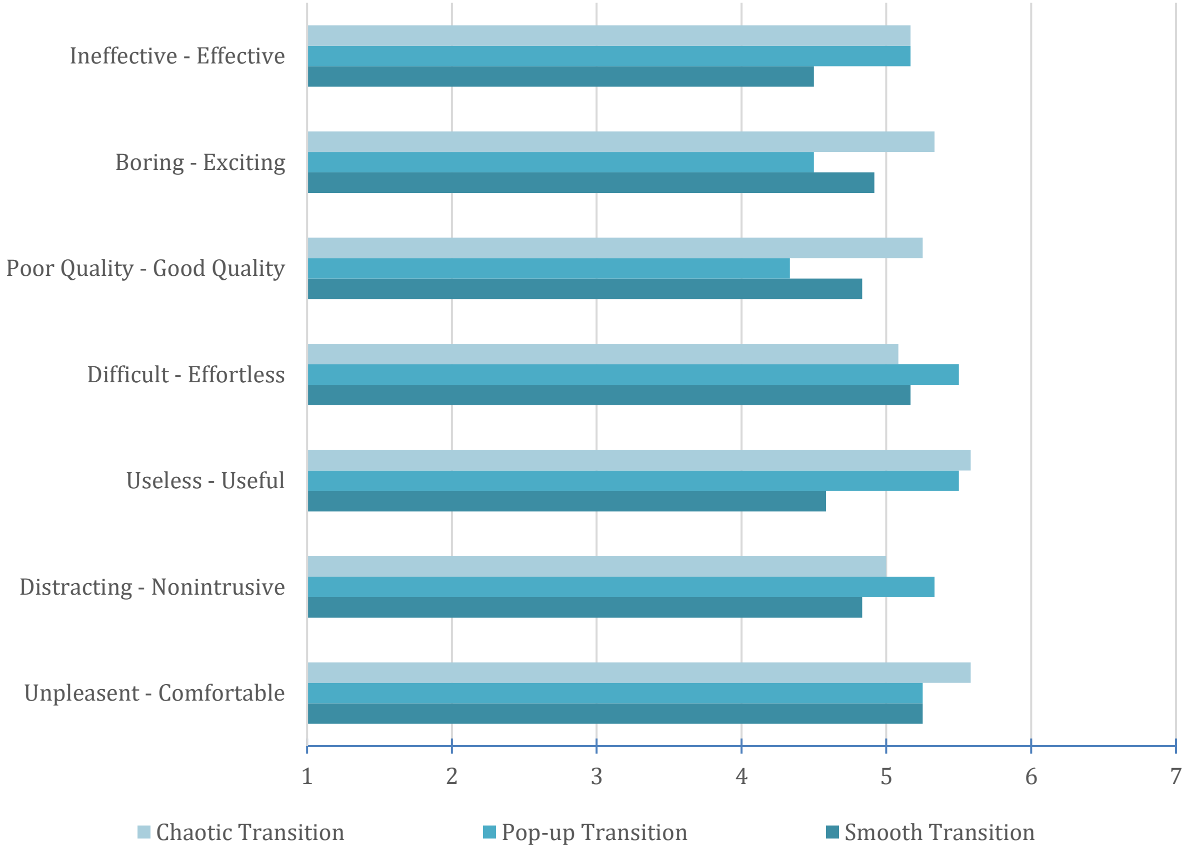


Figure 15. UX rating means of the three different ODV types.

The focus of this test was to answer the following question: Does the ODV content affect the UX of this feature? To put it briefly, yes, the content did affect the UX of the haptic guidance feature in the head area. To summarize, haptic feedback was not always needed and with some participants it was more intrusive than useful. Haptic feedback was rated most positively in the pop-up and chaotic transition ODV types. The smooth transition type was already easy to follow and was thus rated more useless and ineffective. In one case the participant experienced the effects of intermodal selective attention and did not feel the haptic cues due to the fast-paced video and audio of the chaotic video.

4.3. Experienced users versus first timers

It was interesting to discover during the testing phase that experienced users were more positive about the haptic feedback. 50% of the participants did not have any previous experience with ODVs, which made it convenient to compare the experience means of the experienced users and the first timers. In figure 16 one can see that experienced users rated every category more positive than the first timers.

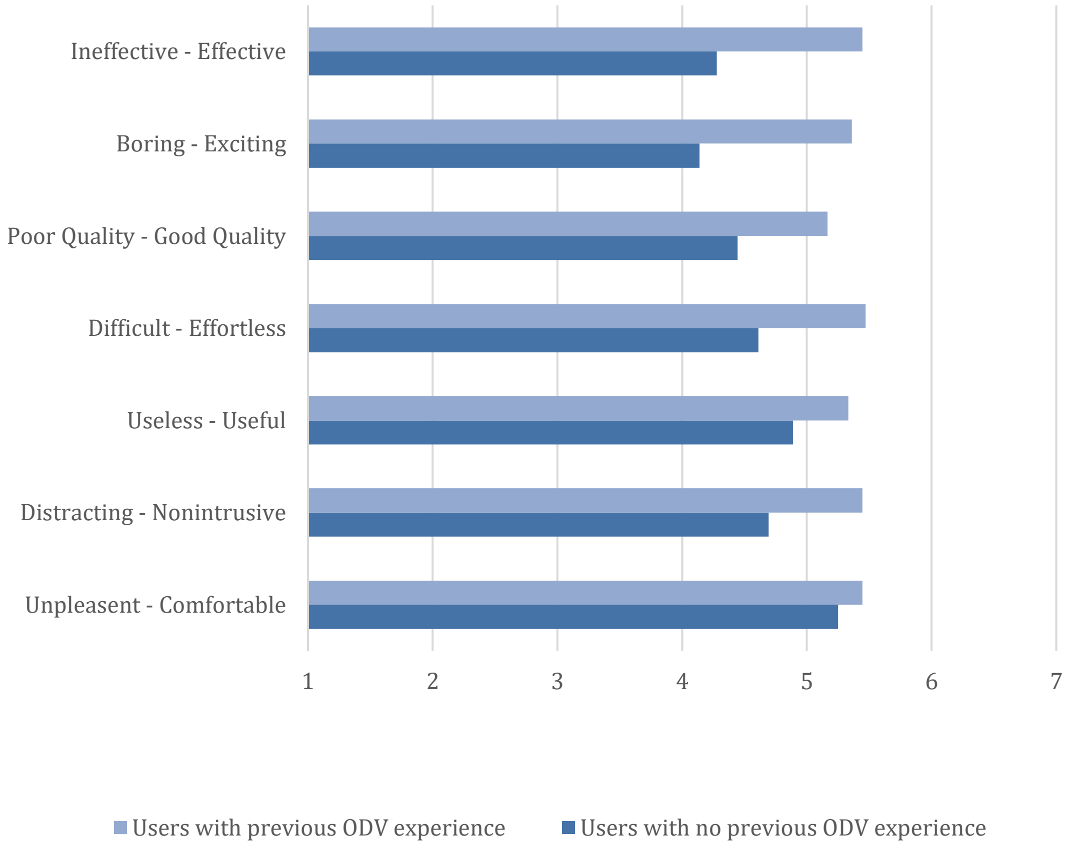


Figure 16. UX rating means of experienced and first timers.

4.4. Post experiment comments

After the experiments the users filled out a questionnaire and could comment about the haptic guiding feature in ODV. 42% of the participants answered that they would use haptic cues in ODV for spatial navigation. Other 42% answered maybe and 16% answered no. See figure 17.

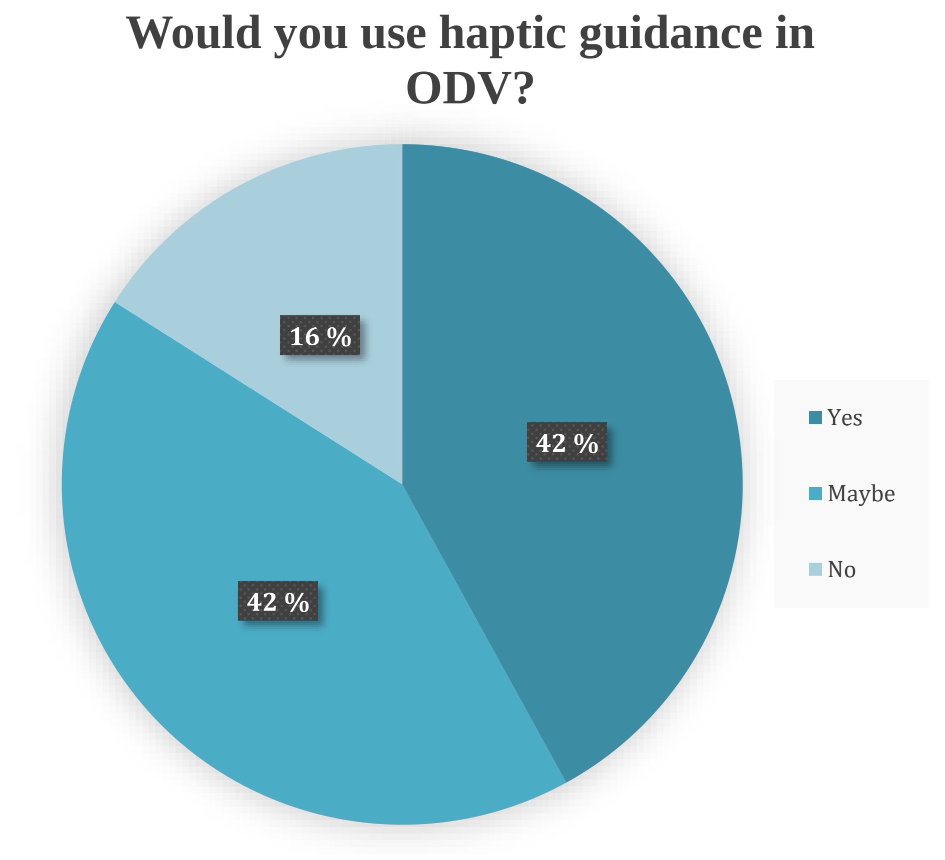


Figure 17. Distribution of the opinion whether the participants would use the haptic guidance feature

Positive feedback consisted of participants saying that it was easier to focus on the essential information. Some specified that the feedback was useful when the event was located horizontally on the same level. One user said explicitly that haptic feedback did add value to the experience. It was regarded as a good feature when the user was lost and when the user's expectations were met. Some also commented that it felt natural and intuitive. One user commented that it made him react faster to the events in the ODVs.

Four users thought it was hard to find events that were not in the same horizontal level as the user's current point of view, also two users thought that when the target was behind the viewer it was sometimes unclear whether to turn right or left. Two users complained about some delay with the haptic feedback, which may have been caused by bad editing or the audio being out of sync. The haptic guiding felt intrusive and restrictive in situations when the users wanted to look elsewhere.

There were also some complaints about the slow-paced ODV: the smooth transition and the video with different modalities. Users thought that they were a bit boring and the feedback was not really useful in those videos. One user commented that if the frequency of different events was high, tracking the events was hard even with the haptic guidance.

Some comments were also made about the vibration. Three users thought that the haptic feedback was too strong. The other user explained that feedback area was too small and made it more irritating for him. Rest of the participants thought the feedback strength was either fine or needed some amplifying. During pilot testing it was noticed that the vibrations weakened significantly if the haptic feedback headband was pushed against the forehead by the Oculus Rift. This made it important to securely put on the head-mounted gear and test them in the tutorial setting before the actual tests.

4.5. Enhancement ideas

Many of the participants had some ideas to tweak the haptic guiding system and enhance the experience. One user thought that the haptic feedback could have been stronger in videos which were more exciting. Other user thought that depending on the excitement level of the videos the vibrations could have had different tempos. Four participants commented that there could have been more actuators to inform vertical feedback or one extra actuator to inform if something was behind the user. One participant who thought that the feedback was irritating suggested that the vibration area could be spread to a wider area so that it would not irritate him as much.

The haptic guidance was considered a more functional feature if it was made optional just like subtitles. One of the participants pondered if the haptic feedback could work better in some other area than the forehead. The participant also thought that the user should be given some time to look for the events and give the feedback after a small delay.

5. Discussion

The results were analyzed and discussed on how they reflect on the future of ODV and haptic guidance. The need for future studies regarding the topic and the future of head-mounted gear were also speculated and discussed.

5.1. Spatial guiding through haptic cues in ODV

The focus of this study was to evaluate and research the functionality and UX of haptic feedback on the head area when watching ODVs with a head-mounted display. All in all, the haptic guidance system did add value to the experience. A small percentage of 16% disapproved of using haptic guidance while watching ODVs.

Even though haptic guidance in ODV did add value, the participants of this study felt like it was not always useful. Haptic guidance was mostly useful in videos where the transition of events was unexpected or moderately fast. It was rated more intrusive in slow-paced videos where the users knew what to expect and had time to look around other parts of the video. While haptic guiding was not something for everyone it could work as an optional feature just like a few participants pondered. It was noteworthy to find out that different users wanted a different strength of vibrations. If haptic cues are to be used as a feature for gaze guiding it should be taken into account that the strength of the vibration should be adjustable just like the strength of sound. The positioning of the actuators might be challenging when users' head size varies and other head-mounted gear might press against it, affecting the feedback strength.

Experienced users rated the haptic guidance feature more positive than first time users. This might have been due to the fact that watching ODVs for the first time is a huge leap in the amount of cognitive processing needed compared to watching a video on a flat monitor. This might have made it hard to adapt to a new method to viewing videos, thus making the haptic feedback less effective and more intrusive for the users.

Some parts of the experiments could have been affected by human error and the fluctuating quality of the ODV. The audio of the experiment came from a different source than the videos and had to be manually started from another computer. In a few cases, this might have caused an out of sync audio experience.

5.2. Future study

This was only a brief experiment and it would be interesting to see how the results would be affected during a long-term usage of the haptic guidance. Long-term testing would eliminate the novelty effect and the more experienced participant population would then reflect a more accurate UX. During this study only one participant experienced the effects of intermodal selective attention and did not feel the haptic cues due to fast paced video and audio. This might occur more frequently if the video length was longer and the users had more time to immerse into the video.

Future studies should also examine if more actuators around the head area enhance the experience. This might help the users in finding events more effectively on the vertical levels and behind them, but downward indicating actuator’s location will be an issue, while it might not be placed onto an intuitive and comfortable spot below the eyes.

This study was focused on how different modalities and their combinations affected UX when watching a smooth transition type of ODV. The smooth transition type was rated as the least effective and least useful ODV type to use haptic guidance, which most likely affected some of the modality test results. It would also be interesting to see how users would review these modalities when they watch a different type of ODV such as a pop-up or a chaotic transition type of an ODV.

ODVs do offer other gaze guiding methods such as directing and editing the video easy to follow or using visual aids. Spatial audio has also been considered a helpful, attention grabbing factor in gaming, but has not really been used that much with ODV. Comparing guidance methods such as visual aids and spatial audio with haptic cues and their combinations will also be one interesting area of research. This could bring forth more information on how to create an optimal UX in ODVs.

One interesting research orientation would be to test the UX of haptic guidance in ODV with people who have hearing impairment. As we could see in the first experiment audio was a major factor in creating a positive experience. Haptic cues as an instrument of guidance could affect a mute experience on a new level just like audio did with non-disabled users. This could introduce a new audience to the world of ODV.

Haptic cues in gaze guiding has a lot of potential. Using this feature with different concepts than entertainment such as journalism, education and health care could give birth to new exciting experiences and ways to perceive certain information. Gaming also has something to gain from haptic guiding in the head area.

5.3. Future of head-mounted gear and ODV

The future popularity of ODV will depend also on the success of head-mounted displays and other VR entertainment. The user base of head-mounted displays has been growing. Thus, there will be more competition in that field. For now, lighter devices having better resolution and faster refresh rates has been enough to make the device user friendly and interesting for the consumers. In the future, companies might have to compete with each other by adding new features such as haptic feedback in the head area. This feedback can then be used for multiple purposes such as guiding the user’s gaze or giving other haptic feedback, such as enhancing the emotional response of the user. The feature might first work as an optional component and slowly be implemented in the final product just like the rumble feature in nowadays gaming controllers.

There will be challenges on how to amplify the haptic feedback without using a separate amplifier and how to channel the haptic frequency through other than audio channels. Besides needing hardware development, adding the essential parts also known as target information will need an editor. The feature is easier to add in gaming where object locations can already be found in the metadata. It can also be automatically attached to objects or to audio sources which makes it easier to implement.

The use of this feature will need directing and cannot be freely implemented into everything. It could work as a guiding feature in gaming when the user is lost or does not know what to do next. This could happen for example by giving hints after a certain delay in the user's actions. As this study showed, using haptic gaze guidance in the head area can be experienced useless in slow-paced ODV. The parts in which this feature is utilized should be well considered and the usage should be done with purpose. Design guidelines for the use of haptic guiding will be needed in the future if the feature becomes more used.

6. Summary

The aim of the study was to answer the following questions: Can haptic cues in the head area be applicable to guide user’s gaze towards essential parts of an ODV? How does this feature affect the UX? Does the ODV content affect the UX of the feature? How?

I examined the UX when haptic cues in the head area were used to guide the viewer’s gaze towards the essential parts of ODV. UX with different omnidirectional video types combined with haptic guiding were compared and analyzed. The study also examined how different combinations of audio and haptic modalities affected the UX. The mix of evaluation methods used longitudinal questionnaires with a comments section, participant observation and a short interview based on the comments.

The participant comments and the questionnaire results on the effectiveness and usefulness point out that the feature did help with gaze guidance. Most of the participants were ready to use the haptic guidance feature in the future.

Results showed that haptic guidance in ODV did add value. Using the haptic guidance feature with sound was evaluated the most positive UX, when compared to using the feature with no audio or not using haptic guidance, but having the audio turned on. The poor results of the part when the participants only got haptic feedback made it clear that the gaze guidance feature does not overwrite the need of audio when watching ODVs.

Comparing the UX of haptic guidance in ODV with different type of ODV resulted in a conclusion that haptic guidance was not always needed. The participants felt like it was not that useful and was rated more intrusive in the slow-paced videos with smooth transitions of the targets. However, when the feature was used in the pop-up transition and chaotic transition type ODV the results were mostly rated more positive and the participants felt like the feature was needed. Fast paced and unexpected events made this feature more necessary, but didn’t entirely make it obligatory for the participants.

Long-term studies need to be made to wear off the novelty effect. This might affect the pragmatic and hedonic quality of the UX. The emotional attractiveness of the feature might fade out. Long-term use could also have an influence on the user’s expectations, affecting the usability of the feature.

Long duration ODVs combined with haptic gaze guiding should also be studied. This might help us understand more accurately how this feature affects immersion. The short video clips used in this study did not necessary have the duration for the users to gain a immersive state of mind. Immersivity might also affect the focus on tactile senses and decrease the usability of this feature.

The individual preferences should be considered when using haptic feedback for guiding. The vibration strength should be controllable and the feature for gaze guiding optional. Also, in the placement of the actuators I would advise to take other head gear, varying head size and skin sensitivity into consideration. These will be important guidelines in the future development of this feature.

As the popularity of VR gear rises, we will see new features introduced in the consumer markets. Future head-mounted displays could easily adapt haptic feedback in the head area and use it either for gaze guiding or means for affective haptics in VR entertainment. If the VR headset sales boom continues the future will look promising for features such like spatial guiding through haptic cues.

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Appendix 1

Human technology interaction research consent form

Spatial guiding through haptic cues in omnidirectional videos

General Information:

You are invited to participate in the experiment in which the effect and functionality of haptic cues in omnidirectional video is studied. The experiment of part of Joona Kinnunen’s Human Technology Interaction master’s thesis at the University of Tampere. In the experiment we will use Oculus Rift to watch clips and vibrotactile actuators to signal haptic cues. The devices and used software are provided by the researcher.

In this experiment, we are going to ask you to compare haptic and non-haptic omnidirectional video experiences. Please note that the experiment is interested in your opinions and we are not testing your personal traits or skills.

Description of the experiment:

During the experiment you will be watching four different omnidirectional video clips. We will be testing how haptic cues to guide your field of view towards the essential information may affect the experience. Before the experiment you are introduced with the device and we will test the actuators and the head-mounted display. After the experiment we will ask your impressions of the omnidirectional video experience by filling a form. Also, we will ask some background information about you. Evaluation will be done after every clip.

Risks and benefits:

Using Oculus Rift and vibrotactile actuators are fully non-intrusive and do not inflict any major discomfort or pain. Should you feel like you need a pause or rest, due to any reason, you can have a break. You may also cancel your approval to participate to the experiment at any time. We are not testing you as an individual – we are interested in the general functionality of the technology. Although there is no monetary compensation in participating in the experiment, your participation will help in studying of watching omnidirectional videos and using haptic cues in the head area as a gaze guiding mechanism.

Duration of the test:

Conducting the experiment will take approximately 45 minutes.

Participant rights:

All the data collected during this experiment will be handled anonymously, will be reported on a group level, and cannot be combined with a person. The participation is voluntary, including that you have the right to cancel your approval any time without any consequences. If for any reason during the experiment you feel uncomfortable or you feel any other need to quit the experiment you are free to do so immediately.

By signing this consent form I agreed to participate in the experiment. I also understood that my participation is voluntary and I am entitled to refuse to participate or stop the performance at any time without any consequences.

NAME AND SIGNATURE ____

DATE AND PLACE ____

CONTACT INFORMATION:
If you have any questions, concerns or complaints about this experiment, its procedures, risks and benefits, contact Joona Kinnunen 040-5146604 or Kinnunen.Joona.P@student.uta.fi

Appendix 2

Participant ___

Background information form

With this form the background information for the analysis is collected. The information is stored and managed anonymously and cannot be combined with the participant.

Age ___ in years

Gender

[ ] female [ ] male

English language skill level

[ ] fluent [ ] average [ ] poor

How often I watch series or movies

[ ] daily [ ] few times every week
[ ] seldom [ ] no previous experience

I play computer games

[ ] daily [ ] few times every week
[ ] seldom [ ] never

Previous experience with omnidirectional videos

[ ] watch them frequently   [ ] watch them seldom
[ ] I've seen some   [ ] no previous experience

Previous experience with head-mounted displays (Oculus Rift, Valve Vive etc)

[ ] use them frequently   [ ] used them a few times   [ ] no experience

Appendix 3

Participant___
Video Modalities Audio

Reviewing the omnidirectional video experience

The video had three parts, parts which consisted of audio and haptic feedback, only audio feedback and only haptic feedback.

How would you review the part with only audio?
Circle your answers.

Unpleasant						Comfortable
1	2	3	4	5	6	7
Distracting						Nonintrusive
1	2	3	4	5	6	7
Useless						Useful
1	2	3	4	5	6	7
Difficult						Effortless
1	2	3	4	5	6	7
Poor quality						Good quality
1	2	3	4	5	6	7
Boring						Exciting
1	2	3	4	5	6	7
Ineffective						Effective
1	2	3	4	5	6	7

Comments (e.g. Was it hard to focus or find essential information?)

Appendix 4

Participant___

Video Modalities Haptic

Reviewing the omnidirectional video experience

The video had three parts, parts which consisted of audio and haptic feedback, only audio feedback and only haptic feedback.

How would you review the part with only haptic feedback?
Circle your answers.

Unpleasant						Comfortable
1	2	3	4	5	6	7
Distracting						Nonintrusive
1	2	3	4	5	6	7
Useless						Useful
1	2	3	4	5	6	7
Difficult						Effortless
1	2	3	4	5	6	7
Poor quality						Good quality
1	2	3	4	5	6	7
Boring						Exciting
1	2	3	4	5	6	7
Ineffective						Effective
1	2	3	4	5	6	7

Comments (e.g. Was it hard to focus or find essential information? Did you feel the haptic feedback?))

Appendix 5

Participant___

Video Modalities Haptic + Audio

Reviewing the omnidirectional video experience

The video had three parts, parts which consisted of audio and haptic feedback, only audio feedback and only haptic feedback.

How would you review the part with the combined audio and haptic feedback?
Circle your answers.

Unpleasant						Comfortable
1	2	3	4	5	6	7
Distracting						Nonintrusive
1	2	3	4	5	6	7
Useless						Useful
1	2	3	4	5	6	7
Difficult						Effortless
1	2	3	4	5	6	7
Poor quality						Good quality
1	2	3	4	5	6	7
Boring						Exciting
1	2	3	4	5	6	7
Ineffective						Effective
1	2	3	4	5	6	7

Comments (e.g. Was it hard to focus or find essential information? Did you feel the haptic feedback?)

Appendix 6

Participant___
Video <u>Smooth</u>

Reviewing the omnidirectional video experience

How would you review your experience with haptic feedback?
Circle your answers.

Unpleasant						Comfortable
1	2	3	4	5	6	7
Distracting						Nonintrusive
1	2	3	4	5	6	7
Useless						Useful
1	2	3	4	5	6	7
Difficult						Effortless
1	2	3	4	5	6	7
Poor quality						Good quality
1	2	3	4	5	6	7
Boring						Exciting
1	2	3	4	5	6	7
Ineffective						Effective
1	2	3	4	5	6	7

Comments (e.g. Was it hard to focus or find essential information? Did you feel the haptic feedback?)

Appendix 7

Participant___

Video Pop-up

Reviewing the omnidirectional video experience

How would you review your experience with haptic feedback?

Circle your answers.

Unpleasant						Comfortable
1	2	3	4	5	6	7
Distracting						Nonintrusive
1	2	3	4	5	6	7
Useless						Useful
1	2	3	4	5	6	7
Difficult						Effortless
1	2	3	4	5	6	7
Poor quality						Good quality
1	2	3	4	5	6	7
Boring						Exciting
1	2	3	4	5	6	7
Ineffective						Effective
1	2	3	4	5	6	7

Comments (e.g. Was it hard to focus or find essential information? Did you feel the haptic feedback?)

Appendix 8

Participant___
Video Chaotic

Reviewing the omnidirectional video experience

How would you review your experience with haptic feedback?
Circle your answers.

Unpleasant						Comfortable
1	2	3	4	5	6	7
Distracting						Nonintrusive
1	2	3	4	5	6	7
Useless						Useful
1	2	3	4	5	6	7
Difficult						Effortless
1	2	3	4	5	6	7
Poor quality						Good quality
1	2	3	4	5	6	7
Boring						Exciting
1	2	3	4	5	6	7
Ineffective						Effective
1	2	3	4	5	6	7

Comments (e.g. Was it hard to focus or find essential information? Did you feel the haptic feedback?)

Appendix 9

Participant___

Reviewing the omnidirectional video experience

I ask of you to review the omnidirectional video experience.

Would you use haptic feedback when watching omnidirectional videos?

Circle your answer.

No Maybe Yes

What was good?

What was bad?

Other comments