

Leveraging virtual reality technology in developing neck exercise applications

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“It's the questions we can't answer that teach us the most. They teach us how to think. If you give a man an answer, all he gains is a little fact. But give him a question, and he'll look for his own answers.”

— Patrick Rothfuss, *The Wise Man's Fear*

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ABSTRACT

The incorporation of Virtual Reality (VR) technology in developing application for purposes such as improving healthcare is prevalent in this era. In this thesis, we present two applications: VRFysio and NeckVR, which leverage VR technology in rehabilitation and neck exercises by using mobile-VR. Using design science in an iterative Spiral-model, the development of the applications was divided into four iterations. The first iteration was used to develop the VRFysio application. The VRFysio application focuses on mimicking neck-stretching. When evaluating the VRFysio application, the main questions to be answered were whether VR could contribute to treating neck problems, and what issues can be solved using the VRFysio application. The results revealed that motivation and working through the pain of exercising played a key role when using VRFysio application. The usability of the application was rated as satisfactory based on the usability tests conducted.

The results from the evaluation of the VRFysio application enabled the development of the NeckVR application. This application consists of a VR-game whereby the player observes a black disk (the background), and boxes coming towards the disk. The goal is to move the reticle pointer over the boxes in order to destroy them before they hit the black disk. The application was tested by conducting evaluations, and open-ended interviews with Physiotherapists from the West Norwegian college. The feedback received from this evaluation was used in the third iteration.

Additional features such as a timer, and a menu where the player can customize different parameters that will affect the game, such as speed and frequency, were included in the application in the third iteration. Usability evaluations and semi-structured interviews were also conducted in this iteration with physiotherapists from West Norwegian College to test the VR-game in the NeckVR application. The results revealed that the best use of the application was for getting patients to move an injured neck and especially for those who were suffering from fear of moving their neck due to severe pain or dizziness

Both applications seemed to have potential, but in the current state could not be used freely as a part of any treatment. The physiotherapists are also required to guide the users through the first time of using the applications.

The usability testing showed that NeckVR were easy to use. The overall indication is that VR was easy to use and that the participants testing the application seemed to enjoy using VR.

The next logical step is to conduct clinical trials and test the application on the user group. Another inclusion for future work is, developing ways in which data can be collected from the sensors in the smartphones and displayed to the users or those prescribing the treatment.

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1 INTRODUCTION

Neck pain is one of the leading ailments of the western world [1]. Acute neck pain is often not a burden that lasts. Most of the pain comes from tense muscles that one gets from working on a computer or sleeping in an awkward position. It usually goes away fast, but, in some cases, it can last longer under certain circumstances or situations. If it lasts for more than three months, it is considered chronic pain. Many people who get chronic neck pain can become afraid of moving because of the fear of reinjury or the pain movement brings. Staying still and not moving is seldom the answer — movement and usage of the muscle are what usually makes the patient better [2].

In recent years, VR (Virtual Reality) has become a popular medium, and it grows in popularity each year. From merely 200.000 users in 2014 to a staggering 171 million in 2018, there is a magnificent rise in VR usage [3]. The rise indicates both the availability of the device and that more and more people and developers are going to be thinking of VR as an option when using digital devices. The term VR was used as early as the '50s [4] and '60s [5] when it appeared in festivals and used in science. The Oxford dictionary describes Virtual Reality (VR) as:

“ A computer-generated simulation of a lifelike environment that can be interacted with in a seemingly real or physical way by a person, esp. by means of responsive hardware such as a visor with screen or gloves with sensors; such environments or the associated technology as a medium of activity or field of study; cyberspace. Abbreviated VR” [6].

Using VR in neck exercises have shown to be both beneficial in regards to pain [7, 8] and to do exercises [9]. Regular VR is connected to a computer, but VR can also mean Mobile-VR, which uses a smartphone and VR-gases to make it a different kind of VR. Using Mobile-VR can be beneficial because of its availability and affordability. In this thesis, it is explored whether there using Mobile-VR can be beneficial for doing neck exercises? Making two applications, with different approaches on neck exercises to see how they will be evaluated and what, if, there are any benefits from using VR for neck exercises.

1.1 MOTIVATION

VR is an up and coming technology that increases in popularity and is used all over the world [3]. To test VR and to work with new and exciting technologies, is an important reason for VR being the main part of

this thesis. Also, the experience of building something, that can be tested, and perhaps further medical knowledge of some sort is an inspiration. Mobile-VR is more affordable than regular VR, and thus more accessible, and therefore, Mobile-VR is chosen for this thesis.

1.2 RESEARCH QUESTION

RQ 1: Can mobile VR technology be used to create an affordable treatment for neck pain?

RQ 2: Can strong involvement of experts secure a safe and proper VR-based tool for treating neck pain?

2 RELATED WORKS

There are multiple mobile applications available for download by people with neck pain. Some have good graphics with informative instruction videos (Figure 1, left), while others have a simple interface with minimalistic drawings and instruction text (Figure 1, right).

Relieve Neck Pain (Figure 1, right) is one of the simple applications available. Once the application has loaded, an automated machine voice starts counting down, and the exercise starts. There are calming waterfall sounds during periods when instructions are not given. It takes three seconds before the exercise is over, and the automated voices start counting down before automatically going to the next exercise. You cannot skip exercises.

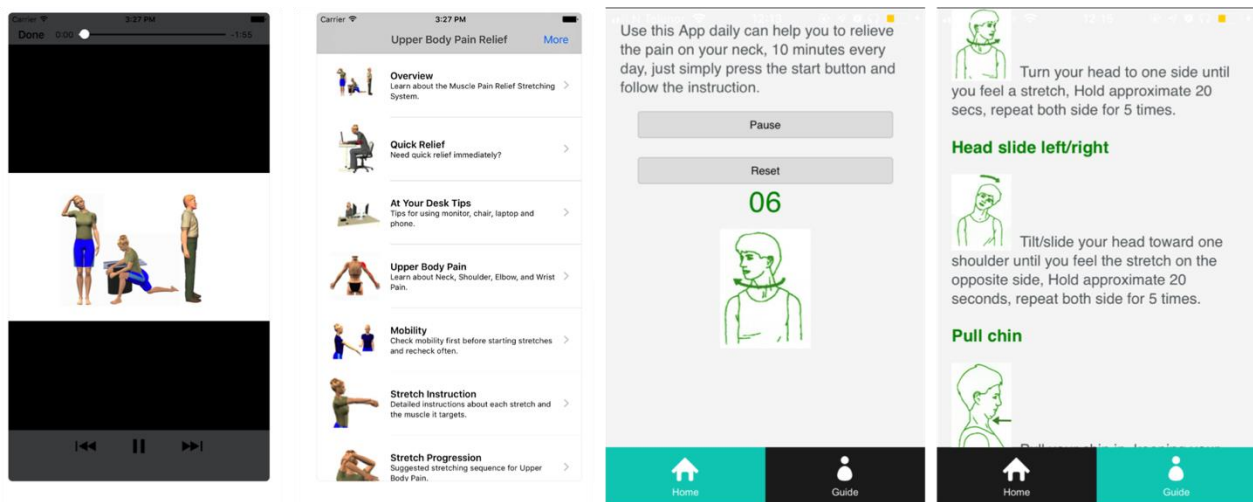


Figure 1: Screenshots from mobile applications. Left: Stretch Away Neck & Arm Pain. Right: Relieve Neck Pain.

2.1 CORPUS VR

InmotionVR is a software company that makes applications for VR with gamified exercises for neck training the neck. They currently have two products on the market: Corpus VR Pro and Corpus VR Personal[10].

Copus VR Pro is described as: “a therapy platform for physio- and Neurotherapy. Corpus VR is intended for physical rehabilitation, pain relief, and treating physical anxiety disorders. Corpus VR Pro has a variety of therapeutic exercises for neck and shoulders. Unlike the ‘usual’ sessions where there is no technology involved, using Corpus VR Pro therapists can monitor and intervene in therapy by measured pain areas!” [10].

They use full VR(Oculus Rift[11] or HTC Vive[12]) in combination with a tablet that has a dashboard-app which is connected to the VR-app. The physiotherapist uses the tablet to monitor the patient while playing the game, and the tablet gives them feedback and statistics from the session while it also mirrors what the player sees, using the VR-application. This product requires a full VR with a PC that can power the device and the use of the application

The second application is the Corpus VR Personal. This application is meant to utilize at home or on the go when the user is not at a medical office with a physiotherapist. To use this application, one does not require full VR as the Pro version does. It can be bought from the Oculus VR store for use on Oculus Go. It is also available for download on the Google Play store and the Apple app store. This means that one does not need a full VR-device. The user can use its smartphone just like in the prototype for this thesis.

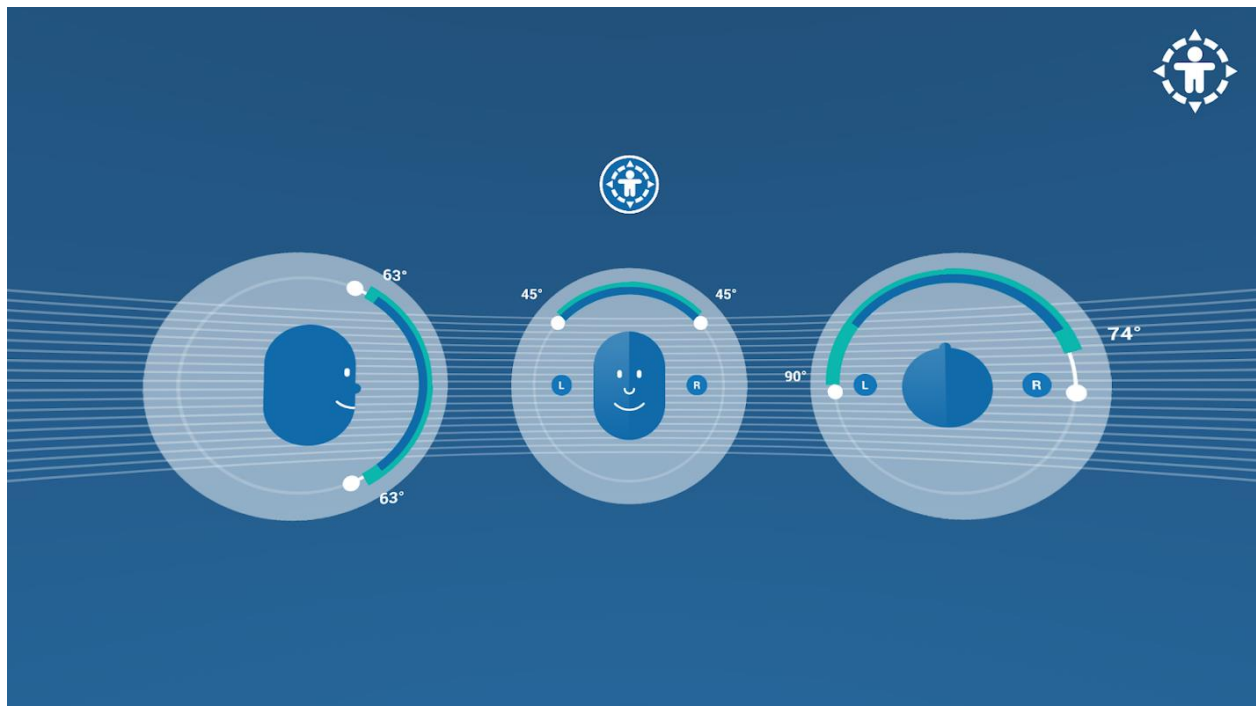


Figure 2: Illustration showing Corpus VR's degrees of movement.

The app starts with measuring the range of motion of the user's neck. By moving the head in every direction, the application creates a radar-chart for the range of movement for the patient's neck and shows how the user can move its head in every possible direction. This gives the users feedback on how many degrees of motion the neck can do.

Displaying this to the user is to indicate the progress made after each session of using the games. (Figure 2). A comparison of what the user's movability was before the exercise, which is indicated in blue, and the progress is shown in green, to indicate where the improvement is.

When all the measuring is done, the player returns to the main menu. In the main menu, there are nine different "games" to use for the exercise part.

- Starry skies – Is a module set on the observation deck of a space station where the task is to look at star formations to make Star signs.
- Open forest – Is a module for relaxing in a forest environment and being at a camping site. The user can look at some wolves approaching, which is surely an incentive to move the neck.
- Happy city – This game is in a park, and the user has to follow the cars as they go by to clean them. The player must follow them with the reticle until they are free of dirt. Following the car is done by moving the head horizontally (Figure 3).
- Chinese dragon – This is an exercise where the player is steering a dragon around to catch fish in the air.
- Lantern – An exercise stretches the neck in a 45-degree angle while holding the head for a couple of seconds in the direction a lantern is glowing. This is done by tilting the head to the right and the left.
- Flower meadow – Steering a bee towards flowers that are marked by arrows. When reaching the flower, there are a lot of small dots that are supposed to look like pollen. The pollen forms a path that the player must follow with much movement vertically.
- Tree of life – The game starts in a soothing environment, and there are floating islands all around. One floating island has a seed that needs to get moved from one to the main island. There appears a blue fog to link between the islands and the player have to guide the seed from the one island to the main island. If doing it too fast or too slow in line with the blue fog, the seed will drop, and you must start over if the main island is reached, a three pops up. The three will grow bigger each time the player gets another seed to the main island.

- Tropical island – Just as it sounds. One can look at a tropical island and relax.
- 360 video – A 3D 360 degrees video of a beach with sounds of the ocean.

The application also shows what kind of muscles or muscles groups that are used in each exercise.



Figure 3: The "Happy City" module..

3 THEORY

3.1 ABOUT VR

VR has over the last years become increasingly available for regular users. “Thanks to commercial Head Mounted Displays (HMDs) and their now reasonable cost (e.g., Oculus Rift[11] \$599, HTC’s Vive[12] \$799, Sony’s PlayStation VR \$399), VR is becoming more and more present in the gaming market. What differs with VR from the past and present, is the immersion and the multisensory of the experience” [13].

People have been dreaming about VR since 1935 when it appeared in the story “Pygmalion’s Spectacles.” VR is becoming mainstream and seems like a new thing, but some say it has been around since early 1950. Not the VR we know today, but scientists and researchers have been trying to create something like VR since the 1950s[4]. Others say the term VR was first used in the 1960s. Some see parallels to VR in the painted murals that stretched 360 degrees around that was done in the 19th century. In the 60s, a VR experience call Sensorama was created. It was a 3D film with sound, smells, wind, and movement featuring a motorcycle [5]. Nintendo and Sega both tried to use VR in the 1980s and 1990s. It was a costly affair, and full immersion was not achieved. When the Nintendo Wii came out, it used accelerometer and infrared as input from the controller. Utilizing the whole body, instead of just the fingers, this was a new level of immersion. PlayStation and the Xbox also got more immersive gear. “Although the Nintendo Wii, PlayStation Move Controllers, and Xbox Kinect were not head-mounted devices their technologies are the core foundation necessary for VR” [4]. Oculus[11] got crowdfunded for 2.5\$ million and made the Rift. A head-mounted display. Google joined the market with a cheap alternative. Cardboard[14] is a VR headset for smartphones, using the phones screen, processing power, and built-in sensors such as the gyroscope. Samsung made the GearVR with Oculus for their mobile phones. HTC made an Oculus competitor in the Vive [12]. It is not only a device with full VR capabilities, but also has 3D room tracking ability. Like the Rift, the Vive[12] needs top of the line computer to be able to run [4].

Immersion is used in context to VR a lot. When talking about VR and immersion, it is defined as involvement of play and lack of awareness of time in the real world. In VR we call the state of immersion Spiritual immersion. Spiritual immersion is when a person has the sense of being in the VR-world that is not real. This is done by using visuals as well as sound and other stimuli. VR does not need to be fully immersive. It can be used a more traditional utility such as keyboard and mouse[5]. Using, VR glasses or Head-mounted display (HMD) used with headphones can feel like being in another place. But to get the full immersion, one must manipulate all the five senses. Today, the focus is mostly on hearing and sight [5].

In the past it was not common to use VR with HMD, mostly because the technology was not that good. Those that were used were expensive. They could make the user feel discomfort, and not everyone was able to use them for long. However, now that the likes of Oculus Rift and Vive[12] are available, more HMD's are finding their way into education and training. With newer technology, the latency and precision tracking make VR more manageable to use[5].

3.2 OTHER USES FOR VR

3.2.1 VR in education

VR and AR are used when there is a need to simulate dangerous situations and cope with emotions. All while being in a safe environment [5]. VR is often used for vocation training in areas that are hard to access or are dangerous. They can use VR for scenarios that do not occur every day. VR can also be used to train supply chain workers or within Architecture [15].

3.2.2 VR in Healthcare

Healthcare rehabilitation is becoming one of the major fields in serious games, showing possibilities to utilize the games in treatment [16]. The games can help younger people and kids, but there are also serious games for patients that suffer from stroke-related injuries, as well as for older people [17].

A lot of VR is used and tested in healthcare and the medical field. Some areas that use VR are the education of nurses, medical training in a virtual hospital, medical professionals training, dental training, and more. One of the benefits of doing exercise and learning in VR compared to regular computer simulations that use screens is that the users are "present" with VR[5]. VR can visualize and show events that are not happening in real life. Some of these include things we cannot see or do in real life or are too dangerous or risky [5]. Not that much research has been conducted on children or people with disabilities[5].

There is a paper by Giuseppe Riva[18] from 2005 that is a bit old, but it focuses on the thoughts and views about Psychotherapy and VR for almost 15 years ago. Even back then, they realized that the use of VR could be beneficial to the treatment they provide and may help. They showed that using VR in the treatment of phobias is beneficial, exposing patients for their fears without doing it in real life. They also showed that VR could be used in treating PTSD, different eating disorders, and body issues. There were two advantages they highlighted in the article. Firstly it is possible to integrate all the methods used in the regular treatments

(cognitive, behavioral, and experiential). Secondly, VR induces the patient in a controlled sensory rearrangement that can modify bodily awareness. The article concludes there exist some barriers, like hardware and standardization. Also, standardization in the protocols was mentioned. The third thing they mentioned in their conclusion was the cost. At that time, the cost of acquiring the necessary hardware and software exceeded 150 000 dollars. Moreover, in the end, they mentioned health and privacy concerns[18]. This indicates the way technology gets better and cheaper and that a mobile VR device would not be possible almost 15 years ago.

3.3 VR APPLICATIONS FOR THE NECK

In a paper by Mihajlovic et al. [9], applications were developed to investigate how to tailor neck exercises to the patient's needs. According to the paper, people in pain often turn to drugs while there are physical exercises that could help them get better. Addressing this, they conclude that VR games can be used to help users do exercises by forcing them to move in intended directions. The idea behind this research is to let the patient have a game which lets them do something fun while taking their minds off the fact that they are doing something which may hurt a little, and which is considered a chore. They used the Oculus Rift VR[11] to get their results.

They made a classical virtual environment using Unity3D to catch a butterfly in a space, a classical VR environment. They also made a more realistic one with Unreal Engine, where the virtual environment was the hallways of the research faculty where they conducted their research. Lastly, they compared the results from the two games with results from traditional neck treatment. The goal of both games is to follow the flying butterflies with a reticle to see how long the user keep up. The butterfly omits a signal that can be the score achieved or a particle system that signals that the player is executing the exercise in an intended way by hitting the butterfly[9]. They also made a program that recorded the test results during the testing to get as much data as possible. The first metric was the players' ability to track the butterfly. Here the more realistic VR-game got a higher score than the classic VR-game. Another parameter head movement, and if guided to a different set of degrees, how much over or under would the patient actual head movement be. Meaning that if the butterflies are set to go 60 degrees in one or the other direction, how close the patient is not to exceed this parameter when doing the exercises. The classic VR game performed well in this test, but the real game prefomed even better. Regular exercises showed a bit worse results than both of the VR games. This means that the games as a rehabilitation system can work for home use and can be used in a way that

starts the patient off with small movements and then evolves it to more movement as is required by the treatment. The test subjects were then asked to rate their experience, and it is clear that VR is preferred over the regular method of doing neck exercises, and that the most realistic game scores a bit higher than the classic VR game[9].

3.4 GAMIFICATION

How to use gamification in a meaningful way? Gamification is in simple terms, a way to make a mundane, dull, and boring task into a game. Gamification has the effect of making the player play over and over, even though it is the same boring task because of the game itself, the progression and the rewards gained when doing it. This can be done using levels or leaderboards or rewarding the player with experience points or just points for a task. Experience points enable the user to gain levels. Also, regular points can be accumulated to a score which is put on a leaderboard. Achievements or badges can also be used for some set tasks. This is originally from videogames but is used in gamification as an incentive for players. This is used a lot in gamification [19]. But there are some pitfalls of just implementing it. In “Gamification by design,” there is a quote that says, “once you start giving someone a reward, you have to keep her in that reward loop forever” [20]. This can be a problem when the game wants the player to use the game for a long time. The rewards then keep coming. Here is where the “meaningful gamification” has a part to play.

There are six key elements of “meaningful gamification” [19]:

- *Play*. In a limited environment that can be explored. Making the player choose to play, rather than forcing it on them. Learning through failure.
- *Choice*. They should be able to choose their own goals. Control to the players. They can emphasize the most important thing with the game and what they want to achieve.
- *Information*. Why is the player, playing the game? Visualize why they are doing the exercises and find out what relevance the game has for the task they are doing.
- *Exposition*. Use a narrative or story. However, it must be relevant and good. Use something that can enhance the experience rather than something that is just added to the game for the sake of adding something.
- *Engagement*. Bring people together. Find other people that are using the same game, to play with, or use the perspective to make the game meaningful.

- *Reflection.* Reflection is a big part of learning — connecting what you have learned to the real world.

Taking these elements into account when using gamification, and combining them with some of the common elements like rewards and points can make a game that a player wants to play, and get them to keep track of how they are doing. Meaningful gamification intends to use common elements to reach the goal, where the goal reflection and find the things that the player is finding meaningful. Customization can also be a valuable tool for a player to make the game they want to play and to make them find goals of their own.

Some researchers have created an application called Fitmersiv [21]. The objective of the game is to show that the lack of motivation when it comes to exercise can be beaten with technology. Using the Fitmersiv application, users were tested while doing exercises on an exercise-bike with the use of VR-glasses. This was to show that gamification can be a pleasant distraction and make a mundane and boring task into a fun activity and doing so, make the user more likely to come back to the task and do it more, which is the intended purpose for gamification [21]. It not only motivated the users to do the exercise but because of how the game was developed, the user did the exercises the right and intended way because the game rewarded the player for doing so using points and badges for the user to get rewards and to distract the player from the pain.

PhysioMate [22] is a serious game that deals with physical and cognitive deterioration. The goal of the game is to get the player to be more physically active. It is a game that functions as a complement to the exercises that are done with a physiotherapist but can also be used without the presence of the therapist [22]. The target users are in wheelchairs and are encouraged to use their upper body. With the use of Microsoft Kinect and motion sensors, the users are guided through a set of exercises [22].

DroidGlove[23] is an Android application for rehabilitation of wrists. The application focuses on exercises that can be uploaded by a physiotherapist, Videos, and information about the exercises can be viewed so that the patient gets all the feedback it needs before doing the exercise on their own [23]. Using the phone with the glove, the different sensors on the phone can be used to track the movement and gather data to see whether the patients are executing the exercises as intended. The DroidGlove also monitors application usage, allowing it to record and send data about exercise duration and other relevant aspects to the physiotherapist. This enables a better follow-up system for physiotherapists to monitor their patient's progress [23].

There is not much research done on VR-based games, but a system called RehabMaster[24] is a good example. It is an interactive task-specific VR game for the rehabilitation of the shoulder region after stroke

surgery. Using gamification to complete tasks makes the repetitive exercises feel less dreary [24]. Another application that utilizes VR is the pain-management game, made within a study named CryoBlast [25]. The goal of the game was to immerse the player in a 3D world, thus distracting with the game. It helps the player focus on what is going on and distract from the current short-term pain.

3.5 VR AND PAIN

A game was developed to find out if pain relief and distraction of pain using VR can be done. This has shown what VR can do for chronic pain. When using the game, the results highlight the use of mobile VR as a substitute for the more expensive VR devices on the market. Patients with chronic pain test both VR systems to find out which gives more pain relief if any. Although the results show that regular VR gives greater pain relief, the reason for using Mobile-VR is that it is a lot cheaper and easier to use at home. This can again make VR more accessible for everyone. The results showed that there seemed to be a use for VR in pain relief, but that there are more definite effects for using fully functioning VR, rather than a Mobile-VR[26].

When battling with chronic pain, people use many opioids and, in some cases, misuses it. Therefore, there is a big need for solutions to chronic pain, namely finding a way for patients to get help with pain without using opioids. VR has been shown to be an alternative to treating pain, using VR to help with burn pain, wound care, and even a significant reduction in acute pain. “Gate Theory“ [7] shows that VR can reduce the perception of pain by “stealing” the attention of the user.

There are some that states that VR also could help with dealing with chronic pain. There are as stated above, ways of dealing with acute pain using VR but not that much is known about using VR to treat chronic pain? Chronic pain is considerably different from acute pain. There are many variables involved in chronic pain, such as processes in the nerve system and psychological factors. Therefore, what can help acute pain does not have the same effect for chronic pain. One study let people with psoriasis, and atopic eczema try out VR to see if there was a change in feeling itching from their condition. There was a significant drop in itching when using VR and 10 minutes after[7].

A study was conducted to see whether VR could help against chronic pain. All the test subjects used VR for five minutes. In those five minutes, they were exploring an application called “COOL!”. It is an interactive journey in a 360 degrees landscape that is fully immersive. Every participant had some chronic pain, from

back pain to abdominal pain. For feedback, the users were supposed to tell how much pain they were in before, during, and after the session. To be able to give a rating to the pain that the test-subjects felt, a rating from 0 to 10 was used. After the tests were done, there was an average of 5.7 in the pain rating before the test, 2.6 during and 4.1 after the test, which means that the pain was decreased by 33% after a session with VR. Also, when using the application, the pain rating was 2.6, which indicates a decreased pain perception was over 60% [7].

The average age of the participants was over 50 years. Even though there was a presumption that older people are skeptical about using technology and that younger people are often more tech-savvy, most of the participants enjoyed using VR and the game despite their age [7].

VR was originally developed for the military to be an entertainment tool, but over the last decades, there has been an increase in the use of VR in healthcare. “As for its therapeutic application, has shown several advantages for more conventional treatments, such as increased patients motivation and engagement the safety of the simulated environment and greater personalized possibilities”[8].

There is a hypothesis that says that; “nociceptive signals are modulated by a gate control system located in the dorsal horn of the spinal cord: depending on whether the gate opens or closes, the flow of pain signals to the brain can be facilitated or inhibited. The gate can be opened or closed not only by sensory factors but also by cognitive and emotional factors”. The gate control theory is more complex than first describe, but it seems to still valid. Another theory states that pain is multidimensional, existing of sensory, affective and cognitive components, that affect different brain regions and are influenced by many signals that affect the neuromatrix and plays a part in the neuro-signatures that go out. The neuromatrix theory has been questioned as a whole, but there is no denying that the complexity of pain network is still very important to understand that pain comes from different factors, such as cognitive and emotional factors [8].

How the individual react to pain is important. The pain demands attention. If there is pain over a longer period of time, the perception of that pain, even though it is the same will be perceived as less. Some distraction techniques work on this kind of pain. Relaxation exercise and cognitive task to name some [8].

In recent years VR has emerged as a tool to use for distraction purposes. VR can activate different senses at the same time, making the user perceive other presences in a virtual environment. This can divert the attention from pain. One of the reasons for this can be the reduction of the nociceptive signals when immersed in, and interacting with, a virtual environment. VR can also help patients who are in the hospital or the like, escape from it. VR can make the patient focus on pleasant stimulus rather than the negative ones, such as stress and anxiety. While using VR, a person can have the ability to achieve positive emotions.

Positive emotions can have an almost painkiller(analgesic) like effect. Why VR does this is not clear, but one plausible explanation is that the analgesic effect of VR seems to be mediated through effective mechanisms[8].

Studies show that while using VR, being in a virtual environment can increase the tolerance of pain, the threshold for pain, and the reduction of the intensity of pain [8].

A study showed that reduction of pain more often accrued if a person had more fun, less stress, and experienced more positive emotions using VR. This all suggests that the painkilling effect of VR is multifactorial [8].

Comparing different VR software and hardware, there are a trend in what kind of setup are the most effective when trying to distract the user from perceiving pain. When comparing a high-tech VR system, with the best display, head tracking, and headset against a low-tech VR system, with low display quality, no head tracking, and no sound and interactivity, it is clear what yields the best results. The high-tech option has a stronger presence in the Virtual environment and a stronger pain reduction. There was also found a relation between presence and pain reduction. Sound is also an aspect of VR, and there is a correlation between pain tolerance and playing a VR game with sound. When comparing VR systems that were interactive with those that were not, and the once that where interactive had a higher sense of presence (see above for confirmation that this means it gives less perception of pain). This again concerns that engaging in a task and doing things while in pain can distract the processing of pain. Shortly stated, interactivity and quality of the VR setup are crucial for getting that important sense of presence and therefore increasing the painkilling effect[8].

There is some concern that the painkilling effect that VR has can fade over time. The concern is that the novelty of using VR will wear off, and with it the benefits of using it. However, that seems not to be the case. After testing this for eight weeks, a study found that there is no correlation between the novelty of VR and the effect it has on the patients[8].

There have also been some studies done on the brains' reaction to VR to see what effect it has on the pain related areas. Some subjects that had no chronic pain was exposed to pain simulations, and brain scans showed that there was significantly less activity in the parts of the brain that is commonly activated by painful stimuli. This gives evidence that the brain reacts to the painkilling effect of VR once again[8].

3.6 MEDICAL THEORY

The cervical spine is the most mobile part of the spine, but it is not that stable. Therefore, there is muscle to control the mobility of the neck. Since its so vulnerable a disturbance to signals in the neck can cause dizziness, unsteadiness, visual disturbance, difficulty moving the neck, and head-eye coordination [27].

The neck has two important muscles that handle different tasks. One is for holding the head steady, which is called static equilibrium, and the other one is for moving the head in a controlled way, which is called dynamic equilibrium. The body has a system to detect movement that is called the somatosensory Subsystem, Vestibular subsystem, and the visual subsystem [27].

The somatosensory Subsystem signals the brain about the perception of pain, temperature, touch, and the sense of self-movement called proprioception. The proprioception in the neck is especially strong. It gives the central nervous system information about the heads position to the rest of the body. This is the only region that has a sense of balance and sight [27].

The vestibular subsystem is the system that controls the muscles in the torso and neck and control of balance with the help of sight. This is also the sensor for the velocity of the neck, and it reports the necks position of the head [27].

The visual system has a dominant role in deciding movement. It overrides the other sensory systems. This system also controls the eyes [27].

These three systems have many connections, and therefore, there can be multiple symptoms for the same sort of neck pain. It also lets the systems work in conjunction to verify the movement and position of the head. Using this can be shown by adding a restrictive brace for five days. This changed the eye movement of the patient, and the while the subjects were exposed to the brace, it swayed and head-neck coordination. There can be many reasons for neck pain, that include chemical changes in the neck done by inflammatory events. Pain in the central nervous system can affect the input in the sensors and affect the neck. Psychosocial events can be a cause as can fatigability. Atrophy of the neck muscles will cause pain. Sensor motions that do not work properly will affect this as well. Pain is not always triggered by the same sensors for the same injuries, so this needs to be considered when diagnosing neck pain [27].

There are many ways of injuring the neck. Here are some ways to detect what kind of injury a patient can have [27]:

Disturbed head neck awareness is when the patient is not in control of the positioning of the head-neck. This can be shown by having the patient have a headband on its head with a laser on it. They move their head, and with the eyes closed, the patient tries to get to the same point with the laser as the starting point. The difference can be measured and converted into degrees to show the difference [27].

Disturbed neck movement control is when a patient has trouble moving the head in a controlled way, movements can feel jerky, the neck is intensely tired, and the head feels heavy. In assessing this, software measures the neck-head movement with a cursor that is controlled with a head mounted sensor. Then a cursor that is controlled by the program starts to move randomly. Then the patient needs to follow the movement of the computer-controlled cursor with the one that is controlled with the head. When this is done, the software measures the deficiency and records it, and they also suggest a clinical trial to measure the patient's ability to trace patterns [27].

Disturbed postural stability: Dizziness and/or unsteadiness. Having this can be indicated by unsteadiness, insecurity, and lightheadedness. There can also be complaints about spinning inside of the head, unlike vertigo, where the spinning is external. There can also be a kind of tipsy state to the person suffering from it. Physical symptoms are stiff neck in the morning and tired neck in the afternoon. Also, quick movements of the neck can cause discomfort. Assessment for these injuries is often done by excluding others. There is an indication that suggests that balance disturbance is the most common in this aspect, but that it can occur in other ailments as well, so it is not definite. Some balancing exercises can be used to diagnose this ailment further [27].

The oculomotor disturbance is when a patient has neck pain and blurred vision, grey spots appear, and many other visual symptoms. Some patients have reading problems as another symptom. Here the assessment is to follow the eyes movement while holding the head still, head movement while focusing on an object, head and eye movement coordination, and quick movement to get the eyes to focus. This is assessed with exercises that efficiently use exercises [27].

Treatment to these kinds of injuries, include pain management, manipulation therapy, active range-of-motion exercises, and exercises to improve neuromuscular control. Using a combination of these seems to give the most satisfactory results. This should not increase the pain, but some discomfort and dizziness are ok [27].

Coordination of movement is desired because it activates the small and large muscles with the right amount of force. Using a laser mounted on the head, the treatment can be used to find what kind of the ailments in the neck that is assessed and to train it — using patterns, following lines, etc. Some computerized versions

come with different levels of difficulty and different ways to train the neck. This includes body posture, awareness of body position in space, etc. The exercise with random movement when following a cursor can also be used in training and exercising as well as assessment [27].

4 METHODOLOGY AND METHODS

4.1 DESIGN SCIENCE

Design Science research is a method that establishes and operationalizes research when the desired goal is an artifact or recommendation. Also, research based on design science can be performed in an academic environment and an organizational context [28]. Design science aims to study, research and find out what the artificial can tell, and how it is in an organizational setting. This is a process to design, solve, and evaluate the artifact that is designed and to present the results and solve the problem it was made for. Using design sciences, the problem can be solved using artifacts and changing it for the better. A Key feature of design science is to get a satisfactory solution for a not so optimal solution. Design sciences are not only for making the gap between theory and practice smaller, but it is also a reference for the improvement of theory [28]. The design science research has major factors that determine the success of the research. Rigor and relevance [28](Figure 4).

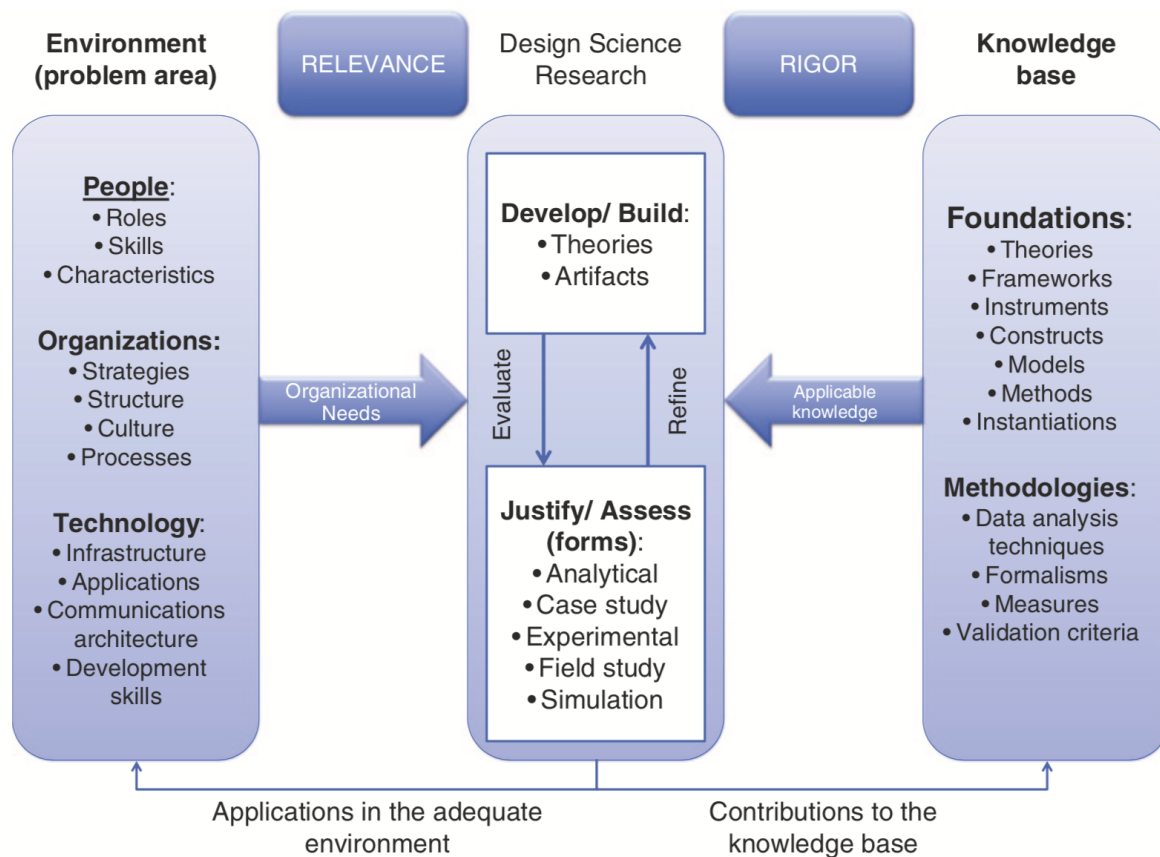


Figure 4: Overview of design science [28]

When doing the research, one should always consider the relevance of the study, because some may use the generated results to solve practical problems. Rigor is important because of the validation of and reliability of the research so it can contribute to improving the knowledge base in the area the research is about. The knowledgebase is where one can find theory and artifacts of previously executed research. Here the raw material for research and artifacts are obtained [28]. However, it is not always enough, so some use trial and errors with their research when designing new artifacts. Then the environment in Figure 4, refers to the environment in which the problem is being observed where the phenomenon of interest to the researcher is obtained. The artifact operates in this context [28]. Design science can, based on the needs and problems of interest, support the making of an artifact, and add to the knowledge base. The artifacts are then valued on the importance and to support this, the existing knowledge base must be consulted and used. The knowledge base is made with methods that the academic community recognizes. Methods that support the and justify and evaluate the artifacts that are made or the improved theory [28].

Helping utilizing Design Science, seven criteria were made to help researchers [28] (Figure 5) ;

1. Design as artifact	Research developed with the design science research method must produce viable artifacts in the form of a construct, model, method or instantiation
2. Problem relevance	The purpose of design science research is to develop solutions to solve important and relevant problems for organizations
3. Design Evaluation	The utility, quality, and efficiency of the artifact must be rigorously demonstrated via well-executed evaluation methods
4. Research Contribution	Research conducted by the design science research method must provide clear and verifiable contributions in the specific areas of the developed artifacts and present clear grounding on the foundations of design and/or design methodologies
5. Research rigor	Research should be based on an application of rigorous methods in both the construction and the evaluation of artifacts
6. Design as a research process	The search for an effective artifact requires the use of means that are available to achieve the desired purposes while satisfying the laws governing the environment in which the problem is being studied
7. Communication of the research	Research conducted by design science research must be presented to both an audience that is more technology-oriented and one that is more management-oriented

Figure 5: Design science principals [28]

4.1.1 Artifact

The artifact is intended to solve observed problems. Design the artifact, observe, make research contribution, display the research contribution, evaluate the design, and show the results in a good way. This can include models, methods, constructs or instantiations, and many more. It can be described as: “any designed object with an embedded solution to an understood research problem”[30]. In this thesis, the artifact will be the VRFysio application and the NeckVR application.

4.2 METHODS

4.2.1 Literature review

To get knowledge on the topics regarding VR in relations with medical use, a literary review has been necessary, to search out whether there was any similar artifacts or applications made, and find if others had found potential in using VR. The literature review has focused on VR in combinations of use in the medical field, regarding pain and other relevant topics.

4.2.2 Sprint

Sprint, or Google sprint was developed by Google venture based on Design Thinking. This combines empathy, creativity, and rationality to solve a problem. Design Sprint takes five days to complete and are aimed to define goals, validate assumptions and define the direction of the product. Key phases that takes one day each are; Understand, diverge, converge, prototype, and test [31].

4.2.3 Interviews

Interviews can be thought of as a “conversation with a purpose” [32]. There are four types of interviews. Structured, semi-structured, unstructured, and group interviews. In this paper, semi-structured, unstructured and group interviews are used.

4.2.4 Semi-structured interviews

Semi-structured interviews are a companion between structured and unstructured interviews [32]. The interviewer has both closed and opened questions and starts with the planned ones. It is important not to phrase a question in a way that hints at the desired answers and always to have neutral reactions to the answers that are received. However, the interviewer should probe for answers naturally and encourage the subject to talk freely [32].

4.2.5 Unstructured interviews

Unstructured interviews are an interview that is less controlled and more exploratory in a field and often go in deep in that field. The questions are open and probing [32]. There should be an agenda, and there needs to be a plan regarding the topics that need to be included to get the answers that need answering, but new information should also be followed up and explored [32]. The benefits of using unstructured interviews are the richness of the data gathered, and there are possibilities to gain new knowledge about the topics that were not already known by the interviewer.

4.2.6 Group interviews

Group interviews are mostly used when interviewing 3-6 people, using the setting to let them interact with each other and discuss the issues that are presented. This can present new insight into the issues that are discussed, that may not have been thought of if it had been a regular interview. Another benefit of using group interviews is that there are often more responses to the questions, because of the interaction of the subjects and the way that they can stimulate each other. During group interviews, there can be brought up topics that the interviewer has not thought about asking. One thing to watch out for in these settings is that some persons can dominate the conversation and others may be quiet. Handling this right is needed to get a balance and the answers that are desired [33].

4.2.7 Observations

Observations are useful in any stage of the development. It can help in the early stages of development but also in the later stages. User may be observed directly, as they perform the activity or recorded to study afterward. They can be directly observed during a controlled environment where they are given a set task to perform. Then there are the in-field observations that makes observations of people in their daily lives doing what they normally do[32].

4.2.8 Design prototype

A prototype is a manifestation of a design that allows stakeholders to interact with it and to explore its suitability [32]. There are two kinds of prototypes; low-fidelity and high-fidelity prototypes. The low fidelity prototype is a simple creation that takes little time to make and therefore cost very little. It can be a paper-sketch of different frames that are in an app. The high-fidelity prototype is a nearly finished product. It is interactive and has mostly the same functionality as the intended finished product. It proves the

opportunity to try out functionality, and it looks and feels like the intended finished product. This makes it as near a finished product as it is possible to come without making the full product.

4.2.9 System Usability Scale

System Usability Scale (SUS) is quick and easy for measuring usability[34]. SUS was created in 1984 by John Brooke[35].

It consists of 10 questions that have five different options. The five response goes from strongly agree to disagree strongly. It can be used to evaluate websites as well as hardware or software.

The reason for using SUS is that it is easy to use, can get accurate results with few people testing it and can tell if a thing is usable or not[34].

Things to keep in mind when using SUS [34]:

- The scoring system is somewhat complex
- There is a temptation, when you look at the scores, since they are on a scale of 0-100, to interpret them as percentages, they are not
- The best way to interpret your results involves “normalizing” the scores to produce a percentile ranking
- SUS is not diagnostic - its use is in classifying the ease of use of the site, application or environment being tested

The questions that are used in SUS are the following[34]:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.

5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

On the questionnaire, there are five ways to rate the thing that is evaluated. Strongly disagree, disagree, neutral, agree, strongly agree are the five ratings that can be given to each of the ten questions. Strongly disagree gives one point, strongly agree gives five. Only in correlation with each other can one test the usability. The value of one question has no meaning on its own. Question 1, 3, 5,7, and 9 is given the score minus one. This means that their final score for each question is from 0 to 4. Questions 2,4,6,8 and 10 gets its score plus one, which means from 1 to 5. Then the scores from each question are added together. This score is then multiplied by 2,5. This is the final SUS score. Then the SUS scale shows the grade the evaluated object gets (Figure 6).

The score given by SUS is not a percent score where a 70% means that it is 70% to perfection. There are some different ways to look at the score and grad it. These can vary for what the intended use is for the application[35]. The most common way to interpret the SUS score is shown in figure 6. This figure shows different ways to display the scores. In a paper from 2018, James R. Lewis[35] presents the curved grading scale(CGS) as the more precise grading scale (Figure 7).

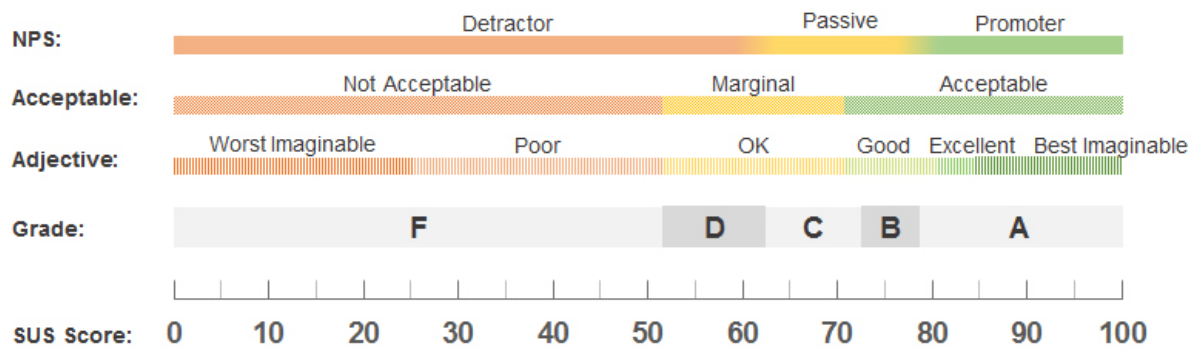


Figure 6: Grades and indications used in SUS [36]

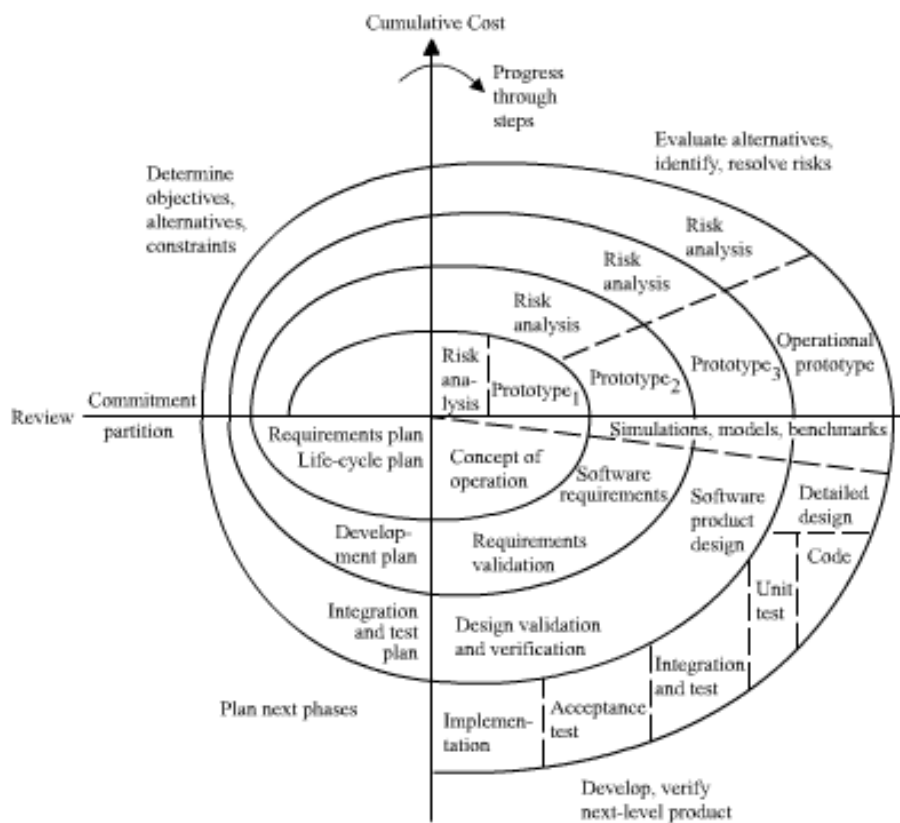
Grade	SUS	Max-Min SUS	Percentile Range
A+	84.1 - 100	15.9	96 - 100
A	80.8 - 84.0	3.2	90 - 95
A-	78.9 - 80.7	1.8	85 - 89
B+	77.2 - 78.8	1.6	80 - 84
B	74.1 - 77.1	3	70 - 79
B-	72.6 - 74.0	1.4	65 - 69
C+	71.1 - 72.5	1.4	60 - 64
C	65.0 - 71.0	6	41 - 59
C-	62.7 - 64.9	2.2	35 - 40
D	51.7 - 62.6	10.9	15 - 34
F	0 - 51.6	51.6	0 - 14

Figure 7: The SGC scale for SUS-score [35]

4.2.10 Spiral model

The development methodology in this thesis was the Spiral model [37] (Figure 8). In this thesis, a simplified version of this method was used to make the application. The Spiral model is combining an iterative process with the steps of the waterfall method. These iterations can be called spirals. Each iteration is made up of the same steps. Determine the objective, alternatives, and constraints, evaluate alternatives, find out what the risks are, develop, and demonstrate the new product and then find a way to plan for the next iteration [37].

In this thesis, there seemed to be a need for an iterative process, to get the needed results and feedback along the way. Using iterations in the development, going back over the spiral and seeing what could get done better next time around was a crucial part of the process. Combined with the evaluation of the prototype, there was a lot of good data gathered, and the next steps in the process were clear to see. The iterations all started with assessing the prototype, the development of new additions to the prototype, and then testing and evaluating the prototype. Doing these four times was a crucial part of developing the prototype as it was at the finish of development.



The Spiral Model

Figure 8: The spiral model [37]

4.3 TECHNOLOGIES

4.3.1 Software

4.3.1.1 *Unity3D*

Unity is; “A game engine is the software that provides game creators with the necessary set of features to build games quickly and efficiently” [38]. Using Unity, the user can make games in 2d or 3d and other kinds of software. Unity has an easy import system for both graphics and audio, making it an easy-to-use development tool for new users. Unity has a great community and assets that are readily available, some for free and some for the ones who are willing to pay. It has an in-built physics engine that allows the user to make realistic games with a small amount of code.

Unity games are primarily written in C#, which is an object-oriented programming language. In the development of the game, Google Cardboard SDK[39] for Unity was used. The reason for using this SDK is that Google Cardboard VR has some readily done code that can be easily implemented and is made for easily making mobile-VR applications. The “RayCaster” is one of the classes that was inserted to the project and worked at once.

Android Studios SDK is used to get the unity application to Android devices. The SDK is used to get the application for a computer to an Android device along with Java development kit (JDK).

When using Unity 3D, the code is often written in Microsoft Visual Studios[40]. Visual Studios is an integrated development environment (IDE). Visual Studios is the standard IDE that is used with Unity3D

4.3.1.2 *Udemy*

Udemy[41] was used to learn both Unity3D and C# by taking a course where both technologies were utilized to develop a game. This lay the foundation for building the game, which came to a type of mold for the VR-game.

4.3.2 Hardware

To be able to use smartphone applications, the user must have VR-glasses for mobile phone available. In the test that is done in this thesis, the Samsung Gear VR-glasses[42] is used. There are a variety of devices

for Mobile-VR; the Gear VR is just the one that is used in the testing for this thesis. The phone used in the testing was a Samsung Galaxy S8.

One of the aspects of this assignment was to show how affordable a solution using one's smartphone with a cheap VR headset could be. The main manufacturer of the cheap VR-headsets is Google, with Google Cardboard VR[14]. This is one of many such devices that are just a cardboard case with two plastic lenses that are used in combination of own smartphone.

5 ESTABLISHING REQUIREMENTS AND DEVELOPMENT

The design was evolved using a modified and shortened version of the Google Sprint [31]. First, the concept was created in the sprint session and after that advanced to a use case for an application. The goal was to figure out where the surface was in order to define where the product and users meet. Focusing on the surface allows for a speedy movement and helps to figure out the main questions before executing the project.

During the first part of the Sprint, ideas were formulated by questions such as “*How can we make neck exercises fun?*”, “*How can we make people continue doing the exercises?*”, and “*How can we make VR a natural part of people’s daily life?*”. Each team member acted individually, not being influenced by other group members. Based on the ideas, use cases were made to define application requirements. Use cases chosen by the majority, combined with the most attractive features, were used to create the mind map and to visualize the design solutions. Finally, the storyboard was created (Figure 9).

5.1 FIRST PROTOTYPE

The focus was on VR, to develop an artifact that could be tested on users. If a viable solution could be designed, it could have the potential to be used to aid neck-therapy. Initial research has shown that VR in combination with mobile technology, could be easily available to many potential users as an affordable option. The project group opted for VR in medical use, focusing on the neck, as a novel therapeutic approach. All VR application requires the use of the neck, so the question was how to take advantage of this and combine it with gamification to see potentials regarding exercise and usability. Exploration of literature has shown application for rehabilitation that delivered promising results.



Figure 9: Storyboard with different scenarios of neck exercise combined with gamification.

An expert physiotherapist was consulted to validate the concept. This led to the physiotherapist referring to the literature that promoted using VR in therapy, which encouraged further development. The project ideas were implemented accordingly, first as a low fidelity prototype, then as a middle and high-fidelity prototype in the Unity 3D [38].

5.2 PHYSIOTHERAPIST EVALUATION OF VRFYSIO

In the end, there was another physiotherapist that evaluated the final prototype. His general assessment was positive; he was enthusiastic and discussed potentials of using VR in therapy. He found that one of the key difficulties of the exercises is keeping motivation. Many patients seem not to follow the recovery program

as advised, which cause longer recovery times. He was intrigued with the prototype and thought that VR application could keep motivation higher during the recovery.

The physiotherapist has also initiated a discussion about ways to make the application fit rehabilitation and exercise by customizing it to the patient. Pain can also be a hindrance. Most neck exercises do not have the ability to harm the patient further, but there can be some pain involved. For example, if the neck hurts during the exercise, this means that the area must be worked on, and the patient needs to push through the pain. Some patients can handle much pain, and some cannot. The physiotherapist thought that the application could help defuse the perception of pain and keep the patient working through the pain. However, the application could add some information about the exercise and what impact to expect. One such message could be to push through the pain but not to the extent that makes the pain severe.

Before a new consensus on the acceptable level of pain, there was a concern that tissue-damage was the reason for the pain. The physiotherapist has stated that newer research showed that this was not the case. If a patient has pain in the neck but knows that some pain is acceptable, the patient will be encouraged to work through the pain and therefore obtain better rehabilitation results. A common example is feeling pain in the legs due to sore muscles in the legs after a workout. The patient knows that this pain is not dangerous and accepts it because of prior experiences and general knowledge. This can be the case for other types of pain. Therefore, there is a need to explain to the patients that pain is not necessarily a bad thing in most cases. Exercising a particular part of the body that hurts is a key factor in getting better. Informing the patients about this fact is important.

The physiotherapist had some concerns regarding the availability and the cost of VR. Another concern is with older users and potential reluctance to use digital devices. Good user experience is important, and so is the motivation. One more beneficial feature would be to see the progress by using the application and getting feedback from it.

The application prototype in its state can have a contribution to the rehabilitation of the neck, especially to increase movement in the neck. There could be some hindrances in usage for everyone, because of the lack of customization of the tasks and rigorousness of the application. Furthermore, the thought of having a more complete and customizable application seemed to be a desirable feature in the physiotherapists' mind. The Physiotherapist was excited about the technological development that helps patients exercising.



Figure 10: VRFysio application start menu

5.3 THE APPLICATION VRFYSIO

The game consists of three different game scenes. In the first scene, the user is instructed to hover the reticle over a “Start” button for five seconds in order to begin the game. A reticle refers to the marking visible as a dot (Figure 10) that transforms into a circle (Figure 11) when hovering over a point of interest.



Figure 11: VRFysio application during the exercise part.

The next scene consists of instructions for the exercise in the middle of the screen. The instructions are directing to the next task where there are two capsules to the left that the users are required to hover over. The first capsule turns green as soon as the user hovers over it, but the next must be hovered over constantly for 5 seconds before it turns green, which means that the task to the left is completed. This is done to simulate neck exercises to one side of the neck. Then this gets repeated on the right side with two new capsules. Here the user is asked to do the same thing, only to the right. Once both the horizontal exercises are completed, the user is directed back to the middle. The user is now asked to look up and hover over another capsule for five seconds. Then the user is asked to look down at a button for the next scene and hold for five new seconds. This transports the user to the last scene.



Figure 12: VRFysio application with the last game scene

Here the user is instructed to tilt the head to the right and hold for five seconds. After that is done, the user is then asked to tilt the head to the left for five seconds (Figure 12). When that is done, the user is asked to hover over a button that takes the user back to the main menu. The sequence of these movements is carried out this way to simulate neck exercises by moving the head to one direction and holding [43].

5.3.1 VRFysio testing and usability evaluation

The goal for this testing was to get short but concise feedback on the usability of an unstructured interview with a short questionnaire.

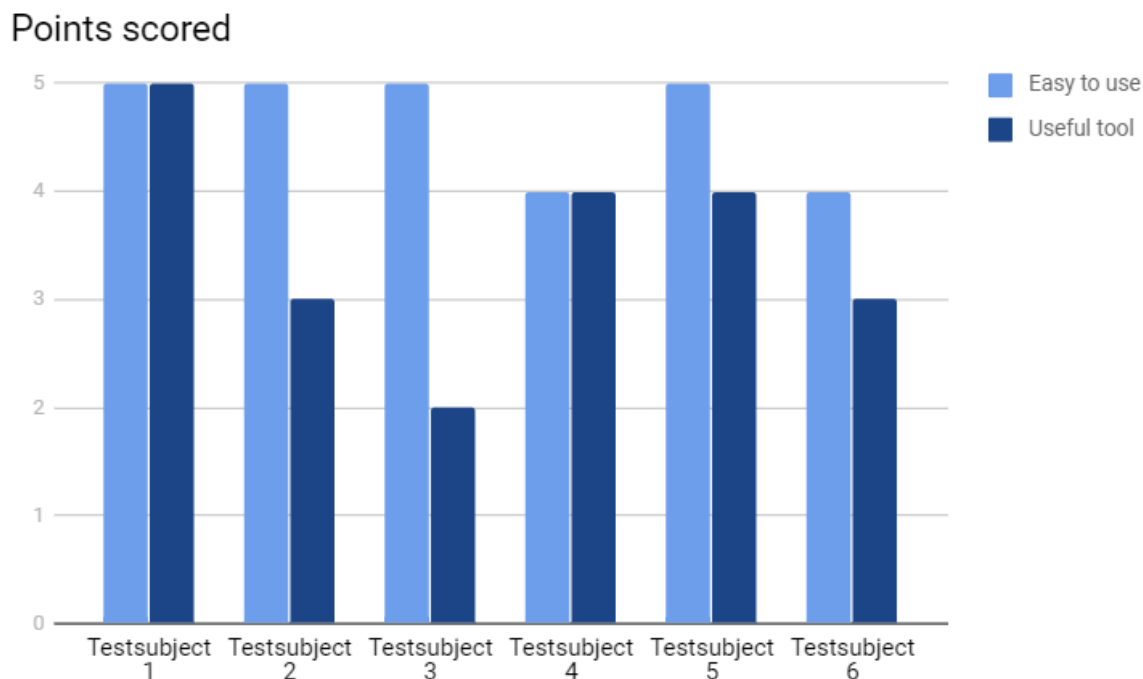
There were six participants in the evaluation. All were in their twenties and with a different experience of problems or pain in the neck. Four of the six test subjects were taking IT-related studies. The experience with VR was varied, but all managed to finish the tasks and did all the exercises that they were expected to do.

All participants received simple and general instructions before trying the application with the VR-headset on. The instructions were similar to those that a physiotherapist would give in a similar situation. Then the participants were instructed to sit with the straight upper body and asked only to move the neck when using

the application. They were encouraged to ask for additional information if needed. Upon completing the testing, they were asked to answer two questions regarding the usability of the application: '*Was the application easy to use?*' also, '*Did you find the application useful?*'.

The feedback was given on a Likert-type scale from ranging from zero to five, where the lowest grade was given to the least satisfying and five the most satisfying evaluation. The results (Graph 1) show that all subjects rate the application four or five on the scale. This means that the test subjects find the application easy to use. Regarding the need for the application, it shows that the opinions were more divided. Some of the subjects could consider using the application. The others did not have neck pain and felt no need to use the application, which was reflected in the score.

The feedback also included comments and suggestions resulting from the unstructured interview. Two of the participants would like to have a counter to record the number of training data, which would be useful to monitor the user's progress during a consultation with a physiotherapist. One of the participants would prefer to have an option to add sound while doing the exercises. One test subject was a bit nauseous, which can occur with VR [26]. All the test-subjects enjoyed participating, and most of them valued this experience positively. Those with IT-background found it somewhat easier to use the application.



Graph 1: Usability testing for VRFysio

5.3.2 Concluding remarks on the VRFysio prototype

The achievement and evaluation of the VRFysio prototype were positive and encouraging; the evaluation has shown that the application was easy to use and could be considered for therapy even from the clinical expert point of view. The main thoughts of the team were to further work with physiotherapists to make sure that the application was something that could be used in the treatment of the neck.

The main goal was to show the potential of VR as a therapeutic tool that could help and assist with the treatment and exercises. The feedback the team got in the process would be to prioritize keeping the user motivated and focusing on the pain aspect relating to the application.

With the results and feedback in mind, the focus of further development would be on trying to add gamification. Making the exercises fun and engaging to get the patient or user motivated is important. Keeping the motivation seems to be one of the most important things when regarding one's health. The aspect of doing something that is both entertaining and beneficial at the same time seems to engage people to keep exercising.

Another feature that is possible to implement is the gathering and visualization of all the data points and other relevant data that can be saved by the application. The data gathered could be presented to the physiotherapist or the patient. So that they could keep track of the progress, find areas that need more focus, or identify and show other relevant representation or any other desirable aspects. This can make the treatment more fun and hopefully, can increase the rate of recovery and wellbeing for the patients.

6 SECOND PROTOTYPE: NECKVR

The next step in the thesis began with the development of a new application. The challenge was to find out what kind of direction this new application would take — using what was learned in the first iteration, with regards to motivation and perception of pain. The first step was to find a new physiotherapist that could assist with the physical part of the thesis and in helping to get test subjects for the application when the application was made. After some searching, a physiotherapist was found, and an informal talk was conducted where ideas were discussed, the VRFysio application was shown, and a general talk of further development. When discussing the development of a game that could help in the treatment of neck exercises, the physiotherapist recommended a game where random movement of the neck was utilized (Personal communication. 08.11.18), which means that the user of this game would need to move the neck in an irregular pattern in order to execute the tasks in the game — using what was learned with assessments and exercises for rehabilitation in medical theory[27], using different analog ways of following a randomly generated cursor on a computer and doing a figure-eight with lasers on the head. This seems to be a precedent for a game that makes the user moves its head randomly, and that can incorporate similar movements as described. Another example of this is the butterfly applications that were made in the study [9], that includes following a butterfly with the use of VR. The goal must be to incorporation an object that moves in an irregular pattern and gets the user to move in the desired way using the game-objects to do so.

The next process of development was to make the new game. Hoping to use the feedback from the coming iterations, the data that was already gathered and using what was learned with VRFysio to change the direction. The focus shifted from mimicking stretching exercises to getting the patients to move of the head and neck. The second application was also made in Unity 3D[38], and there will be more emphasis on movement than stretching.

6.1 ELEMENTS OF THE APPLICATION

The application was named NeckVR.

The game starts in a VR-3D environment with an unclear horizon that stretches as far as one can see. When the game is loaded, there is a big black disk right in front of the initial viewpoint. When looking at the disk, boxes are coming from behind the viewpoint of the user. The boxes are turquoise and are “spawning” from behind the player, advancing towards the background in a constant velocity.

The disk fills the entire view of the user, and only when the user looks around it becomes clear that it is a disk. On the black disk, there are two parameters showing: BG hit and ScoreText. The BG hit is a parameter that registers the boxes that touch the background. For each box that hits the background, the parameter increases incrementally by one. If a box hits the background, it is also destroyed in addition to increasing the value of the parameter. This value is shown next to the text (Figure 13).

Underneath the BG hit- text there is ScoreText which is increasing every time a box is destroyed by the red reticle when it is directed over the box by a user. The goal of the game is to destroy as many boxes as possible before they reach the background. The game indicates what it is like to use VR in gaming-sense and at the same time stimulates the neck.



Figure 13: NeckVR application shown in action with boxes and parameters.

6.2 NECKVR: EVALUATION OF THE FIRST ITERATION

Within this design iteration, the focus was on the expert evaluation to gain clinical feedback from the medical professionals regarding the use of the artifact, and especially whether the artifact could facilitate neck exercises and what was important to consider for further development.

All the test-subjects were physiotherapists. One was proficient in using VR, with experience and an understanding of the development process. Another had a good understanding of using VR in treatment. The other three physiotherapists had no prior experience with VR. Two of these subjects have a neck specialization.

In the evaluation, each of the test-subjects took their turn in trying out the artifact for a duration of 2 to 3 minutes. They were given a brief instruction on how it worked and what the goal of the application was. An interview was conducted with all the participating physiotherapists.

Most of the feedback was positive; moreover, there were exclamations of excitement using the application. It seemed like they had fun doing exercising. Some of the physiotherapists mentioned that they felt a bit dizzy afterward. However, the VR-glasses were comfortable to use, and the extra weight on the neck was not an issue.

One of the most emphasized topics of this evaluation was the duration of the exercise, and whether the artifact would be useful for their patients? Before testing the artifact, and in the first minutes afterward, the physiotherapists said that the duration of a session in the application should not exceed five minutes. By the end of the evaluation and with some discussions between the physiotherapists, they concluded that the duration of a session in the game should not exceed two minutes for users new to the application. Shortly after using the application, they started to feel the effect the application had on their necks. The physiotherapists felt strained muscles, which emphasized just how effective the application had been. This may indicate that this kind of application could be beneficial. The physiotherapist thought if they, who had no pain or neck problems, could feel the effect after using the application for two to three minutes, it would be expected that people with neck problems would feel this effect even more. That is the reason why it is important for patients who try the application for the first time to be accompanied by a therapist before training on their own. The clue when using the application is to increase the duration gradually, if necessary. The physiotherapists advised that if the duration of exercise exceeds the capacity of the neck to train, the body will compensate by using other muscle groups, as well. They also mentioned that when some task that is fun, like when playing games, a user can overstrain the physical capabilities burdening the body to the

disadvantage of the treatment. Hence, the importance of guidance during the first time, the patients are using the application and perhaps adding the possibility of restrictions to the application.

Another relevant topic is dizziness and balance. It can be a challenge for some users to feel dizzy doing neck exercises; some may feel resistant due to the feeling of dizziness rather than the pain associated with neck exercise. Other patients are afraid of movement because of fear of pain. These are all conditions that could benefit from using the application, but it is important to define criteria of usage under the supervision with a therapist. With certain conditions and for patients that can feel uneasy, overusing the application can trigger fear and potentially cause more damage than good. However, with neck pain, there should be no great risk for further damage, nothing more than to irritate the muscles, thus leading to increasing the pain.

The physiotherapists appreciated the design of the application. The fact that the contrast is clear between the objects and the background seems to be satisfactory. The simple design of the artifact makes it clear what is in focus, and there is no “visual noise” that can distract the user from the task. The grades of neck injury differ, and a patient with whiplash or bad neck to eye coordination could have a negative impact with too many visual stimuli. The application is in this regard suitable and can train these kinds of injuries without a negative impact on users.

During the interview and application test session, the physiotherapists had suggested changes, additional features, and comments. This feedback was the basis for the next iteration of the application. One of the first things to add was the ability to change the difficulty settings in the application. For example, parameters that could be modified are speed and the area where the turquoise boxes come from. It should be possible to control the speed and the “spawning area” by adding an options menu. Here the user should be able to set different values to speed, the frequency of the appearance of the boxes, where the “spawn point” is located and how big the “spawn point” should be.

There was also a desire for saving the score and thus making it possible to monitor the progress. Time should also be added; both the time spent in the game for the player to keep track of how long the exercise has been going on, as well as a possibility to set the time of the exercise. There should be a default set time per session, or it should be possible to change the time before the start of the game.

Physiotherapists rejected a presumption that the target audience of the application would be younger people. On the contrary, they thought this would not be the case according to their own experience. They reasoned that younger people are used to technology and therefore are not so easily awed by it. They assess that the level of complexity and engagement of an application for the younger users must be a lot higher and therefore are much harder to achieve. In their experience, the medical field usually does not offer so much

innovation to captivate young people; medical devices are not at the level of other digital experiences that they use in their daily lives. By the physiotherapists' assessment, the artifact in its current state is more suited for the older generations. More and more of the older generation are comfortable and proficient with smartphones; the novelty of VR can be exciting. Another advantage is that the application can be easily accessible as they need only cardboard VR glasses to function. This was pointed out as another positive feature. The older generations might be more stationary than the younger generation, and they could appreciate exercising at home.

One of the physiotherapists mentioned that using the accelerometer and the other sensors in the device was advantageous; a lot of vital data could be collected over time. This is something that can be utilized in further development. The application could be used as a part of the future treatment that will emphasize the patients' engagement, especially in cases when people lack motivation for doing the exercise.

One of the physiotherapists insisted that there should be a clinical study to see what the effects are on different injuries. In its current form, the application is more a supplementary tool than a complete one.

6.3 DISCUSSING NECKVR: EVALUATION OF FIST ITERATION

Given that this was the first iteration of the second application, getting much feedback was a huge benefit, with a lot of positive comments and constructive criticism. One thing that was clear right away was that every physiotherapist that tested the application seemed to be enjoying themselves. This could be the novelty of using VR, but it could also indicate was fun, and in turn, could motivate other people to use the application because of this. It seems important to set a maximum duration of a session on the application because of the emphasis the physiotherapists put on this. After trying the application for two to three minutes and feeling the strain in their neck in that short amount of time, it is safe to say that a person with an injury in the neck would feel it as well. Even though the physiotherapist stated that it was not dangerous to over stimulate an injured neck, it could cause more irritation and therefore induce more pain. This again could cause the patient to refrain from using the neck and even more so refrain from using the application. In the next iteration, the time of a session should therefore not exceed two minutes.

The applications visual design pleased the physiotherapist. The few elements had a soothing effect, and helped the patient focus on the task and not get distracted or overstimulated by things around and in the background. This is a part of the application that was pleasing, and it was decided not to change anything with the design to the next iteration.

The physiotherapists seem to want to change and add other features. A way to customize the boxes appeared to be an important feature. There should be a way to customize the frequency of boxes that are spawning, the start position of the boxes, the speed in which they go towards the background, and lastly the size of the spawn point. Another feature that was recommended was a timer, so the player could see how long it takes to do the exercises and to be aware of how long it has taken. It was also mentioned that saving the score could be beneficial.

The age group that the application should target according to the physiotherapist is the older generation. This was not what was expected, but with the reasoning that younger people have a higher standard for an application like the one we are making, it may be reasonable. There are not that many changes to the application that would make a difference for the older user, so there will not be more implemented here. In the article by Jones[7], it is also mentioned that older users do not seem to have a problem with VR.

The other aspects of the evaluation were more of what was expected. They seemed to be intrigued and excited for the innovation of what the application can bring — stating that there was a use for assistance in the treatment of neck and that VR could be a good asset in that regard. However, they insisted that a clinical trial must be performed in order to get the right results.

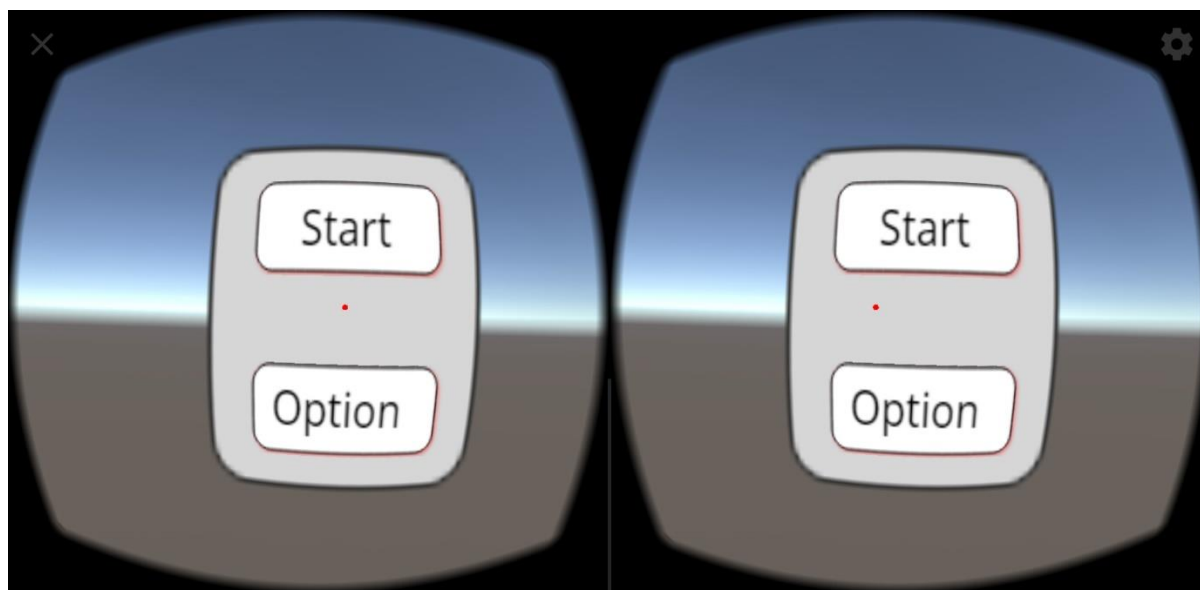


Figure 14: NeckVR application Start menu

6.4 NECKVR: SECOND ITERATION

With the evaluation of the second iteration done, it was time to implement some of the changes that were suggested by the physiotherapists. When adding the possibility to customize a parameter, there must be somewhere to add these changes. Therefore, the Main menu was made with two buttons. One button said, “Start,” where there was a predetermined setting for the parameters, giving the player the ability to start a game at once. The second button says, “Option.” This button takes the user to another menu where four parameters can be customized.

- Speed of the boxes
- Spawn frequency of the boxes
- Spawn point Placement
- Size of the spawn point.

Every parameter has three buttons that have the numbers 1,2 and 3 on them. This is to indicate the different preset settings for each parameter. 1 would indicate a low value, 2 a medium value, and 3 a high value. The reason for setting each parameter in a set value it is easier to hit buttons than to use sliders or any other kind of tool that can change the value of the parameters. It is less customizable than a slider, but three values to pick from, should be enough to make sure the application can be evaluated, and to provide a feel for the essence of the game. There is also a “Start” button on the top of the menu, to start the game after the player is done setting the parameters.



Figure 15: NeckVRs second iteration with visual information about score and time.

6.5 NECKVR: EVALUATION OF THE SECOND ITERATION

The evaluation and interviews have been carried out to get feedback on the changes to the application, get feedback on the things that were added in this iteration, the physiotherapist's thoughts on the added features, and to get the answers on the questions that on things that have appeared since the last interview.

Before the evaluation and interview took place, each of the physiotherapists completed a SUS-test. The tasks they were asked to do in section 6.7. After this was done, they would start the evaluation and answers the questions in the interviews. This time the evaluation/interview panel was smaller. The two physiotherapists that have experience with VR was attending, and one of the neck experts were also attending.

When asked what they thought of VR in general one responded with great enthusiasm, while another said that VR seemed silly at first, adding that he used to be a firm believer in that exercises are supposed to be done without the aid of anything but some figures on a sheet of paper. However, after testing VR, being captivated by the possibilities of using it as a tool in rehabilitation, he changed his mind. There seemed to be a general excitement for the use of VR for rehabilitation and therapeutically purposes.

When asked about how their neck felt, the response was that there was no added neck-pain when using the application. One of the physiotherapists said, however, that there was some discomfort in the eyes when using the application. This is probably because the VR glasses' focus setting had not been adjusted to the individual user prior to the test. The discomfort disappeared once the glasses were taken off.

The panel felt that the application was focus intensive. They also said that it was a bit soothing, but mostly they felt that the use of VR made them fully concentrate on the task at hand, and not any other things because there was nothing to distract them.

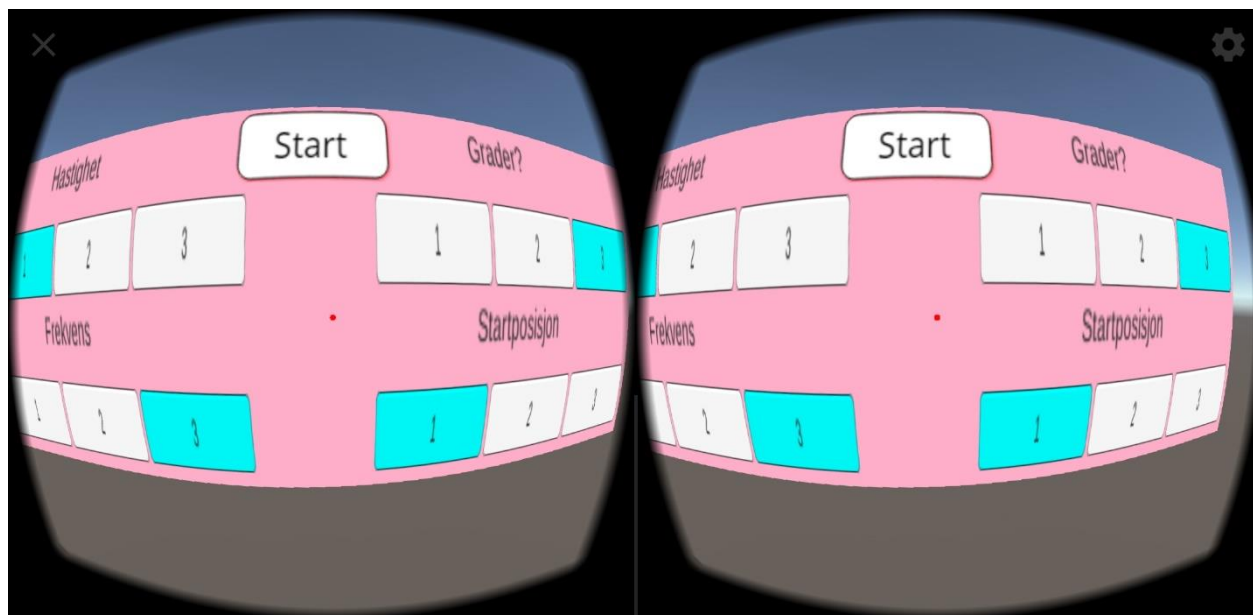


Figure 16: NeckVR options-menu, where the customizable parameters are.

The physiotherapists had a lot to say about the current utility of the application. The only focuses on the neck, not how the neck functions with the rest of the body. Stretching of the neck is not a thing they think the application would be able to do. The application would need to be more individually adapted. This should be tested on patients and adapted individually to suit each patient's needs. The application would fit patients who need to move the neck more in order to get better. It was suggested that patients who have problems with dizziness and neck to eye coordination could benefit from using this app because of the fear of movement. When asked if the application could be used as the only treatment of the neck, they repeated that this was not the case. The correct usage would be to integrate the application as a supplement to regular exercises. They stated that the application is useful, both if it gets fully developed and even in the current NeckVR test version.

The changes done in this iteration seem to please the physiotherapists. However, there was some constructive critique. One thing that was confusing to the physiotherapists is the way the boxes now came from the front of the viewpoint, rather than behind. This was added not to get the extreme movements to look for boxes before or right after they spawned into existence. However, now there was no indication that the spawn point and the trajectory of the boxes were narrower than before. The background was large, and there was nothing to indicate that the boxes were only coming in that narrow path. This made one of the physiotherapists look around for more, and thus rendering the newly added feature in some sense obsolete. The menu and navigation were criticized. It was too easy to hover over a button and activate it

unintentionally. Adding to the critic was that there was no return button in the game screen, that would bring the user back to the main menu, where the user could then select the desired parameters without having to play the game to the end to get back.

It also seems that patients with any neck injury may use the application and that the physiotherapist thinks there is no risk involved. Whether the patient should use the application for treatment should be decided by the physiotherapist.

The physiotherapists think that the distraction it provides is a benefit for neck exercises using VR. VR's ability to make a patient forget the surroundings, and the perception of pain appears to be important.

Several comments were made about the possible functionality. The application appears to be well suited for random neck movement, but to make it more complete, there should be more modules that target the different exercises and areas of the neck that demand attention. A physiotherapist recommends an exercise following an object from side to side in constant motion. This can benefit another part of finer coordination in the neck and are probably more like the everyday movement of the neck. One of the physiotherapists mentioned an exercise made by another physiotherapist that would use a laser on the head of the patient and make the patient move its head in a labyrinth with the laser pointer. The goal was then not to hit the edges.

Stretching may not be suited for VR use. VR may be more suited for use when there are movement involved. When explaining about the prototype that was more of a stretching exercise and with a demonstration on how it worked, one of the physiotherapists exclaimed that the back was moving as well as the head and this demonstrated that it is not optimal to do the stretching exercises in VR.

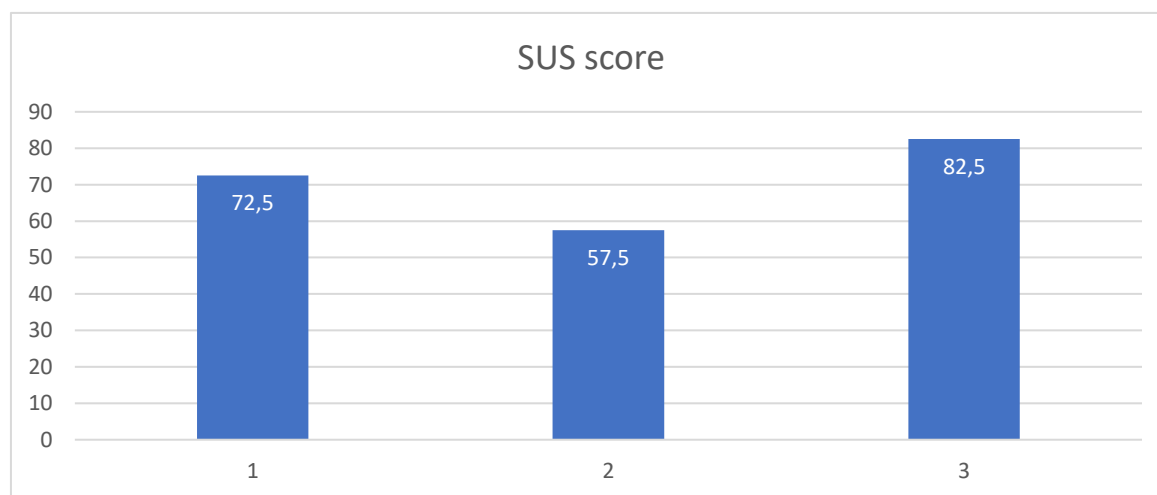
Stretching may not be suited for VR use. VR may be more suited for use when there are movement involved. One of the physiotherapists thought that the back was moving, as well as the head, and this demonstrated that it is not optimal to do the stretching exercises in VR.

When asked about the reluctance and hesitation of some patients moving the neck, the therapist found this common in patients with more severe pain. They can also have a fear of falling because of the pain. They choose to not move because of the chance of falling and then experience the pain. They also have mentioned with dizziness, which can be sometimes experienced.

The expert panel had also some thoughts regarding the design. Using a lot of graphics and other elements is not necessary. They think that the main task should be in focus, as it was when they tested the application. They think adding much graphics, and other elements are redundant.

The session was concluded with the statement that the application is a tool to be used in treatment, but not a treatment method on its own.

As future work, it is suggested to add data collection from the movements (speed movement, range) in the application and displaying them. This merited a positive response from the physiotherapists who appreciated with a tool of this kind.



Graph 2: The SUS-score of each physiotherapist.

6.6 DISCUSSING NECKVR: EVALUATION OF THE SECOND ITERATION

There seemed to be much excitement for VR by the physiotherapists, in general, and regarding physiotherapy.

The physiotherapists estimated that the NeckVR application's focus is limited to training the neck, not the rest of the back or other parts connected to the neck. Also, it does not cover all neck exercises – e.g., stretching the neck is not supported. In conclusion, the application movement of the neck should be facilitated by the application. Thus, the application or similar applications would not be enough for the full treatment of neck injuries and should be used as an added part in the treatment.

There are some indications from the physiotherapists regarding the interaction with the application, the user, and the way the treatment is conducted. This can be achieved by adding modules or features in a fully customizable application. Alternatively, sending push-notifications to remind the patient to exercise more.

Regarding the features that were added, there was some critic of the navigation of the application. If the player were accidentally hovering over the wrong button, it would trigger. This made it a bit hard to navigate. There was also no way to end the game when it was started, and the player needed to play it until it was finished. These issues are some that needed to be fixed before the usability testing.

Regarding the features that were added, there was some critic of the navigation of the application. If the player accidentally hovered over the wrong button, it would trigger. This made it a bit hard to navigate. There was also no way to end the game once it was started, and the player needed to play it until it was finished. These issues need to be fixed before the usability testing.

The SUS-scores seemed to indicate that there are things to improve when it comes to usability. There are only three users, so the score is not valid, but these figures can be used as an indication that usability is not optimal (Graph 2).

6.7 NECKVR: THIRD ITERATION

The fourth and last iteration has been conducted to fix problems which were highlighted in the previous evaluation, and to test the usability of the NeckVR application. Based on suggestions from iteration three, the following was added:

- A three-second timer on the “Start” buttons, to avoid unintentional triggering when the player hovers over them.
- A “Back” button situated 180 degrees behind the player’s starting point, which returns the player to the main menu.
- A new set of buttons with clear text, based on a complaint from one physiotherapist who thought the buttons seemed pixelated, making the application a bit blurry.

6.7.1 IT experts evaluate NeckVR

To test the usability of the application, ten IT experts were consulted. The usability test was done in two parts:

- The first part consisted of three small tasks that the subjects had to accomplish:
 1. To start a game, then use the “back to menu” button to take the player back to the menu.

2. Use the “Option” button, and change all four parameters to 2, then start the game and play for one minute.
 3. After the game was over, to return to start, set the parameters to whatever they liked, and start a new game.
- The second task was the SUS questionnaire.

Most of the test subjects had never used VR before. There was a lot of exclamation and awe of the experience, and the main takeaway from the testing was positive and encouraging. One important finding, however, was the way the player is “searching” for the boxes if there are no boxes on the screen. This is exactly mentioned in the second interview with the physiotherapist (Section 6.5). This is an issue that could affect the overall experience of the application.

During testing, the player got their instruction while wearing the HMD (Head mounted display). When asked to start the game and then use the “back to menu” button, some players had a hard time reaching it, because of where it was placed. It took some of the testers a couple of tries to understand that they would not reach the button without turning their body as well as their neck. Some of the experts did not expect there to be a button 180 degrees from the starting point, and there should probably be an indicator that shows that there is a button “behind” the player. A text that explains that there is a button there or an arrow that points to the button could be added.

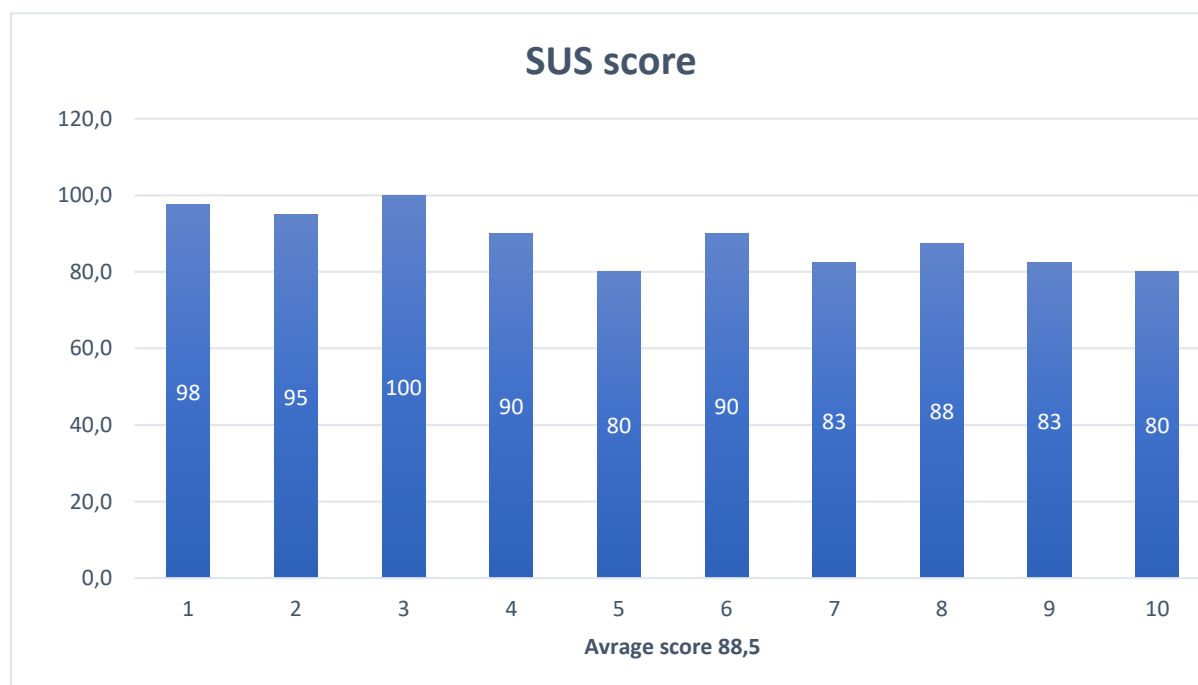
The second task was the biggest task, where the test subjects were asked to go from the main menu to the options menu. There they were asked to set all parameters to “2” and to start the game and play it to the end. This was the biggest task of the three tasks they were asked to do. Here the user was experiencing changes in the parameters of the game. Setting parameters was mostly successful, but a few of the experts hovered over the other buttons after the number 2 was picked, so they had to go back and do it again. However, those that did not get all right on the first try only took a couple of seconds more to start the game. This shows that the menu needs some improvement but still works as intended. Still, this was not mentioned by any of the test subjects, and it took longer than 15 seconds from the start of pushing the “options” button after the game started. After the start, the testers were aware of the goal of the game.

Except for the “searching” that is mentioned above, there were no difficulties mentioned or observed while testing the gameplay. Everyone seemed excited, and some of the subjects exclaimed their enjoyment. After one minute, once the game was over, the user was instructed to use the button that would get them back to the main menu. The final task was for the player to go to the options menu, select some parameters of their choosing, and then start the game again. This would then conclude the testing. There were no problems for

the test subjects to carry out that task. The test subjects took off the HMD and started on answering the SUS questionnaire.

As seen in Graph 3 the SUS average score is a satisfactory 88,5. This indicates that the usability of the application is appropriate for its purpose. The lowest test score was 80, and the highest was a perfect 100. Comparing this to the SUS score that was given by the physiotherapists, this is a clear improvement in usability. The average SUS score for the physiotherapist was 70.8. Using the feedback given in the third iteration, there seems to be an improvement in usability.

The experts have taken roles of the users to avoid exposing patients to new, unproven tools. They relied on their knowledge and experience to evaluate the prototype thoroughly. Ideally, intended users should have tested it to estimate usefulness and get critical feedback regarding the feeling, pain, and potential relief. For that purpose, the study would have needed ethical approval and longer run time (beyond the time of this thesis).



Graph 3: SUS scores for each test subject.

7 DISCUSSION

7.1 DESIGN SCIENCE

The design science framework applied for a methodic and effective research process. Using the seven principles in design science for the most effective and rightful way to do the research. Design science is recommended for anyone that is making something that is involving both experts and methods [28].

The following describes how this thesis has integrated the seven principles of design science[28]:

Design as artifact

- *Research developed with the design science research method must produce viable artifacts in the form of a construct, model, method or instantiation*

The artifacts produced by the research are the VRFysio application and the NeckVR application.

Problem relevance

- *The purpose of design science research is to develop solutions to solve important and relevant problems for organizations*

The purpose of both applications has been to figure out whether using VR in exercising and rehabilitation of the neck is beneficial and could be advantageous for patients. Taking on one problem with VRFysio, then proceeding in another direction with NeckVR regarding neck exercising.

Design evaluation

- *The utility, quality, and efficiency of the artifact must be rigorously demonstrated via well-executed evaluation methods*

Using research methods such as literature review, interviews, observations, and System usability scale (SUS), much data has been gathered and analyzed. The results in this thesis concur with other research on the same subjects.

Research contribution

- *Research conducted by the design science research method must provide clear and verifiable contributions in the specific areas of the developed artifacts and present clear grounding on the foundations of design and design methodologies*

The artifacts developed for this thesis have contributed to medical informatics, and in the field of VR used as a medical tool. For patients with neck injuries, a need has been identified for motivating exercises that can be conducted at home, to make it easier for patients to help themselves and improve their treatment. The need for motivation and working through pain has been the basis for this application. Assisting people in taking an active role in their rehabilitation and using technology to motivate patients seems to have its merits. The effects of VR on motivation, pain, and general medical use should, therefore, be further studied.

Research rigor

- *Research should be based on an application of rigorous methods in both the construction and the evaluation of artifacts*

The two applications were made using four iterations. The first application was developed using a condensed version of Sprint[31]. Using the results from the Sprint, an artifact was made and evaluated. Based on the experiences and acquire information from the first iteration, a second artifact was developed. The second artifact was improved on using several methods and through three more iterations.

Design as a research process

- *The search for an effective artifact requires the use of means that are available to achieve the desired purposes while satisfying the laws governing the environment in which the problem is being studied*

This thesis started with the assumption that VR could benefit neck rehabilitation and exercises. To investigate this, the research uses literature and evaluations to argue that this can be the case.

Communication of the research

- *Research conducted by design science research must be presented to both an audience that is more technology-oriented and one that is more management-oriented*

A part of this thesis has been accepted for publishing and presentation at the 17th International Conference on Informatics, Management, and Technology in Healthcare. The article will be indexed in the PubMed database.

7.2 METHODS

7.2.1 Literature review

Early in the thesis work, to investigate how VR could help in rehabilitating and exercising the neck, a literature review was conducted. During the first iteration, there was an emphasis on gamification combined with health. After evaluating the first iteration, the focus shifted to pain management and movement of the neck, and there was a need to find literature on these subjects as well. Especially in the pain management and analgesic effect of VR. The reason for the special focus is that there was no time for patient testing, so the data about pain, in general, was taken from other studies that also used VR.

7.2.2 Sprint

Sprint was used to find the scope of this thesis, to set the goals and get the prototyping started. Though the process was significantly shortened, it served as an immense boost when starting with the project. Using the five stages to understand VR, diverge into the possibilities, converge the ideas using a storyboard, starting prototyping, and finally take what was made and testing it.

7.2.3 Interviews

A combination of group interviews, unstructured interviews, and semi-structured interviews were conducted to obtain information from physiotherapists in the first three iterations. The data acquired from these interviews were mainly feedback on the effectiveness of different features and how the artifact could

stimulate and encourage users to exercise. The data helped the iterative process, yielding useful information on which features to add, and confirmation if features were successful or not.

7.2.4 Observation.

Observations were used in the last iteration to see how the test subjects were doing during the evaluation. During the SUS-tasks, they were observed while doing the set tasks, resulting in observations on how the application was to use. There were, for the most part, no problems with navigating the application, but there was some confusion on where the “back to menu” button was.

7.2.5 System Usability Scale

System usability scale (SUS) was used in the evaluation of the third and fourth iterations to get feedback on the usability of the application.

In the third iteration, SUS was used on the three physiotherapists that evaluated the application. To get valid SUS results, there should be more than three users in the study. Regardless, the results in this iteration were useful as a guideline and an indicator of usability and indicated - since the score was average - that there was room for improvement.

The fourth iteration used SUS mainly for testing the application’s usability. The test subjects were given a set of tasks to complete and then answered the questionnaire. The score was high, showing that the usability of the application was good in its current state.

SUS is supposed to be used on the intended users. Some may argue that this is patients that have neck pain or injuries in the neck and need rehabilitation. However, people can use the applications proactively and therefore; the IT-experts could be potential users.

7.2.6 Spiral model

Using the spiral model for iterative progress, the applications were improved by going through a set of tasks before repeating the same tasks: Develop, evaluate, use the evaluation to find things to improve or change, and then repeat.

7.2.7 Development

Two prototypes were developed for this thesis. The first prototype is the VRFysio application. It was made to mimic stretching exercises that are given to patients with neck pain. The second prototype, NeckVR, was made with an emphasis on getting the user to move the neck. It was developed during three iterations and combined what was learned in the first prototype with conversations with a physiotherapist and the use of literature. In the first two iterations of NeckVR, physiotherapists evaluated the application. These evaluations were used to improve and change the application. The last iteration tested the application's usability.

Both applications were developed using Unity3D[38] and prepared for Mobile-VR glasses (Section 4.3.1)

7.2.8 Pain

Perception of pain is an issue and consideration that the thesis considered. part of this thesis. Because there are no clinical trial and no patient testing, it is not easily done to test if the use of the application can lower the perception of pain. Therefore further research is needed to assess the potential of VR in distracting the user from pain. VR is supposed to provide an analgesic effect when used, making the person feel up to 60% less pain[26]. It can steal the attention to the VR-user from the pain that is felt [7]. The level of Immersion is an important part when it comes to the perception of pain. The more immersed and feeling of presence in a virtual world, the more the painkilling effect it has [8]. Pain in the neck, it is for the most part, not dangerous (Section 6.2). Managing exercises the wrong way can lead to irritation, thus causing pain. As such, excessive use of the NeckVR application is not recommended. (Sections 5.2,6.2).

7.3 LIMITATION

The research has some limitations. The most significant was that there was no time for the testing of the applications of the patients with neck pain. The validity of the data collected from a physiotherapist is sound because of their medical knowledge and their knowledge of what exercises and treatments that work. However, using patients would have been the next phase if there was time.

Somewhat limited programming skills and experience of developing VR based applications also hindered addition of more gamification in the NeckVR application.

In the NeckVR, there was also supposed to be more gamification added. The features that were added was just the two scores, and the fact that it was a simple game.

Using a cardboard VR in the testing could also have been done. This to see if there was any difference from it and the Gear VR used in the evaluation of the applications.

7.4 ANSWERS TO THE RESEARCH QUESTIONS

RQ1: Can mobile VR technology be used to create an affordable treatment for neck pain?

Two Mobile-VR applications were made to investigate if this was possible. The VRFysio application mimicked neck stretching, and the NeckVR application used random accruing elements to prompt more movement of the neck. Using mobile-VR with a case like Google cardboard [14], or other affordable VR-glasses, makes it possible to utilize a smartphone for neck exercise. This is an affordable economic solution, costing around 10\$. Both prototypes were tested by experts, physiotherapists, resulting in positive feedback, suggested that VR could be considered for treatment.

Regarding the VRFysio application (Section 5.3), the physiotherapist has seen a therapeutic potential for patients recovering from injuries and training at home at their own pace. The therapist who tested the VRFysio (Section 5.2) agreed that getting the patient to move is one advantageous feature of the VRFysio. The NeckVR application seemed to be best suited for getting patients to move the neck more. This was emphasized during the second evaluation of NeckVR (Section 6.5).

However, caution is required to avoid patients, not overusing the app (Section 6.2).

All the experts, who participated in the evaluation, suggested that VR applications might not suffice as a standalone treatment. It would be advisable to use VR-based applications in combination with regular treatment.

RQ2: Can strong involvement of experts secure a safe and proper VR-based tool for treating neck pain?

Using experts in all design iterations of this thesis secured valuable professional feedback concerning functionality, possible therapeutic effects, and patient safety. It was stated that VRFysio could be utilized to motivate users to work through some pain (Section 5.2). The NeckVR showed great potential to move

users through a range of small, randomly directed moves, but it was recommended that the applications should be used in shorter sessions only (Section 6.2). During the last expert evaluation, it was also said that the application would be best suited for patients afraid of movement, as it would make them distracted, and potentially move more (Section 6.5). It was also added that if the patients would use applications like the two made in this thesis, the first time it should be used together with a physiotherapist to make sure it fits the treatment (Section 6.2).

The final expert evaluation gave the application an excellent SUS score (Section 6.7.1).

8 CONCLUSIONS AND FUTURE WORK

8.1 CONCLUSION

The Design Science approach was used to leverage virtual reality (VR) technology in developing neck exercise applications. Two mobile applications were created: the VRFysio and the NeckVR in four design iterations: the first one was focused on the VRFysio and the following three on the NeckVR application. The evaluation included physiotherapists in the three first iterations and IT experts in the last.

The first iteration resulted in the VRFysio application. The main goal was to explore whether VR technology could be used in medical treatment and, more precisely, in neck treatment. With an expert evaluation, it could be concluded that there was a potential for using VR in treatment. Also, it was reasoned that the application could help users to stay motivated and work through the pain.

The second iteration was the biggest one and included both the literature review and the expert sessions. The evaluation gave considerable feedback, both encouraging and constructive. The physiotherapists were satisfied with the application design; they found it soothing and appreciated the lack of visual noise. It was advised not to use the application for longer periods, and that the patients should not start using the VR-exercise without prior consultation with a physiotherapist.

The third iteration is similar to the second. Interviews were conducted with three physiotherapists who evaluated the features returning a System usability scale (SUS) score of 70.8. The idea was to introduce short, random movements to train different neck muscles. The evaluation suggested the NeckVR application was best suited for people who have a fear of movement and dizziness to help them with these ailments by exercising their necks.

The fourth and final iteration was aimed at improving usability for which IT experts were involved in the evaluation. The SUS score of 88,5 was obtained, as well as comments and suggestions for further development. The app seems to be to the liking of the IT experts, and with some minor adjustments, the NeckVR application could become a viable treatment tool.

It could be concluded that solutions based on a combination of VR and mobile technology can be utilized in the rehabilitation and treatment of the neck in the form of exercise and rehabilitation. Therapy could be customized for each patient during consultations with physiotherapists who are trained to advise about

possible side effects such as lagging and dizziness. With a smartphone and minimal additional equipment, the users could exercise according to the given instructions and whenever convenient.

8.2 FUTURE WORK

Further research should be conducted to see the therapeutic effect of the mobile-VR applications VRFysio and VRNeck. The positive and encouraging expert feedbacks, as well as the simplicity of usage, are points of great appeal, but users need to test the effect over a longer period. A proper study should be carried out to record the user condition in the beginning and during training. It would be of interest to see whether there VR could help a higher percentage of patients to accomplish their treatment goals.

More functionality could be implemented, such as recording data and performing analysis. The data could help give the users good feedback on what to do next, how to progress, and monitor the level of pain, for example. Therapists could utilize the data to both assess and advise the patient.

More modules could be added to the current applications. According to the interviews with the physiotherapist in the VRFysio evaluation (Section 5.2), as well as with the physiotherapists involved in the third iteration (Section 6.5), the scope of the application could be broadened. Additional different exercises could be introduced to train different parts of the muscles and ailments that are rooted in the neck. This, again, could be done in consultation with a physiotherapist as a part of the therapy and rehabilitation program.

Using the application to assess patients' neck injuries could be designed and implemented in a future application. There are many different ways of assessing injuries related to the neck [27]. To find out what kind of treatment is needed, an assessment tool can be included in a VR application related to neck injuries in cooperation with medical experts.

The gamification could be expanded in the NeckVR application. This could help motivate the user to workout more at home. As stated by the physiotherapist in the VRFysio evaluation (Section 5.2), motivation is key for doing exercises at home.

LITERATURE

- [1] Blödt S, Pach D, Roll S, et al. *Effectiveness of app-based relaxation for patients with chronic low back pain (Relaxback) and chronic neck pain (Relaxneck): study protocol for two randomized pragmatic trials*. Epub ahead of print 2014. DOI: 10.1186/1745-6215-15-490.
- [2] Neck pain - informedhealth.org, <https://www.informedhealth.org/neck-pain.2374.en.html> (accessed 20 May 2019).
- [3] • Active virtual reality users forecast worldwide 2014-2018 | Statistic, <https://www.statista.com/statistics/426469/active-virtual-reality-users-worldwide/> (accessed 20 May 2019).
- [4] Maravilla MM, Cisneros A, Stoddard A, et al. Defining virtual reality: Insights from research and practice. In: *iConference 2019 Proceedings*. iSchools. Epub ahead of print 2019. DOI: 10.21900/iconf.2019.103338.
- [5] Freina L, Ott M. *A Literature Review on Immersive Virtual Reality in Education: State Of The Art and Perspectives*, <http://www.google.com/patents/US3050870> (accessed 20 May 2019).
- [6] Oxford. Oxford Dictionaries. *Oxford University Press*. Epub ahead of print 2010. DOI: 10.5860/CHOICE.48-1195.
- [7] Jones T, Moore T, Choo J. The Impact of Virtual Reality on Chronic Pain. *PLoS One* 2016; 11: e0167523.
- [8] Indovina P, Barone D, Gallo L, et al. Virtual Reality as a Distraction Intervention to Relieve Pain and Distress During Medical Procedures: A Comprehensive Literature Review. *Clin J Pain* 2018; 34: 858–877.
- [9] Mihajlovic Z, Popovic S, Brkic K, et al. A system for head-neck rehabilitation exercises based on serious gaming and virtual reality. *Multimed Tools Appl* 2018; 77: 19113–19137.
- [10] InMotion VR - Optimize treatments with VR, <https://inmotionvr.com/corpusvr/> (accessed 7 June 2019).
- [11] Oculus Rift S | Oculus, <https://www.oculus.com/rift-s/> (accessed 5 June 2019).

- [12] VIVE™ | Discover Virtual Reality Beyond Imagination, <https://www.vive.com/us/> (accessed 11 June 2019).
- [13] Pallavicini F, Ferrari A, Zini A, et al. What Distinguishes a Traditional Gaming Experience from One in Virtual Reality? An Exploratory Study. In: Ahram T, Falcão C (eds) *Advances in Human Factors in Wearable Technologies and Game Design*. Cham: Springer International Publishing, 2018, pp. 225–231.
- [14] Kjøp Cardboard – Google VR, https://vr.google.com/intl/no_no/cardboard/get-cardboard/ (accessed 30 May 2019).
- [15] Kamel Boulos MN, Brewer AC, Karimkhani C, et al. Mobile medical and health apps: state of the art, concerns, regulatory control and certification Mobile medical and health apps: state of the art, concerns, regulatory control and certification OJPHI Background. DOI: 10.5210/ojphi.v5i3.4814.
- [16] Watters C, Oore S, Shepherd M, et al. Extending the Use of Games in Health Care. In: *Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06)*. IEEE, pp. 88b-88b.
- [17] Rego PA, Moreira PM, Reis LP. Serious games for rehabilitation: A survey and a classification towards a taxonomy. *Iber Conf Inf Syst Technol*; 5, <https://www.semanticscholar.org/paper/Serious-games-for-rehabilitation%3A-A-survey-and-a-a-Rego-Moreira/702b0f5d2b18967ddd0f215622ed520a4e978ae5> (2010, accessed 12 April 2019).
- [18] Riva G. Virtual Reality in Psychotherapy: Review. *CyberPsychology Behav* 2005; 8: 220–230.
- [19] Nicholson S. A RECIPE for Meaningful Gamification. In: *Gamification in Education and Business*. Cham: Springer International Publishing, pp. 1–20.
- [20] Zichermann G, Cunningham C. *Gamification by Design*. 2011. Epub ahead of print 2011. DOI: 10.1017/CBO9781107415324.004.
- [21] Tuveri E, Macis L, Sorrentino F, et al. Fitmersive Games: Fitness Gamification through Immersive VR. DOI: 10.1145/2909132.2909287.
- [22] Madeira RN, Costa L, Postolache O. PhysioMate - Pervasive physical rehabilitation based on NUI and gamification. In: *2014 International Conference and Exposition on Electrical and Power Engineering (EPE)*. IEEE, pp. 612–616.

- [23] Deponti D, Maggiorini D, Palazzi CE. DroidGlove: An android-based application for wrist rehabilitation. In: *2009 International Conference on Ultra Modern Telecommunications & Workshops*. IEEE, pp. 1–7.
- [24] Shin J-H, Ryu H, Jang S. A task-specific interactive game-based virtual reality rehabilitation system for patients with stroke: a usability test and two clinical experiments. *J Neuroeng Rehabil* 2014; 11: 32.
- [25] Tong X, Gromala D, Amin A, et al. The Design of an Immersive Mobile Virtual Reality Serious Game in Cardboard Head-Mounted Display for Pain Management. Springer, Cham, pp. 284–293.
- [26] Amin AM, Tong X, Gromala D, et al. Cardboard Mobile Virtual Reality as an Approach for Pain Distraction in Clinical Settings. In: *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '17*. New York, New York, USA: ACM Press, pp. 2345–2351.
- [27] Kristjansson E, Treleaven J. Sensorimotor Function and Dizziness in Neck Pain: Implications for Assessment and Management. *J Orthop Sport Phys Ther*. Epub ahead of print 2009. DOI: 10.2519/jospt.2009.2834.
- [28] Dresch A, Lacerda DP, Antunes JAV. *Design science research: A method for science and technology advancement*. 2015. Epub ahead of print 2015. DOI: 10.1007/978-3-319-07374-3.
- [29] Hevner, March, Park, et al. Design Science in Information Systems Research. *MIS Q*. Epub ahead of print 2004. DOI: 10.2307/25148625.
- [30] Peffers K, Tuunanen T, Rothenberger MA, et al. A Design Science Research Methodology for Information Systems Research. *J Manag Inf Syst* 2007; 24: 45–77.
- [31] Knapp J, Kowitz B, Zeratsky J. *Sprint: How to Solve Big Problems and Test New Ideas in Just Five Days*. 2016. Epub ahead of print 2016. DOI: 10.1017/CBO9781107415324.004.
- [32] Sharp, H., Rogers, Y., & Preece J. *Interaction Design: beyond human-computer interaction 4th edition*. 2015.
- [33] Oates BJ. *Researching Information Systems and Computing*. 2009. Epub ahead of print 2009. DOI: 10.1017/CBO9781107415324.004.

- [34] Affairs AS for P. System Usability Scale (SUS), <https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html> (2013, accessed 16 April 2019).
- [35] Lewis JR. The System Usability Scale: Past, Present, and Future. *Int J Hum Comput Interact* 2018; 34: 577–590.
- [36] Jeff Sauro. 5 WAYS TO INTERPRET A SUS SCORE. *September 19*, <https://measuringu.com/interpret-sus-score/> (2018).
- [37] Boehm B. A Spiral model of software development and enhancement. In: *Software Management, Seventh Edition*. 2007. Epub ahead of print 2007. DOI: 10.1109/9780470049167.ch2.
- [38] Game engines - how do they work? - Unity, <https://unity3d.com/what-is-a-game-engine> (accessed 25 March 2019).
- [39] Unity - Manual: Google VR, https://docs.unity3d.com/Manual/googlevr_sdk_overview.html (accessed 25 March 2019).
- [40] Visual Studio 2019 | Visual Studio, <https://visualstudio.microsoft.com/vs/> (accessed 5 May 2019).
- [41] Learn about Udemy culture, mission, and careers | About Us, <https://about.udemy.com/?locale=en-us> (accessed 10 April 2019).
- [42] Samsung Gear VR with Controller - The Official Samsung Galaxy Site, <https://www.samsung.com/global/galaxy/gear-vr/> (accessed 25 March 2019).
- [43] Kloster M, Babic A. Mobile VR-Application for Neck Exercises. *Int Conf Informatics, Manag Technol Healthc*; 17.

APPENDIX

Related publications

Mobile VR-Application for Neck Exercises

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Abstract. A VR-based application was developed to explore the potential of mobile technology and the use of mobile-VR to assist in treatment, rehabilitation, and prevention of neck injuries. A prototype was developed through user-centered design and Google Sprint. The application simulated a typical set of exercises that a patient would get from a physiotherapist in the case of neck pain. A semi-structured interview was conducted with a physiotherapist, and an open-ended interview followed to assess usability. Expert and user evaluation indicated that the aim should be to keep patients motivated and working through the pain. The usability was judged as very good. However, clinical evaluation with a patient group would be recommended in the future.

Keywords. Neck pain, Neck exercise, VR, Gamification.

1. Introduction

Everyone owns a smartphone; they are changing our everyday lives [1]. The smartphone is equipped with an array of different built-in sensors that consist of gyroscope, accelerometer. We can utilize smartphones with a recurring activity or solving a problem in a person's life. That is the main reasons for the rise of medical applications. mHealth applications deliver or collect healthcare data [2], some of the applications are intended for healthcare workers [1], but more and more are intended for patients. Some mHealth applications have incorporated gamification features and concepts that are typically seen in video games. This can include scoreboards, trophies, and achievements compelling the user to use the application more [3]. mHealth application using VR is on the rise. Using the pre-existing sensors of smartphones, with a cheap VR headset, could make an excellent addition for treatment and prevention. The VR headset is mounted on the head, and as such could be a tool for neck exercises [4]. This study is aimed to explore the potential of VR and mobile technology for the treatment of neck pain using expert evaluation and usability testing.

2. Method

The User-Centred Design (UCD) approach was applied to this study, meaning that design was based upon a clear understanding of users, tasks, and environments. It is

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driven and refined by user-centred evaluation, addressing the whole user experience [5]. In this case and context, users are people who have neck problems that can be rehabilitated by neck stretching and neck exercises. The context of use would be a crucial point, due to the mobility of the application. The user could exercise at home or work whenever convenient. To specify requirements, google sprint was used [6]. During the sprint phase, the initial idea was developed and use cases outlined. Following the steps in the sprint methodology the use case with the most potential was selected, and a storyboard was made. The storyboard represented what the visuality and functionality of the prototype would be. After the sprint, a low-fidelity prototype was created. With feedback from a medical professional and through another iteration, a high-fidelity prototype was developed, using Unity3D. Resulting was an application for a smartphone that could be used with a VR headset. Elements of gamification were applied. The evaluation was done in two parts. The expert evaluation included a physiotherapist with whom a semi-structured interview was conducted. The second part was a usability test with users who tried the application.

3. Results

3.1 The application

The application consists of three game scenes. The first scene is a start menu where the player initiates the game. Once the game has started, the player gets instructed to move their head to the right and hold over a capsule that turns green when the timer of five seconds is up (Figure 1). When this is done, the same procedure is repeated on the left. The player must do the same looking up to the capsule and, in the last step, looking down and holding for five seconds before getting to the next scene. In this scene, the player is instructed to tilt the head to the right side and hold for five seconds, and then to tilt to the left and hold for five seconds (Figure 2.). This simulates and gamifies a set of simple exercises that a person would usually get from a physiotherapist but can now do at home.



Figure 1. Neck exercises when the application suggest looking to the right.



Figure 2. Neck exercises when the application suggest tilting the head to the side

3.2. Evaluation

The application was first used by the physiotherapist and an interview was conducted thereafter. The physiotherapist was positive about the prototype. He felt that the need for a tool like this could make the exercises more fun and with potential for further development that would tune into patients' needs. The potential concerns are home exercises and rehabilitation, as well as prevention. The physiotherapist stated that the rehabilitation processes sometimes gets hindered by the lack of participation from the patient. Motivation, or lack of it, is probably the main reason treatment takes longer and is not as effective as it should. Another reason for avoiding exercises is pain. Pain can make patients refrain from exercise. Any tool that could help a patient exercise through pain without being harmful would be an asset. This is where VR can be beneficial and aid the patients. It is also documented that VR has a distracting effect; the perception of pain when using VR is decreased [7].

Cost was an initial concern for the physiotherapist, but when told the actual price of smartphone VR-glasses combined with the patient's own phone, it became clear that the cost is not an issue. Regular VR-headset that usually need additional hardware are costly. The patient can get treatment-option on their own smartphones at the fraction of the cost.

The application was also tested on six users. Two with experience of neck pain, and four without were recruited for usability testing. Four of the test subjects had good IT skills and the remaining two had average IT skills. They were given the same instructions as a physiotherapist would give a patient when trying the application for the first time. They tested the application for an average of two minutes which is the average time for one session with the application. All the test subjects managed to finish all the given tasks. A scale from one (low) to five (high), was used to collect the feedback. The easiness of use was given the highest scores. When asked if the test-subjects found the application useful, the response was more divided, because of the relevance of use for them. There was also some concern about nausea, sometimes occurring with VR. The overall experience of using the application was however was positive and exciting.

4. Discussion

The applications allow frequent and convenient use, so it could simulate patients to exercise more often than during visits to therapists. The therapeutic effect could be significant given that exercise is well designed. One essential requirement to consider is patient safety. Therefore, a physiotherapist was consulted during the application development. He was fond of the idea to use VR and to implement it within the prototype. However, more work needs to be done to address the patient's medical condition and develop guidelines for continuous training. Keeping patients safe and interested in training ought to be one of the goals of using application. To that end, a few more clinical experts are being consulted in the future design upgrade. Several design variations of the interface and elements of gamification could be introduced, to keep patients interested in repeating and exercising.

The current solution is built in a way that can be implemented using other tools that can introduce elements of the game and provide feedback to patients over a time period. The application could also be used to prevent neck pain and injuries, not only to treat it.

5. Conclusion

There is no doubt that there is a need for a VR-application that assist in the treatment, exercises, and prevention of neck problems and injuries. This study has shown one efficient way of implementing exercises in an application which is indicated by the expert and user evaluation. The main aim of future development should be motivating and working through the pain. A clinical study is needed for a complete evaluation.

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References

- [1] Kamel Boulos MN, Brewer AC, Karimkhani C, et al. Mobile medical and health apps: state of the art, concerns, regulatory control and certification Mobile medical and health apps: state of the art, concerns, regulatory control and certification OJPHI Background. DOI: 10.5210/ojphi.v5i3.4814.
- [2] Sama PR, Eapen ZJ, Weinfurt KP, et al. An evaluation of mobile health application tools. *JMIR mHealth uHealth* 2014; 2: e19.
- [3] Miller AS, Cafazzo JA, Seto E. A game plan: Gamification design principles in mHealth applications for chronic disease management. *Health Informatics J* 2016; 22: 184–193.
- [4] Brian Chau M. Health app to prevent & treat neck pain among office workers tested in pilot study - iMedicalApps, <https://www.imedicalapps.com/2016/12/neck-pain-app-study/> (2016, accessed 7 April 2019).
- [5] User-Centered Design Basics | Usability.gov, <https://www.usability.gov/what-and-why/user-centered-design.html> (accessed 5 April 2019).
- [6] Knapp J, Kowitz B, Zeratsky J. *Sprint: How to Solve Big Problems and Test New Ideas in Just Five Days*. 2016. Epub ahead of print 2016. DOI: 10.1017/CBO9781107415324.004.
- [7] Tong X, Gromala D, Amin A, et al. The Design of an Immersive Mobile Virtual Reality Serious Game in Cardboard Head-Mounted Display for Pain Management. Springer, Cham, pp. 284–293.

Apendix NSD approval and consent form

Forespørsel for deltagelse I forskningsprosjekt

«Bruk av Virtual Reality(VR) i behandling med fokus på nakkeskader og nakkeplager»

Formål

Dette forskningsprosjektet er en del av et mastergradsstudium ved instituttet for Informasjons og medievitenskap ved Universitetet i Bergen. Forskningsprosjektet ønsker å få svar på hvilken effekt VR har på behandlingsprosesser ved opptrening og forebygging av skader ol., med fokus på nakkeøvelser. Vi ønsker også å se om det kan ha andre positive effekter som motivasjon til videre trening og om VR kan minske persepsjon av smerte.

Din relevans

Du har blitt bedt om å delta på denne undersøkelsen fordi du har kunnskap som relaterer seg til teamet i studiet. Du vil bli brukt som en ekspert, og du vil bli bedt om å bruke relevant kunnskapen til å evaluere og prate om studiet og applikasjonen. Lyden kan bli tatt opp og transkribert.

Hva går testen ut på.

For å teste ut hvordan applikasjonen er å bruke, vil du delta i en brukertest. Under brukertesten ønskes det å få tilbakemelding på applikasjonen, observere din bruk og ta opp lyd av deg. Dette for å videre analysere din reaksjon på bruken av applikasjonen. Vi ønsker også å få relevant tilbakemelding innen for ditt fagfelt, men også generelle tanker om studiet.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Studenten og veilederen er de eneste som vil ha tilgang til dataene om deg.

- Dine personopplysninger vil bli anonymisert og erstattet med alder og kjønn. F.eks (Kvinne, 35). De vil bli oppbevart på en privat datamaskin med passord.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Dine opplysninger og eventuelle lydfiler vil bli oppbevart på en datamaskin fra Instituttet for Informasjon og medievitenskap.

Prosjektet skal etter planen avsluttes 01.06.19 og alle persondata vil da bli slettet.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Instituttet for Informasjons og medievitenskap har NSD – Norsk senter for

Forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine personopplysninger vil bli oppbevart på en maskin fra Instituttet for informasjon og medievitenskap ved UiB.

Hvor kan jeg finne ut mer?

Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Instituttet for Informasjon og medievitenskap ved Ankica Babic.
- NSD – Norsk senter for forskningsdata AS, på epost (personvernombudet@nsd.no) eller telefon: 55 58 21 17.
- UiBs personvernombud Janecke Helene Veim. Tlf 55582029.
Epost: Janecke.Veim@uib.no

Med vennlig hilsen

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Tlf: 95817417

Jeg har mottatt og forstått informasjon om prosjektet «*Bruk av Virtual Reality(VR) i behandling med fokus på nakkeskader og nakkeplager*» og har fått anledning til å stille spørsmål. Jeg samtykker til:

- å delta i *brukertesting*
- å svare på spørreskjema
- å delta på et intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet og da vil de bli slettet.

Prosjektet er ferdig ca. 01.06.19

(Signert av prosjektdeltaker, dato)

NSD PERSONVERN

12.02.2019 09:40

Det innsendte meldeskjemaet med referansekode 599737 er nå vurdert av NSD.

Følgende vurdering er gitt:

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 12.02.19, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

MELD ENDRINGER

Dersom behandlingen av personopplysninger endrer seg, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. På våre nettsider informerer vi om hvilke endringer som må meldes. Vent på svar før endringer gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET

Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 01.06.19

LOVLIG GRUNNLAG

Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

PERSONVERNPRINSIPPER

NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke behandles til nye, uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet

- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER

Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER

NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og/eller rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET

NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Silje Fjelberg Opsvik

Tlf. Personverntjenester: 55 58 21 17 (tast 1)