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VIRTUAL REALITY AND EXERGAMING

Application in a Campus Environment

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Tiivistelmä

Tämä opinnäytetyö tutkii virtuaalitodellisuuden ja hyötypelaamisen nykyisiä ja tulevaisuuden teknologioita ja sovelluksia ja käy läpi virtuaalitodellisuusaktiviteettialueen toteuttamisen kampusympäristössä.

Opinnäytetyön tutkimus koostuu kahdesta osasta: teoreettinen osuus, jossa tutkitaan aihealuetta ja selvitetään lopputulos, ja käytännön osuus, jossa aktiviteettialue suunnitellaan ja testataan. Kohdeympäristönä toimii LAB-ammattikorkeakoulun M19-kampus ja kohderyhmänä ovat koulun opiskelijat.

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Avainsanat

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Abstract

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Abstract

This thesis explores current and future virtual reality and exergaming technologies and applications and goes through the process of implementing a virtual reality ‘activity area’ in a campus environment. The client for this thesis is the Ministry of Education and Culture.

The research consists of two parts: a theoretical part involving studying the subject area, and a practical part where the activity area is planned and tested. The target environment was the M19 campus of the LAB University of Applied Sciences and the target users were the students of LAB.

This research provided the client with a view of current and future technologies and applications of virtual reality and exergaming and provided and an insight into applying these technologies on a campus in the future. The client was also advised on planning a virtual reality activity area and on acquiring a set of virtual reality systems and games to be used for gaming and exergaming by students on the campus.

Keywords

virtual reality, exergaming, applications

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1 INTRODUCTION

The client for this thesis was the Ministry of Education and Culture, and the project that this thesis is part of, is called “Tikissä työelämään”, or “TiKi”. TiKi’s objective is to explore different ways to cultivate an active campus environment and activate students. The client had plans to use virtual reality technology to offer students a new, different way to stay active on campus. They wanted to know more about the available technology and possible applications for this use. The client also wanted to acquire two to four virtual reality systems along with a selection of games for the same purpose. The final configuration should be movable and easily set up in different locations and between campuses, used independently by students and executed within the allotted budget. The configuration would be implemented as a virtual reality ‘activity area’ on the campus with the virtual reality equipment ready to be used at any time by students.

From these parameters, the research questions of this thesis were formulated, and they are as follows:

- What are the possible current and future applications of virtual reality and exergaming?
- How will the virtual reality activity area be implemented on the campus?

The thesis consists of a theoretical part and a practical part. The theoretical part involves studying various virtual reality and exergaming technologies and their current and future applications. The practical part involves planning a ‘virtual reality activity area’, choosing the virtual reality technology for this use and testing it. The practical section also includes a planned demo session with a focus group of students.

2 VIRTUAL REALITY

2.1 Definition

Virtual reality, or VR, means a computer-generated, three-dimensional simulated environment. VR is typically interactive and immerses the user into the virtual experience. The term VR has varying definitions and is often used incorrectly. (Woodford 2019.) The Merriam-Webster Dictionary defines virtual reality as follows:

> *Virtual Reality: an artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment.*
>
> *also: the technology used to create or access a virtual reality* (Merriam-Webster 2020.)

VR offers a way to interact with computers in a more intuitive and immersive way compared to traditional peripherals like the keyboard, mouse and monitor. With VR the user is put directly into the experience and may interact with it intuitively using their own body. The user's sense of involvement in the experience reflects on their level of engagement and immersion. In VR the user's body becomes a part of the virtual world and thus the user is also mentally more engaged. Most modern-day VR systems use a head-mounted display (HMD) and motion controllers, but in some cases even devices such as omnidirectional treadmills or hand-tracking gloves are used. (Sherman 2019; Mazuryk 1999, 6, 14, 27, 28.) Image 1 below shows a VR system in use:

Image 1. HTC Vive HMD and motion controllers (European Space Agency 2017.)

When discussing VR, ‘immersion’ is a term used to describe the level of engagement that the user feels in the experience. Another commonly used term for user engagement or immersion is ‘presence’. All senses of the human body attribute to the user’s immersion in VR. Most modern VR systems simulate the senses of sight, hearing and touch. In some cases, even smell is simulated. Immersion is an integral part of what defines virtual reality and what makes it effective. Immersion can be divided into two parts: mental immersion and physical immersion. Mental immersion is the feeling of being engaged and involved in the experience. Physical immersion refers to the bodily experience from stimuli produced through different technologies. (Sherman 2019.)

It is important to note that there are other technologies that are very similar to VR in certain ways. These technologies are augmented reality (AR) and mixed reality (MR). VR, AR and MR are often mixed up as they utilize very similar systems and technologies, but they do have some key differences.

Whereas VR features a fully computer-generated environment, AR creates a kind of virtual overlay over the real world that can be seen and interacted with using devices such as an AR HMD or a smartphone. Essentially, AR adds on top of the real world, or augments it, with virtual elements or features. Image 2 shows AR being used to overlay computer-generated furniture into a real environment using mobile devices. MR is a mix of virtual and real elements where these elements are in interaction with each other and together create new environments and visualizations. In practice this could show as an added virtual element getting occluded by a real-world object when the real object moves in front of the virtual one. The term ‘extended reality’ (XR) is used when referring to VR, AR and MR as an area of technology in order to bring them all under one term. (Irvine 2017; North of 41 2018; Valmet 2020.)

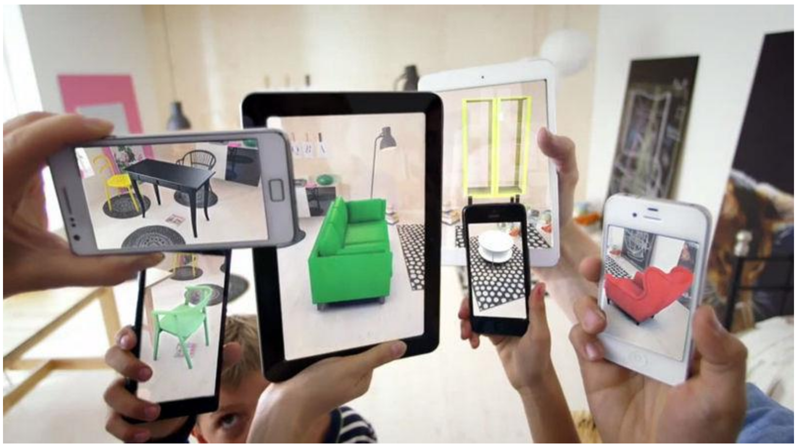

Image 2. AR on mobile devices (Wikimedia Commons 2016.)

2.2 History

The history of VR could be thought of in different ways depending on how virtual reality is interpreted. One could consider the earliest panoramic paintings to be a form of virtual reality as they are an attempt at presenting their content to the viewer in an immersive way. (Virtual Reality Society 2020c.) However, in this thesis the history of VR will be examined through the evolution of its technologies and applications. This section covers the most relevant milestones in the history of virtual reality.

The earliest examples of stereoscopic imaging can be seen in Charles Wheatstone's research on the subject in 1838. Modern HMDs utilize stereoscopic imaging to show their view to the user in three dimensions by projecting it from a slightly different angle for each eye. (Wade 2002; VRTL 2020.) Nearly a hundred years later, in 1929, American inventor Edwin Link created the world's first commercial flight simulator "Link Trainer". These were used by over 500,000 pilots for training during World War II. (ASME International 2000.) In 1962, Morton Heilig patented the Sensorama Simulator, which is considered one of the earliest virtual reality systems. This device featured 3D video, stereo audio, simulated wind and even smell. (Turi 2014.) Two years earlier, in 1960, Morton Heilig had patented the Telesphere Mask – the first example of an HMD. Later during the 1960s, the Headsight, The Ultimate Display and Sword of Damocles HMDs were invented. These early HMDs were large and heavy, but they already had similar features as modern HMDs, such as tracking the user's head movement. (Brockwell 2016; Strickland 2020.) In 1978, the Aspen movie map was created in the Massachusetts Institute of Technology. It was an early example of virtual travel that featured an interactive tour of the city of Aspen using photographs from a camera mounted onto a car driving around the city. The Aspen movie map allowed the user to navigate their way around the city using a computer. (Naone 2008.) In 1982, Thomas Furness created the Visually Coupled Airborne Systems Simulator (VCASS). VCASS was a virtual flight simulator which featured a virtual overlay on top of the real world. (Aitoro 2016.) In 1987, the term 'virtual reality' was invented by Jaron Lanier. (Virtual Reality Society 2020j.) In the 1990s, virtual reality technology saw advances especially in the video game industry, as the first VR arcade games were released in 1991 and Nintendo and Sega developed their own VR systems at around the same time. In 2007, Google announced Street View, which allowed users to view panoramic images from all around the world. In 2010, the most advanced commercial VR technology until then, the Oculus Rift, was prototyped. Oculus VR, the company behind the Oculus Rift, was acquired by Facebook for USD 2 billion in 2014. By 2017, HTC and Oculus VR had released their own VR systems, and companies such as Google, Apple, Amazon, Sony and Samsung were also developing and releasing their own VR systems.

In 2018 and 2019, mobile VR devices were mostly replaced by ‘standalone’ VR, and steady progress was still being made in the field of VR. (Virtual Reality Society 2020k; Poetker 2019; Dormehl 2017.) In 2019, the market value for VR was USD 11.52 billion. (Mordor Intelligence 2020.)

In 2020, there is plenty of VR technology available aimed for different uses and audiences and new technology is being developed and released frequently. (Dingman 2020.) The industry and market for VR have seen huge growth during the 2010s and are expected to keep growing for at least the next several years as the market for VR is estimated to reach USD 120.5 billion by 2026. (MarketWatch 2019.)

2.3 Technology

Modern VR usually involves an output device which projects the image of the virtual environment to the user, and an input device or system which translates the user’s actions into the virtual space. These together can create an immersive and interactive VR experience.

Output devices allow the user to see the virtual world. Output devices are technologies such as monitors, projectors and HMDs. Most VR systems today use an HMD as it is an essential component in immersing the user into the virtual environment. The HMD (head-mounted display) is a type of visor with screens for each eye, which display the digital content to the user in three-dimensional vision. This gives the user the sense of being inside the virtual environment and allows them to look around using their head. Motion controllers provide the possibility for the user to interact with the environment using their own hands. Devices like an omnidirectional treadmill enable the user to move within the virtual space by walking. (Anthes et al. 2016, 3; Virtual Reality Society 2020i.)

To grant the user more interactivity with the virtual experience, different input devices are used. VR input technologies can be divided into the following categories: traditional controllers, motion controllers, optical trackers, locomotion controllers, hand trackers and motion trackers. (Hui 2017; Virtual Reality Society 2020b; Virtual Reality in Tourism 2020.) Image 3 shows the different categories of VR input technologies.

Image 3. VR input technologies (AllThingsVR 2015.)

Traditional controllers are peripherals such as a mouse, keyboard or joystick. These controllers generally offer less interactivity in comparison to other VR input devices. Motion controllers are the most common VR input device. Motion controllers are usually handheld controllers whose movements are tracked into the virtual environment. Optical input devices use cameras to track the user or objects into the virtual world. These are less accurate, but often enable the user to use their whole body to interact in VR. (Mazuryk 1999, 6, 14, 27-28; Virtual Reality in Tourism 2020.) Locomotion technology is used to give the user the possibility to walk or otherwise traverse in the virtual environment. These devices include omnidirectional treadmills and different pads or platforms that track the user’s movement as they walk on them. (Cyberith 2020.) Hand tracking technology covers different devices that track the user’s hands including fingers. Motion tracking technology typically tracks the user’s entire body with good accuracy. This method, however, can be quite intrusive to the user, and the equipment can be very expensive. (Mazuryk 1999, 6, 14, 27-28; Virtual Reality in Tourism 2020.)

Current VR systems can be divided into computer-powered and standalone systems. The difference between these is that computer-powered VR systems require a computer to work whereas standalone systems do not. The drawback of standalone VR is that those systems do not allow for the same graphical fidelity as computer-powered systems. Standalone VR devices are considerably less expensive than computer-powered devices, especially since they do not require the user to own a powerful computer. Other main advantages of standalone systems are that they are easy to use, mobile and completely wireless. Both these different types of VR systems have their uses, but recently there has been a shift in interest from computer-powered VR to standalone VR. (Vitillo 2018; Harper, 2018.)

Some popular modern VR systems are the Oculus Rift, HTC Vive, Playstation VR and Windows Mixed Reality systems. All of these include an HMD, motion controllers and sometimes external sensors that track these devices. Current commercial VR systems have slightly different features, but the main differences are the platforms that they are compatible with, such as a computer, mobile device or game console. (Greenwald 2020.)

New advancements in the VR field are being made frequently. Technologies that are being developed include human-eye resolution displays (Nichols 2019.), eye-tracking HMDs (Rogers 2019b.), wireless adapters (Lang 2019.) and numerous haptic devices (exiii Inc. 2019.).

2.4 Applications

Due to its advantages in viewing and interacting with virtual worlds, VR holds significant potential that has, in recent years, been recognized by consumers and companies alike. While the real world has limitations that render certain things impossible or too impractical to actualize, VR can be used to visualize and interact with the impossible. (Virtual Reality Society 2020i.) Image 4 shows an example of the possible virtual worlds featured in VR experiences.

Image 4. Example of a virtual world (Pixabay 2017.)

2.4.1 Virtual reality in entertainment

Entertainment is the most popular use for VR technology, and it encompasses most of VR's uses today. (Rubin 2019; Morozova 2020.) VR video gaming is the largest market within the VR entertainment landscape. In 2018, out of the worldwide USD 7.3 billion invested in the VR industry, (Fortune Business Insights 2019e.) USD 4.15 billion was invested in entertainment and gaming. (Fortune Business Insights 2019a.) VR gaming can offer a more engaging experience and higher level of interactivity than non-VR games. VR gaming also brings opportunities for new ways to socialize online, especially for long-distance social interactions. Some examples of social VR are AltspaceVR and Facebook Horizon, which feature virtual worlds where players can come together virtually for different activities and socialize. (Kyselova 2020.)

Most VR entertainment content is aimed at home use, but video and VR arcades are also a big employer of VR entertainment and gaming content. These arcades can offer a unique experience compared to regular consumer VR. VR technology is still not affordable for everyone, so VR arcades can provide an alternative for those who do not have regular access to VR. (Singletary 2019.)

Another use for VR can be found in museums, galleries and other exhibits. With exhibits, VR is typically implemented in two different ways: a location-based experience where visitors may experience immersive context-related content at the location, or a virtual tour of the real location for anyone to access through computer or mobile VR. VR implementation has been reported to have increased museum visitations. (Coates 2020; Song 2017.)

Sports, concerts and other live events can also be viewed from home with VR. Some other popular applications for VR in entertainment include interactive film and video, amusement parks and discovery centers. (Morozova 2020; Virtual Reality Society 2020f.)

As with VR as a whole, the VR gaming and entertainment market is rising fast and it is estimated to reach USD 70.57 billion by 2026. (Fortune Business Insights 2019a.)

2.4.2 Virtual reality in healthcare

Healthcare is one of the largest fields to utilize VR technology. In 2018, the global market for VR in healthcare was USD 1.56 billion. (Fortune Business Insights 2019d.) Some of the main uses for VR in healthcare are for training, surgery, pain management, therapy, rehabilitation and treatment of mental disorders like autism and post-traumatic stress disorder.

Medical students can be trained to perform surgeries or other stressful, high-risk operations without the pressure and risks of the real situations. (Virtual Reality Society 2020a; Visualise 2020; Chebanova 2020.) Image 5 shows VR being used in a surgery simulation.

Image 5. VR in a surgery simulation (Army Medicine 2015.)

Robotic surgery is an application of VR technology and robotics that allows a surgeon to perform an operation on a patient remotely from a different location. This technology still has its problems, as it needs to have sufficient haptic feedback for the operator and no noticeable latency. (Virtual Reality Society 2020.)

VR has also been used in pain management for different acute and chronic pains. This application makes use of the high level of immersion that VR offers, to engage the user by stimulating their senses to limit their focus on the sensations of pain. (Li et al. 2012.)

In rehabilitation, VR has been used to make rehabilitation more engaging for patients, as it can often be tedious. It can be used to keep the patient motivated to stick to the therapy routine and provide customized experiences for each patient. (Marchionne 2019.)

Another application of VR in healthcare is the treatment of autism, PTSD or anxiety disorders by placing a patient into a simulated situation that may present difficulty in everyday life. This way the user can tackle these challenging situations in a safe environment. (Virtual Reality Society 2020g.)

VR's application in healthcare is still new, but interest in it is rising as the technology advances. The global market for virtual reality in healthcare is estimated to reach USD 30.40 billion by 2026. (Fortune Business Insights 2019d.)

2.4.3 Virtual reality in education

Educational use is another popular application of VR technology. The market value for VR in education was USD 656.5 million in 2018. (Fortune Business Insights 2019c.) VR can offer a uniquely engaging educational experience and the opportunity to learn in a way that is not possible through other mediums. It can be easier to learn and internalize information through experiencing it firsthand in VR, rather than reading about it. (Babich 2019.) VR can boost the student's motivation, and a higher motivation results in more effective learning. (Sutcliffe 2019.) The interactivity of VR encourages students to actively interact and experiment, thus keeping the student motivated. (Martin-Gutiérrez et al. 2017.)

Educational VR content lets the user explore far-away locations, historical events and micro- or macro-cosmic worlds. Workers in different fields can be trained in VR simulations when training in real life would be impractical or impossible. An example of VR training would be the use of VR in flight simulators in the military or training engineers to operate machinery. (Virtual Reality Society 2020l; Virtual Reality Society 2020m; Virtual Reality Society 2020n.) Image 6 showcases an example of a virtual world that can be used in teaching astronomy through VR.

Image 6. VR in teaching astronomy (Pixabay 2012.)

Virtual classrooms and campuses are examples of educational uses of VR. Schools could offer a new way of distance-learning through VR, or a place for students to work together and socialize. (Barnard 2017; Learnbrite 2020.) Some science-fiction works have even played around with the idea of having students attend school completely in VR. (Burapachaisri 2018.)

Though VR has many benefits and advantages when used for educational purposes, it does also have its problems. Some of these problems are the high cost of VR systems, content not being engaging or effective enough, and hardware-related usability issues. (Kavanagh et al. 2017, 104, 106, 109.) However, the potential of educational VR is clear, and its global market value is heading up and is estimated to reach USD 13 billion by 2026. (Fortune Business Insights 2019b.)

2.4.4 Other applications

The military industry has been a big influencer in the development of VR technology as it has invested a considerable amount of money into the field. (Velichko 2020.) In the military VR is used to simulate combat situations and other dangerous tasks in an immersive way without the risks of real life. Approximately one in twenty deaths of soldiers in the military happens during training. (Farmer 2016.) Minimizing injuries and deaths in training is a high priority, so VR is considered one potential solution to this. (ThinkMobiles 2020.) Some of VR's applications in the military are flight simulations, battlefield simulations and medical training. (Virtual Reality Society 2020h.) Image 7 shows VR being used by soldiers in a battlefield simulation.

Image 7. VR battlefield simulation (Berner 2013.)

In a similar way to the military, VR technology is also being used for training the police force. The New York Police Department (NYPD) has been experimenting with using VR for active shooter training of their police officers. This makes for a safer and more immersive training scenario, allows officers to train more frequently and is a cost-effective addition to regular training. With a virtual training system, these training scenarios can be based on real incidents and they can be created and customized easily. A significant benefit of using VR for training like this is the possibility of gathering data and tracking performance. This data includes information such as the participants' accuracy, bullet trajectory and negotiation performance. (Melnick 2019.)

In engineering, VR is used in industries such as the automotive, aerospace and construction industry. Most of VR technology's applications in these fields are in design, visualization and training. For example, the automotive industry uses VR when working on new car designs. (Virtual Reality Society 2020e.) Visualization and modelling in VR is also possible outside of industry use, as there are commercially available programs where the user can do 3D modelling, sculpting and painting with handheld motion controllers in VR. This makes for an intuitive method in creating and moulding computer-generated geometry. This use of VR can provide a useful addition to traditional 3D design tools. (Harris 2018.) Image 8 shows VR being used in the automotive industry in the design process.

Image 8. VR in the automotive industry (Pixabay 2019.)

Many businesses have employed the use of VR in several different ways. A common application of VR among businesses is to offer a virtual tour or look inside company spaces or some other location. This is usually created with panoramic 360-degree images, but sometimes even three-dimensional virtual environments are used. This allows clients or workers to get familiar with the location before visiting in person. Another application is to give clients the possibility to view a product through VR as if it was in their hands already. (Virtual Reality Society 2020d.) Companies can also host virtual booths or showrooms. This can offer a way for people to attend an exhibit or trade show remotely. (Takahashi 2018.)

2.4.5 Future

VR could be likened to early-day cinema, video games or other forms of media in their early days. The first video games were two-dimensional, crude and offered very little inter-action. Over decades of time, video games developed into being three-dimensional, immersive and more interactive. The same can be seen in cinema, as the movie-going experience has become more and more immersive with features such as 3D viewing and the addition of simulated movement or wind in theaters. VR is a natural continuation to the progression of interactive and immersive media. (Visartech 2019; Ranger 2019.)

Entertainment is likely to stay as VR’s most popular use case in the future. Most of the VR projects that were being developed in 2019 were in the field of gaming. However, education and training were also popular areas in VR development and are likely to stay relevant in the field. Other potential uses for VR can be found in healthcare and communication, and these are also likely to be main drivers in the field of VR. VR’s immersive and interactive capabilities will be its main appeal in all of the aforementioned areas. (Rubin 2019; Visartech 2019; Shah 2020.)

The quality of VR content will play a large role in how VR is received in the future. VR users have been waiting for the “killer app” in the VR field for years. This would be an application that provides sustained, frequent value to VR users. Social VR is something that could potentially bring users into VR consistently. VR content is still not at the level where it could be, and this could possibly be because VR’s potential for immersion has not yet been explored enough. (Shah 2020; Visartech 2019.)

As VR is still quite a new branch of technology, it has its problems and challenges to overcome. Besides the lack of high-quality content mentioned earlier, perhaps the biggest issue with current VR is that this technology is still quite expensive and often requires a powerful computer to run it. However, as standalone VR systems have become more prominent in recent years, they have offered a more cost-efficient option to experience VR. Another big issue with current VR is that the user experience can often be quite uncomfortable. HMDs are often heavy and bulky, and they feature low resolutions and are prone to cause many users motion sickness. Motion sickness in VR is caused by a disconnection in what the user is seeing in VR versus what they are sensing in real life. This can happen if there is, for example, noticeable latency or tracking issues with the HMD. (Trescak 2019; Jenkins 2019; Rogers 2019a; Hardawar 2019.)

3 EXERGAMING

3.1 Definition

The term ‘exergaming’ comes from the amalgamation of the words ‘exercise’ and ‘gaming’. Sometimes other terms have been used, such as activity-promoting video games, active video games and physical gaming. (Oh 2010, 2.) In different studies, there have been some inconsistencies in the use of the term. Generally speaking, exergaming means playing video games that require physical activity from the player. (Oh 2010, 1-2.)

> *The activity of playing video games that involve physical exertion and are thought of as a form of exercise.* (Dictionary.com 2020.)

Exergaming is still quite a new field of study, but it has received a considerable amount of traction in recent years. This is largely due to declining health especially among the youth, and the emergence of new relevant technology. (Rizzo et al. 2011.) In 2017 and 2018, the average American adult spent over 11 hours per day consuming media. This, however, includes passive media consumption as well, such as listening to the radio or being otherwise influenced by different forms of media. (Fottrell 2018.) Playing video games is typically a sedentary activity, if physical activity-promoting video games are not taken into consideration. It is important to note that the common consensus about exergaming is that it should not be regarded as a primary way to exercise, but rather an addition to regular exercise. Exergaming generally does not offer the same level of intensity as regular exercise, but it can be more engaging and enjoyable. (Rizzo et al. 2011.)

3.2 Benefits and applications

Due to the high level of engagement and enjoyment that video games can offer, they hold a potential to enhance exercise motivation, engagement and even performance. Studies have shown that exergaming can boost energy expenditure during exercise and provide low to medium levels of exercise and positive social effects. (Sween et al. 2014, 4-9; Wikipedia 2020.)

In all its simplicity, the main advantage of exergaming is that video games are fun, and exercise, often, is not. Exergaming can enhance enjoyment during exercise as well as boost the user’s motivation to get some exercise when they might otherwise not be inclined to do so. The user may be so immersed and focused on the game that they may not even feel like they are exercising. (ACSM 2020; Health24 2018.)

Exergaming can also be a social experience. The player can play with people in the same space or participate in online multiplayer over the internet and interact with other players. The player may compete against other players, which boosts motivation. Some VR games let players participate in different exergaming activities together and socialize. (ACSM 2020; Fitday 2020.)

Some examples of systems used for exergaming are Nintendo Wii, Microsoft Kinect and virtual reality systems like the Oculus Rift. Different systems offer varying levels of interactivity for exergaming. Some devices allow the player to use their entire body, while others only track their hands or feet. (Cruickshank et al. 2017; Thin et al. 2013; Shaw et al. 2015.) Even traditional exercise equipment like an exercise bike has been combined with gaming to make exercising more engaging. (FG Team 2017.)

One classic example of an exergame is the game Dance, Dance Revolution (DDR). DDR is a dancing game where the objective is to step on pressure sensitive plates with the correct timing and order as shown on a screen. (Thin et al. 2013.) Image 9 shows DDR being played by a group of players. Other examples of exergames are Xbox Fitness using the Kinect, Wii Fit for the Nintendo Wii and BOXVR for VR devices. (Reed 2015.) These games are designed specifically for exergaming, but plenty of other games require the player to be active while playing, such as Beat Saber or Knockout League for VR. (Rogers 2020.) In these different exergames for varying systems, the player might dance, jump or move their arms around while completing some sort of objective or overcoming a challenge. (Reed 2015.)

Image 9. Example of exergaming (BeFitt 2008.)

Today, as VR technology has seen huge advancements in recent years, exergaming has become more relevant than ever. Not all exergaming is done using VR, but VR does suit exergaming purposes quite well. As VR allows for the user to interact with the virtual experience using their own body, exergaming can utilize this to get players moving in a way that is fun. VR provides a new, accessible way for gamers and others to get exercise in an immersive and engaging way. (Harveston 2019.)

There is a wide range of exergames for VR systems with varying levels of intensity. Some of these games feature sports such as table tennis and boxing, shooting guns and different interactions using the player’s hands or body. Most popular VR experiences offer at least some degree of physical activity and some can offer approximately the same energy expenditure as tennis for instance. (Virtual Reality Institute of Health and Exercise 2020.)

4 IMPLEMENTING THE ACTIVITY AREA

The client's goal for this project was to activate the students of the LAB University of Applied Sciences on the campus by implementing a VR activity area that would be free for students to use at any time. What was required for the goal, were the VR systems which were going to be used in the activity area. This makes up the second of the two research questions of this thesis, which were the following:

- What are the possible current and future applications of virtual reality and exergaming?
- How will the virtual reality activity area be implemented on the campus?

Before beginning the research on potential technologies, it was first necessary to further define the requirements of this project. The target demographic was going to be the students of LAB and this could be reflected in the technical proficiency of the users. As the users were likely going to be using the VR system independently, the overall experience needed to be easy and safe to use for them and others around them. The VR system itself needed to offer a reasonable amount of interactivity as its main purpose was to promote activity.

4.1 Choosing the technology

At the beginning of the research process the client requested that augmented reality (AR) technologies also be explored for possible use in the project. This process began with making a survey of the different current and future technologies and applications of AR. What was discovered in this process was that while AR is widely regarded as highly prominent, emerging technology, it was still somewhat lacking in both hardware and software. The few AR displays or other devices that were commercially available were too expensive and unsuitable for the purposes of this project, due to mainly being intended for industrial use and not offering relevant content. The AR glasses that were researched include Magic Leap, HoloLens, Everysight Raptor and Nreal Light. Very few gaming or entertainment applications were found to be available for these AR systems. Instead, what became clear was that the realm of mobile devices was where most AR content was found. Mobile AR has a variety of games and applications, but they are mainly aimed toward personal use outside of a campus environment. Some examples of popular mobile AR games are Pokemon GO or Ingress. These games promote physical and social activity, but they were not applicable for this project due to being self-contained experiences that anyone could already play on a campus or elsewhere.

Some possible applications of AR on a campus could be using a mobile application to see and interact with virtual, embedded elements around the campus or providing a virtual guide for the premises. One example of an AR guide is GuideBOT, which can be used to create a virtual AR guide of any space. (ViewAR 2020.) Many AR development tools are also available and can be used to create custom AR content and applications. Some of these AR development tools are SparkAR, Apple ARKit, Google's ARCore and Adobe Aero. (Zaitsev 2019.) One possible application for this project could have been to create a customized AR experience for the LAB M19 campus. It was decided, however, that this solution would have been slightly outside of the scope of the project but could be a potential future application. At the end, it was decided that the use of AR in this project would not be the right solution but showed potential as a future application on the campus.

The research began with exploring available VR hardware, software and applications. This was done by studying various VR gaming and exergaming research papers and online articles. Different HMDs, motion controllers, optical trackers, locomotion controllers, hand tracking controllers and motion trackers were considered during this phase. Some of the relevant VR technologies that were explored are compiled into Figure 1:

HMDs	Motion controllers	Optical trackers	Locomotion controllers	Handtracking gloves	Motion trackers
Oculus Quest	Oculus Touch	Microsoft Kinect	Cyberith Virtualizer	Manus VR	Perception Neuron
Oculus Rift S	Vive Controllers	LEAP Motion	Virtuix Omni	HaptX	
HTC Vive Cosmos	Valve Index Controllers	OptiTrack Flex		Dexta Robotics Dexmo	
HP Reverb	Samsung Odyssey Controllers				

Figure 1. Chart of the explored VR technologies

Gamepads such as an Xbox or Playstation controller are easy to use and are compatible with most VR systems and experiences, but their movement is not tracked into VR, meaning that the user cannot use their body to interact with the experience. These controllers are easy to use, but for the purposes of active gaming they would not be likely to offer enough interactivity.

Motion controllers are the standard VR input method and they allow the user to interact with their hands and arms in VR. The different motion controllers that were examined included the Oculus Touch for Oculus VR devices, the Vive controllers for HTC Vive systems, the Samsung Odyssey controllers and the Valve Index controllers. All of these motion controllers are easy and intuitive to use, they are supported by most VR content and they offer reasonable upper body movement and interactivity in VR.

Optical trackers can encourage higher activity in VR gaming, as they track the user's entire body, but these devices may not be as accurate as non-optical tracking methods. Most optical trackers are also not supported by most popular VR platforms and content. The optical trackers that were explored in this project were Microsoft Kinect, LEAP Motion and OptiTrack Flex. The Microsoft Kinect is an optical tracking device that tracks the user's entire body using a camera. The Kinect's tracking, however, is not perfect due to limitations in its hardware and software. It could be suitable for active VR gaming in some cases, but due to outdated content and limited support for VR, it did not meet the requirements of this project. The LEAP Motion is a hand and finger tracking device for VR and AR that tracks the user's hands with a camera. This device can be attached to a VR HMD to provide additional hand tracking. Studying the LEAP Motion provided an insight into different possibilities of VR, as this technology could be used, for example, in tasks where precise interaction is necessary. The LEAP Motion could be a useful addition to a VR system, but since it only provides tracking for hands, it was not essential for the project. Optical full-body motion tracking for VR was explored through the OptiTrack Flex system. This system allows for full-body tracking that can be combined with VR to give the user full freedom of movement in the experience.

Locomotion technology for VR was briefly looked into as well, and the device that was studied was the Cyberith Virtualizer. This device is a treadmill that tracks the user's feet and transfers their movements into VR. This can be used for VR gaming or other cases where more natural traversal in VR is desired. The Cyberith Virtualizer's shortcomings are its large size, high price and niche uses. For these reasons, this technology was found to be unsuitable for this project, but as this technology advances, it could prove useful for gaming and exergaming purposes.

Perception Neuron was studied to learn about the use of motion capture for VR. This technology allows for full-body tracking by using a harness with small trackers attached to it. This technology can be quite intrusive for the user but offers precise tracking. One reason for looking into this specific motion capture system was that this project's target campus owned one of these tracking systems, meaning that it could potentially be prototyped with VR at a later point. This technology lacks support by VR content, meaning that it would require custom content in order to be fully utilized with VR. The Perception Neuron tracking system was not used for this project as it was slightly outside of the project's ambitions.

The most suitable available VR systems were found to be the Oculus Quest, Oculus Rift S, HTC Vive Cosmos and HP Reverb. These systems were selected for further inspection because they were within an acceptable price range, offered a comfortable user experience, supported sufficient graphical quality and had favorable user experiences and reviews online. (Caddy 2019; Robertson 2019; Pino 2020; Knapp 2019.) Other hardware that was considered was the HTC Vive Pro, HTC Vive, Oculus Rift, Sony Playstation VR and Oculus Go. However, these were not found to be suitable for the purposes of this project due to either being too expensive, not being available for purchase or not meeting the general quality standards of this project.

The group of VR system candidates for the project could be divided into two categories: standalone and computer-powered VR. A standalone VR system does not require a computer to work unlike computer-powered systems.

Standalone:

The Oculus Quest is a VR system that includes an HMD and motion controllers for each hand. It is a completely standalone VR system, which means that it does not require a computer, external sensors or wires. This feature allows the user to move around with more freedom, but results in a lower graphical fidelity due to having no external computer powering it.

Computer-powered:

All the VR systems in this category, the Oculus Rift S, HTC Vive Cosmos and HP Reverb, feature an HMD and a pair of handheld motion controllers. The HMDs have built-in sensors, meaning that no external sensors are needed. Being computer-powered, they can support higher graphical quality than standalone VR systems but require a reasonably powerful computer to run most VR content. They must also be tethered to the computer, which limits the user's movement.

None of the considered computer-powered systems had any major technical differences between each other, so the main difference was price. Both the HTC Vive Cosmos and HP Reverb were notably higher in price compared to the Oculus Rift S and as they did not offer any major advantages over the Rift S, they were found to be unsuitable for the project. The Rift S was priced higher than the Oculus Quest and requires a computer to work, so it was decided that it would be too expensive for the allotted budget. In Figure 2 below, there is a list of the main differences between the standalone and computer-powered VR systems:

Computer-powered VR		**Standalone VR**	
Oculus Rift S	+ No external sensors + Supports high graphical quality - Tethered to computer - Requires powerful computer	Oculus Quest	+ No wires + No computer + No external sensors - Less computing power than non-standalone
HTC Vive Cosmos	+ No external sensors + Supports high graphical quality - Tethered to computer - requires powerful computer - Expensive		
HP Reverb	+ No external sensors + Supports high graphical quality - Tethered to computer - requires powerful computer		

Figure 2. Chart of the studied HMDs

After this process of elimination, the Oculus Quest was deemed to be the best option for the project considering the pre-established requirements. The Oculus Quest's shortcomings in graphical quality were made up for by its relatively low price, ease of use, portability and lack of wires and sensors. Thus, four Oculus Quest VR systems were acquired.

4.2 Choosing the content

The selected VR systems were still going to require installed content for the users to experience. Since the VR systems were going to be used mainly for gaming, the content needed to reflect that. Ideally, the content should have a mix of games and experiences with varying levels of activity, social aspects and competitive and non-competitive aspects. The content also needed to be available for the chosen hardware, the Oculus Quest.

Some available VR content was made purely for exergaming, while some was made for regular gaming but featured a wide range of activity levels. The database of the Virtual Reality Institute of Health and Exercise was used to reference the physical activity levels of the most popular, available VR games. (Virtual Reality Institute of Health and Exercise

2020.) It was found that many popular VR games offer physical activity ranging from low to high levels, but most fall into the low to moderate part of the spectrum.

The most suitable VR experiences for the goals of the project were found to be sports games, rhythm games and action games. Some limitations in choosing the VR content were that some games and experiences were more prone to causing motion sickness for some users, and some were thematically unsuitable for a campus environment. Taking all these factors into consideration, a list of the most suitable VR games and experiences was compiled into a chart shown in Figure 3:

Sports games:	**Creed: Rise to Glory** Boxing game. Activates upper body and some lower body.	**BOXVR** Boxing exergame. High physical activity.	**Racket: Nx** Futuristic sports game. Activates arms and upper body.	**Racket Fury: Table Tennis** Table tennis. Activates upper and lower body. Requires large playing space.	**The Climb** Rock climbing game. Activates the arms.
Other games:	**Beat Saber** Rhythm game. Activates upper body and some lower body.	**Fruit Ninja** The player uses swords to slice fruit. Easy to understand, allows for short sessions.	**SUPERHOT VR** Shooter game. Activates upper and lower body, theme needs to be considered for use in campus.		
Non-active games:	**Nature Treks VR** Game for relaxation. Offers good variety to active games.	**Real VR Fishing** Fishing game. Relaxing and fun gameplay.			

Figure 3. Chart of the chosen VR content

These VR games were selected because they were positively reviewed online, they offer a wide range of different types of gameplay, they do not easily cause motion sickness and they were available on the selected VR system. After compiling this list of games, it was relayed to the client.

4.3 Testing the concept

Once the required VR equipment was acquired, an internal test session was conducted. This session involved trialing the functionality of the VR systems and preparing them for public use. This yielded a better understanding of how the VR activity area could be implemented and what the user experience would be like. This testing showed that the Oculus Quest could offer a highly engaging and interactive experience that often encouraged the participant to be quite active. The VR system was found to be fast and easy to set up, proving that it could be used independently by the target group.

A separate demo session with the equipment was planned to be carried out with a focus group of students from the university. However, this plan came to a halt as the university's premises were closed due to the COVID-19 pandemic. This demo was planned to consist of at least one test session at the university, where the student group would use the VR equipment to play different exergames under supervision. This would have allowed for the opportunity to gather information about user enjoyment, engagement and the overall experience as well as the functionality of the VR activity area. After this demo session, a questionnaire would have been used to gather data of the user experience. The questionnaire would have consisted of a handful of questions tailored to yield a better understanding of the participants' experience with the VR systems and how the VR activity area could be improved.

5 CONCLUSIONS

The purpose of this project was to offer an alternative way for students to stay active on a campus to combat the low physical activity among students. This thesis aimed to explore the current and future technologies and applications of virtual reality and exergaming and implement a virtual reality activity area on the LAB University of Applied Sciences M19 campus. The purpose of this exploration was to provide the client with an idea of how these technologies could be implemented on campuses in the future.

The theoretical part of the thesis showed that the market for virtual reality is growing rapidly and that many companies worldwide are showing interest in this fairly new technology, and virtual reality hardware and software are advancing at a fast pace. Although most of virtual reality's uses are in entertainment, other areas such as education and healthcare have adopted virtual reality technology as well.

In the practical part of the thesis, suitable VR technology was chosen and purchased based on online research. The chosen VR systems were tested internally and a demo session with the focus group was planned. In the end, the client was provided with four VR systems in accordance with the established requirements and given a general look at current and future VR and exergaming applications and technologies.

Going forward, the implemented virtual reality activity area could draw influences from virtual reality arcades. These arcades offer a way for people to get together and play virtual reality games as a group or by themselves. This offers a more active and social alternative to playing regular, sedentary video games at home especially for those who do not have access to a virtual reality system.

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