Western Norway University of Applied Sciences

University of Bergen

Master of Science in Software Engineering

Virtual Reality games and gamified exercises in physioterapeutic treatment of non-specific low back pain patients with kinesiophobia

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Why shouldn't people be able to teleport wherever they want?

PALMER LUCKEY, OCULUS VR

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Preface

This document constitutes the report of my master's thesis project, to be submitted in fall 2018 in pursuit of the degree of Master of Science in Software Engineering. The programme is a joint degree given by Western Norway University of Applied Sciences (HVL) and the University of Bergen (UiB).

The thesis project is a collaborative participation in an experimental study that was initiated by physiotherapist and master's student of Health Sciences, Maja Sigerseth, who had begun the work a year prior to my joining. The project was carried out with some delays due to health issues on my part, which extended the pilot study to June 2018 and reduced the scope of contribution. Theses from the project work are written and published separately.

The project has garnered attention in several circuits. I've been fortunate enough to participate in some of these, given short talks, and helped stands on Forskningsdagene, Fysioterapikongressen (National physiotherapy congress). Four students from the University of Bergen also made a documentary film on the work as their bachelor's thesis project.

The interest is encouraging, and I hope this contribution can be of help in furthering the project's goals and other interdisciplinary collaborations in future works of health technology.

Project approval by western Norway's Regional Committees for Medical and Health Research Ethics (REC).
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Bergen, October 2018

Thomas Fiskeseth Larsen

Acknowledgements

First and foremost, my heartfelt thanks go to my ”dream team” of supervisors for their enormous support on the academic and personal level, for their guidance and valuable insights, critique, and their sheer availability, time given beyond their call of duty. I never would have made it to the finish line without them, and they never gave up on me when times were tough. My deepest thanks.

And to Maja, it’s hard to properly express in words the gratitude I feel for the opportunity to join this endeavour. I’ve witnessed an inspiring drive for innovation of the health sciences and patient care by you and your mentors. Participating in the project and working with you has been a rejuvenating experience to say the least. I must also thank you for your patience and understanding in the face of obstacles. I treasure our friendship and this learning experience. I would also like to thank the aforementioned mentors and project leads, Dr. Kjartan Vibe Fersum and Dr. Tasha Stanton. Formally, I thank and acknowledge Maja Sigerseth for all the valuable assistance during development, shared efforts, ideas, discussions, knowledge, research/resources and clinical insights.

Furthermore, I would especially like to thank Lars Peder Vatshelle Bovim and SimArena, with Bård Bogen and the department of health and functioning at HVL, for all help during the project, including the generous use of laboratories and equipment for testing, development and VR sessions. Both have devoted time for discussions and invaluable insight in both domains of the thesis, as well as the two interviews that were carried out.

The film crew from the University of Bergen who made a documentary on the project deserve praise for an amazing effort. Joachim Christian Barth, Mads Holm Neset, Markus Rønne Malmo, Viktor Fylling—you’re great! Thanks for taking an interest in the project, your impressive work, and for letting us show off the video at presentations.

For the clinical trial of the project, huge thanks go to developers of the commercial VR games Holoball (TreeFortress Games) and Holodance (narayana games), who let us use their games and provided custom builds tailored for our needs. These experiences made up two thirds of our VR trial regiments. We’re extremely grateful and wish you continued success.

Special thanks go to Dax Phandi of Quadspinner, who helped me out with using their Geoglyph suite for World Machine when designing worlds/levels for the prototype.

To all my family and friends who kept me grounded—thanks for all the loving support; notably my parents, Simon, Ingeborg, Aksel, Anette, Trond Eivind, Kjetil and more. A final dedication I give to Per Lønning Kallevik, David Tovi and Kristin Sårheim, to whom I owe so much.

Abstract

Virtual Reality (VR) hardware has become increasingly cheaper and more available in recent years. Consumer markets, developers and researchers alike have embraced new opportunities to explore novel uses and interactions for this technology, particularly through video games. VR has already been used in various forms of experimental therapy since the early 2000s, including pain modulation and sensory distractions aimed to reduce acute pain experiences, treatment of phobias with graded exposure therapy etc. Recently, this approach has also been considered for experimental use by physio- and manualtherapists' treatment of chronic low back pain patients.

Chronic low back pain is one of the leading causes of debilitating pain conditions, sick leave and healthcare costs worldwide. A subset of these patients will also develop a fear of movement (kinesiophobia) that can be further exacerbating to their condition, despite not having a specific pathology, prevailing injury or danger of re-injury. Maintaining this condition over time can, among other things, lead to increased pain experiences, maladapted cognitive-behavioural patterns and lessened quality of life at the onset of chronicity. Treating this condition has proven difficult, and there is currently little consensus on demonstrably effective treatment regimes.

This thesis aims to explore applications of VR games in the domain of physiotherapy, mainly by way of contributing to a clinical trial and research project conducted by physiotherapist and master's student of health sciences, Maja Sigerseth. The aim of this technological application is to subtly encourage back flexion (through graded exposure) beyond the patients' maladapted comfort zones while immersed in sensory-distracting exercise games. A prototype game was developed that constituted one third of the stimuli used alongside two commercial titles. Ten patients (n = 10) with non-specific chronic low back and fear of movement participated in the single-subject experimental study, and unstructured observational data was gathered by the author on their interactions with the VR experiences. Health-related outcome measures will be published separately by Sigerseth—forthcoming at the time of writing.

Results from the trial observations and two health-domain interviews conducted afterwards suggest that the VR experiences and graded approach are able to encourage back flexion in the relevant areas through exercise games. They provided beneficial sensory distractions such that patients in this group could perform exercises that would typically be avoided due to pain response.

The interviews further suggest that the technology and prototype experience may indeed be applicable as tools for treating this patient group, but further research and clinical tailoring is warranted before realistically being deployable to specialized use.

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Glossary

Affective gaming Area of study concerned with the study of human affects in play (and video games). Research into this often applies physio-physiological measures, using technologies like Electroencephalography (EEG) and Galvanic Skin Response (GSR). 7, 100

Artificial Intelligence In video games, Artificial Intelligence (AI) is used to instill or emulate human-like intelligent behavior in non-player actors/characters. Techniques from the field of Artificial Intelligence may be used, but in video games, seemingly convincing behaviors may take presedence over modelling truly autonomous agency due to lesser needs or design complexity. 7, 9, 54, 71

Asset In video game or multimedia terms, an asset can mean any resource or binary file that contributes some form of data or artistic content to the media, such as images/textures, audio clips, 3D models, level/map constructs, special data containter files etc. In Unity (and commonly in other engines), specialized asset files encapsulate functional components and parameters. 7

Biopsychosocial From the Biopsychosocial (often abbreviated BPS) model or perspective on disease outcome. Argued by George Engel in 1977 as a counter to the prevalent bio-medical perspective on health and disease, in medicine and particularly psychiatry, as being too reductionistic. BPS considers psychological, behavioral, and social dimensions in addition to strictly physiological mechanisms. This is a key perspective applied in modern pain science and the research that inspired Sigerseth's project.[10] 7, 21, 92, 96, 101

Exergaming Short hand for "Exercise Gaming", meaning titles that facilite physical exertion through play. 7, 18, 37, 93

Game Engine Modular software framework for building games and virtual environments. 7

Graded Exposure Therapy (GET) A form of psychological/cognitive behavioural treatment, where the patient is gradually exposed to a source of fear, avoidance, anxiety etc. in order to gradually disensitize him or her. 7, 18

Guardian System The name given to a safety system used with the Oculus Rift software that shows a 3D-mesh grid of the play area boundaries if the HMD or Touch controllers get too close to the edge. 7

Interpupillary Distance (IPD) Often referred to as **Real IPD** in Virtual Reality (VR) vernacular—the distance between the centers of the pupils of the eyes. This is useful, or necessary, in calibrating the lens distance in the HMD to achieve an optimal focus, as VR content must appear directly in front. Deviation is likely to cause blurry appearance and/or eye strain. A **Virtual IPD** is the distance between two cameras–representing each eye–in a scene, and should not be confused with the physiological and calibratory measurenment as defined above. 7, 110

Kinesiophobia A type of fear-avoidance behaviour, fear of movement, that can trigger pain-experiences, psychological distress. *See background chapter.* 7, 15, 19, 35, 63, 89, 90, 93, 98

Navigation Mesh A 3D surface mesh that covers one or more areas on top of scene geometry that is considered ”walkable” or traversible (often by characters and/or Artificial Intelligence agents). For example, in a Unity scene, a 3D robot character with a NavMesh agent behaviour will be able to move freely on the NavMesh's surface, but will not consider moving on surfaces not encompassed by the mesh. (usually defined to be unreachable due to slopy terrain, obstacles in the path, water etc.) 7, 56

Neuroplastic The brain's ability to form new neurons, neural connections/pathways, and reorganize throughout life. 7, 15

Prefab A Unity asset type that allows storing a ”template” GameObject complete with behaviours, components, child GameObjects etc. attatched. A prefab can be saved to a file, ready to drag and drop in-editor, or instantiate at runtime from a reference to the prefab. Well suited for re-using GameObjects across use-cases, scenes, even projects.

While generic by intention, this description may not be encompassing of the new or coming prefab workflow (including nested prefabs) that is being introduced by Unity at the time of writing. 7, 53

Presence Related to 'telepresence', an older term used to describe remote communication paradigms. Presence in VR, being immersed in the virtual world and accepting the stimulus as actually *being* in the virtual environment. 7, 24

Proprioception The unconscious perception of the body's movement and spatial orientation that is detected by neural stimuli and the vestibular system. (The brain's model of how the body and its parts are located, oriented and moving in space.) 7, 22, 37

Scriptable Object Special data containers in Unity that can persist shared data independent of class instances and does not need to be attached to other (game-)objects. They can be stored as .asset files, used as "pluggable" data, such as configuration values and parameters—see Chapter 3. 7, 45, 61, 62

Spawn Point Term frequently used to refer to starting locations for an actor in a video game.) 7, 56, 57

Stereopsis The appearance of depth when both eyes are open. From the Greek word for "solid light".[11] 7, 24

Tween Tweening, or "inbetweening", is a process in animation for generating intermediate steps, frames or units between two defined key frames. In computer animation, this is analogous to interpolating between states, values, positions etc. Smoothing or "easing" functions are often layered in as well. 7, 74, 75, 105

Vection (Not to be confused with the term used in medicine) Illusion of self-motion that occurs when the brain cannot reconcile input from the vestibular system with visual stimuli, or defined succinctly by [12] as *"an illusory phenomenon which occurs when self-motion is felt by a stationary observer"* when such conflict in input occurs. In virtual reality, this commonly occurs when the visual system percieves acceleration (linear or angular) while the innear ear does not, because in reality the body is stationary or moving differently. 7, 23, 33, 34, 37

Vignette In photography and optics, vignetting is the gradual reduction in brightness or saturation in the edges/peripherie of an image. Frequently used as an image effect in video games to shade the edges and draw attention towards the centre. 7, 34, 49

Acronyms

AA Anti-Aliasing 7, 60

BCI Brain-Computer Interface 7

DoF Degrees of Freedom 7, 26

EEG Electroencephalography 7, 8

FA Fear-avoidance 7, 98, 99, 101

FOV Field of View 7, 34, 35

GEQ Game Experience Questionnaire 7, 64, 81, 83, 89, 95, 96, 110, 130, 132

GPU Graphics Processing Unit 7, 103

HCI Human-Computer Interaction 7, 17, 63, 65

HDMI High-Definition Multimedia Interface 7, 103, 104

HMD Head-mounted Display 4, 7, 9, 19, 25–28, 32–34, 36, 42, 44, 46, 48, 49, 54, 60, 63, 66–68, 72, 79, 90, 91, 93, 94, 97, 101, 104, 110

HUD Head-up Display 7, 33

HVL Western Norway University of Applied Sciences 7, 80

IK Inverse Kinematics 7, 42, 43

IR Infra-red 7, 26, 42

LBP Low back pain 7

LOD Level of Detal 7, 56

NSCLBP Non-specific chronic low back pain 7, 15, 18, 19, 21, 30, 32, 63, 66, 81, 82, 86, 89, 92, 93, 96–98, 100, 102

SSED Single-Subject Experimental Study 7, 30

UI User Interace 5, 7, 57, 58, 62, 71, 82

UX User Experience 7

UX User Experience 7, 17, 63–65, 77, 80–82, 90, 96, 100, 101

VAS Visual Analog Scale 7, 31, 68

VE Virtual Environment 7, 17, 19, 27, 33, 37, 43, 44, 60, 68, 78, 94, 98

VOR Vestibulo-Ocular Reflex 4, 7, 22

VR Virtual Reality 7, 9, 14–19, 21, 22, 24–26, 28, 30–38, 41, 42, 44, 47, 48, 58, 61, 63–69, 79–82, 86–93, 96–98, 100, 101, 103, 104

VRISE Virtual Reality-Induced Symptoms and Effects 7

VRTK Virtual Reality Toolkit 5, 7, 50, 53, 54, 60, 61, 79

Chapter 1

Introduction

This section will serve as an introduction for the thesis, outlining the research topics and disposition of the document. The author notes that some background research and references were made available from collaborator's original project plan and sources, especially those pertaining to past work in pain science, healthcare and physiotherapeutic topics.

1.1 | Outline

The first chapter introduces the thesis topics, research questions, and also covers some related past work. Chapter 2 concisely introduces background topics pertaining to technologies and health-domain subjects of the project. This is needed to support further discussions of methodology and solutions, which is given in Chapter 3. The prototype game that was developed is described therein, preceded by investigations into design practices and commercial titles in VR games. Also covered briefly is the clinical trial protocol. Results, discussions and evaluation is given in Chapter 4, where observational data is presented, followed by health-domain expert interview summaries. Finally, the thesis is concluded in Chapter 5, where implications and considerations for future work is given. Appendices will contain the interview transcripts, hardware specifications and list of external game assets used in developing the prototype game.

1.2 | About the thesis

Problem description and outline Patients suffering from chronic musculoskeletal back pain make up some of the largest groups of disabled and functionally reduced individuals both nationally and worldwide.[13, 14] A large subset of these patients (85%) have specific pain-syndromes in the low back area [15], which can be disabling as a chronic condition, even in the absence of an established clear pathology for this after an initial acute- or trauma-phase. This is clinically referred to as **Non-specific chronic low back pain (NSCLBP)**.[15]

Of particular interest in this thesis project is a type of fear-avoidance behaviour that can arise in NSCLBP patients, modelled as Kinesiophobia, which in turn can exacerbate the chronic aspects of the illness, as well as elicit actual physiological changes (Neuroplastic) from the perceived threats of re-injury, disruption of homoeostasis, pain experience, psychological fear and subsequent maladapted cognitive behavioural patterns.[10, 16] An assumption of the model is that patients with high levels of pre-existing pain-related fear are likely to interpret pain as serious tissue damage, thus instigating avoidance of movements that triggers this. These patients often require significant resources invested in long-lasting treatment regimes and interventions to improve their health status (when successful) and/or regain their former quality of life, capacity for work (often from longer periods of sick-leave), social- and family-lives etc. Thomas et al (2016) [17] cite figures describing a high prevalence and cost in the U.S., and in Norway, high national spending, sick leave and disability due to low back pain is also prevalent.[18] Clinical literature seems to affirm that this is a worldwide problem.[19] By these scales alone, it is of immediate and significant interest, to both patients and health personnel, to improve upon the tools employed in these interventions, embracing technological innovations that can be conjoined with the existing or concurrently advancing health sciences.

We aim to explore one such possibility by leveraging young, but rapidly maturing, consumer-grade technologies in VR.

1.3 | Motivation

Due to the often limited effect of long-lasting therapy interventions for NSCLBP patients, it becomes important to explore many possible avenues that can offer treatment- and motivational benefits for healthcare-givers and patients alike. For the patient, an early, effective treatment that reduces the impact or possible onset of chronicity, can greatly improve quality of life prospects. There's also the significant burden of resources placed on the healthcare systems to consider, which in itself is important given how much resources society is required to place in these services, both presently and with the large future growth expectancy.

In pursuit of such goals, physiotherapist and master's student of Health Sciences, Maja Sigerseth, initiated a thorough research endeavour into immersive VR technologies aimed at the relevant medical uses, having been guided towards the idea from within the *Body in Mind* research group, of which she is a contributing member under mentorship and tutelage of Dr. Tasha Stanton, whom is also one of her thesis advisers, and a referenced previous project.[20] Significant bodies of research were examined, resulting in a consensus that great potential exists for using VR in physiotherapeutic interventions, and also many other areas of pain science. After a year's time of research and experimental design, I had the fortune of joining the project through my thesis supervisors, late in the spring of 2017, initially as the sole developer of a broad-scope, multi-module game prototype and technical assistant to Sigerseth. From there on, we collaborated through the summer on researching various VR-experiences, technologies, interaction paradigms and related products, while the experimental study design was finished, and the author developing for the technical prototype. Summary discussions of this process will follow in later chapters. From research of more novel aspects of this approach, discussions with supervisors of both students encouraged an investigation into which hardware, accessories and peripherals could provide additional data sources or feedback mechanisms for the patients. Biofeedback, accelerometers/gyros and various motion capture technologies were considered for this purpose, but would not end up being used as data sources for analysis or objective measurements of engagement, exertion, back flexion etc. Choice of software was the prominent point for discussion—whether a sufficiently sophisticated prototype could be developed with the set goals in mind for the study, or a viable selection of existing commercial products could meet the same needs if necessary. Emphasis was put on methods that could be later transferred or applied in clinical settings.

An additional aspect of these novel experiments researched is the use of gameful design and video game elements to increase engagement, patient education and motivation. In many cases, it was also found to affect a modulation of the patient's pain experience while immersed in VR/engaged in game-activities, and could offer patients a distraction from their otherwise prominent expectations of discomfort and pain. Given the power of VR to facilitate embodied agency [21] while *immersed* in the Virtual Environment (VE), using the whole body, it was apparent that the gamified approach to a psychotherapeutic intervention could have great potential. This will be explored in the *related work* section, and has formed the basis for an interest in tailored VR-game experiences as tools in medical interventions, where researchers have full control of the VE and thus consistent or standardized variables.

From the perspective of software- and game development, this presents an opportunity to explore the intricacies of VR design, differing a great deal from designing an experience for 2D-displays, aspects of Human-Computer Interaction (HCI) and User Experience (UX) for this use, and in general it could inform us better in the disciplines of constructing software that bridges the needs of healthcare personnel to use novel tools with our own growing interest in cross-domain modelling, development and understanding. VR and video games are both powerful media, creating an engagement that speak to the very core of the "playful human", *homo ludens*. It is of great importance that the crossing of these paradigms be understood further as the rise of immersive virtual worlds is introduced to ever more aspects of our lives through technology, and the application of this knowledge as proposed in the project could be a stepping stone towards lowering the global costs of a particularly prominent health epidemic. There is also a general call for empirical HCI research on conceptual problems, to which software engineers and computer scientists should eagerly contribute.[22] With that in mind, we proceed to formulate the thesis goals that drive the project's focus in the coming sections.

1.4 | Thesis goals and research questions

The primary thesis goal is to investigate how VR-technology can be utilized in the healthcare professions, specifically focused on physiotherapy, by way of prototyping a set of VR-experiences featuring game designs that motivate patients to push beyond their comfort zones. Relevant expert input will help shape the design for these exercises.

Secondary to this is the exploration of how this can be expanded upon, to encompass a larger toolset or framework for use in following up the VR exercise regimes—in the clinic and at home, where adherence to clinically issued exercises plans is beneficial. The project's clinical study is premised on an approach of Graded Exposure Therapy (GET) using VR, in which the patients are encouraged to exert themselves, with exercises that can be tailored to gradually increase difficulty. In the presence of forthcoming and existing commercial Exergaming titles (including any available from other research projects), it is therefore prudent to explore what combinations of game elements need tailored development for clinical use, or if a selection of other titles cover the same needs.

The research questions thus become:

- How can the use of VR technology and consumer video games aid in physiotherapy treatments of NSCLBP patients?
- Are clinically tailored games more viable for use than a combination of commercial titles that feature similar sensory-distracting and exercise benefits?

1.5 | Scope and limitations

The scope was unfortunately subject to change due to the author's declining health, both at the beginning and towards the end of the project; this prompted some major changes to the timetables of both researchers, and reduction in scope of the contributed prototype, which is described further in chapter 3. Two commercial titles ended up being used along a prototype game developed by the author, and evaluation methodology changes will also be outlined in chapter 3, which includes methodological choice regarding prototype evaluation. In addition to the trial, some efforts were devoted to exploring future works and use of the technology, further described in the aforementioned chapter.

1.6 | Methodology

The method chosen to answer the research questions was a qualitative approach in researching the technology that was relevant to Sigerseth's chosen trial criteria and methods. Research was needed to examine VR technologies, data collection tools, video game paradigms, past clinical use and game design practices for VR, some of which was already considered by collaborator in the existing project plan. Further, to evaluate the result, qualitative data collection methods were used and are discussed in chapter 4, with scope-limiting considerations as specified above.

1.7 | Related work

Research using relevant technologies for therapeutic use goes back several decades [23], where prominence is shown for treatment of various anxiety disorders and phobias. But of special interest in acute pain modulation, several past works have established the immersive and engaging properties of VR as distracting from pain.[24, 25, 26, 27] Studies by Hoffman et al feature the VR game *Snow World*, in which players fly through a VE featuring snowy, icy landscapes and thematics, described by the game's author as the antithesis to fire/burning sensations associated with the patient's wounds and pain. Results indicated a decrease in pain experience by the burn victims during painful procedures such as wound dressing, and were tested as an alternative to pharmacological (opioid) agents for pain control. Pain modulation has also been shown in other areas of pain science, where the medium has allowed for modification of the user's sensory perceptions, and thus of their own body.[28, 20]

More recently, Thomas et al (2016) conducted a randomized clinical where NSCLBP patients with Kinesiophobia played a virtual dodgeball game using 3D-shutter glasses (no HMD).[17] Increased lumbar flexion was noted during the interventions; however, the authors did not find that the brief interventions translated to movements outside the study, but concluded with a demonstrated safety for functional tasks with lumbar flexion in the intervention type, and a call for longer exposure periods. Interventions of graded exposure in VR for this patient group have further been previously discussed in depth by Trost et al.[29, 30]

Additional work and existing commercial titles will be referenced later in the thesis and may also be found in the separate publication. Following these introductions, we proceed to review background materials and theory in chapter 2.

Chapter 2

Background

This chapter will introduce the reader to theoretical background matters of the thesis. It is necessary to visit subjects related to the domains of physiotherapy, physiology and pain science to encapsulate the thesis and experimental foundations. Bridging this theory with the domains of Human-Computer Interaction, Game Development, VR-modalities and Software Engineering will be done to the best of the author's abilities.

2.1 | Physiology

2.1.1 Non-specific chronic low back pain

Low back pain (LBP) can have a wide range of causes and symptomatic displays. In LBP the cause and/or symptom is localized at around the lumbar spine, surrounding muscle tissues, nerves or skeletal components. A set of diagnostic steps are usually followed to rule out serious injuries and other pathological conditions (that require further intervening and specialized care), but a majority of causes are classified as *non-specific*, most of which are then attributed to ligament injuries or muscle strains. Literature reviewed are found to classify the LBP by its duration as *acute* (less than 6 weeks), *sub-acute* (more than 6 weeks) or

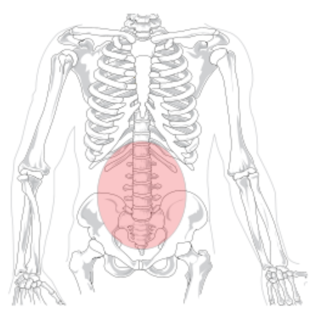

Figure 2.1: Lumbar region on the human skeleton.[1]

chronic (12 weeks or more). It is the latter category that is ascribed to the NSCLBP group, which is at increased risk of long-lasting disability, depending on many factors. In reviewed recent literature, O'Sullivan [14] affirms that such conditions must be approached as multidimensional disorders, considering Biopsychosocial factors and other co-morbid health conditions.[19] The condition is described as heterogeneous, neuro-biological, behavioural, complex and difficult to generalize treatments for. Additionally, there are predictors such as fear of re-injury that are common in transitions from acute to chronic conditions. This will be elaborated on in the next section.

Fear-avoidance behaviour

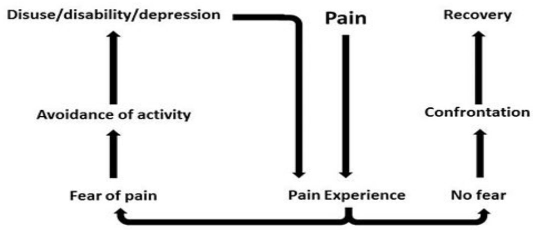

Figure 2.2: Fear-avoidance model of pain.[2]

In the vast populace of people suffering from back pain, a subset of 85% are considered "non-specific chronic low back pain" patients.[15] Approximately 3-10% of these develop a chronic condition as a result. From the perspective of cognitive-behavioural models, a leading explanatory model is the "Fear-Avoidance Model of Musculoskeletal Pain".[31] A crucial notion in this model is that *fear of re-injury* greatly influences behaviours that predispose for chronicity to develop. Once manifested, these changes can be observed using medical imaging in regions of the brain that have associations with emotional processing and acute pain.

It is noted that return to regular physical activity is key in recovery from acute injuries, and that avoidance behaviours reaffirms self-perpetuating psychological distress that precedes transitions from acute to lasting condition.[30] Patients can also present with a distorted body image at onset of chronicity, showing conditional improvement as their own body image normalizes. Senkowski and Heinz view VR based multisensory feedback training as a promising course of intervention for treating this type of chronic pain.[28] Another prominent study that inspired the project is Harvie et al's experimental use of VR to manipulate visual feedback to the patient in order to increase the range of neck movement before onset of pain.[20] The study suggests that pain can be triggered by stimulus that is *associated* with pain, and that the threshold can be modulated.

The next section will introduce another physiological component related to some of the thesis topics.

The vestibular system

Figure 2.3: The internal ear.[3]

The vestibular system is part of the body's sensory system and is part of the inner ear.[32] Its relevant components are comprised of semicircular canals and the otoliths, which together can detect rotational motion, angular velocity and linear acceleration. It is a component of Proprioception. Fluid in the canals are displaced and stimulate small hairs when relevant motions are sensed, which through electric signalling informs other parts of the nervous system. Among the systems informed are several cranial nerved that enable the *vestibulo-ocular reflex*, allowing a stabilized visual image to be preserved during head movements (stabilizing vision). In VR, the vestibular system is of significant interest

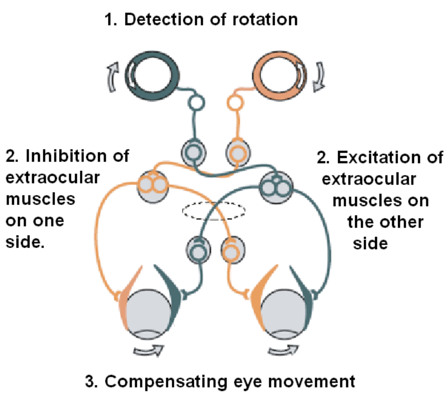

Figure 2.4: The Vestibulo-Ocular Reflex VOR.[4]

due to its role in *simular-/motion-/cyber-sickness*.

Motion Sickness

Motion sickness occurs when there is a mismatch or ”disagreement” between visually perceived motion and the vestibular system’s sense of motion. It has other recognizable, context-specific names such as seasickness, airsickness, car sickness etc., with the same root cause. It is also known as *simulator sickness* or *cyber sickness* which carry contextual relevance to the thesis domain. The prominent theory encountered in literature is *sensory conflict theory*, which posits that the irreconcilable input causes a likely evolved physiological defence mechanism that induces nausea and related disorientation. Motions likely to cause these are accelerations perceived from visual input, or optical flow in the peripheral vision, known also to induce Vection which is further explained below.[33, 34] Warren et al also make some novel observations on the sensory conflict theory, but this will not be discussed further.[35]

2.2 | Human-Computer Interaction

2.2.1 Virtual Reality

Decomposing the term into 'virtual' and 'reality', considering the meaning of the terms separately, readily yields a basic insight into the definition of VR: a technology that allows a user to experience a computer-generated virtual world, considered here in three dimensions, being free to orient their perception by some interactive means, as though *"it were real"*. The term has also encompassed virtual worlds that are viewed on traditional 2D-screens, but in this thesis, modern immersive technologies facilitate sensory input from sophisticated hardware, this affords 6 degrees of freedom for the user to navigate the environment–back & forth, up & down, left & right, pitch, roll and yaw. Another central component is the ability for a user to *interact* with this world, the means through which will be discussed further. In order to

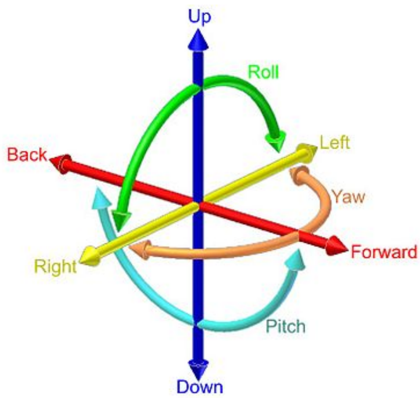

Figure 2.5: Axis-mapped 6 DoF.[5]

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establish Presence and experience immersion on the visual level, a fundamental component in VR is stereo-imaging; presenting two separate images, one for each eye, adding perceived depth to the view, and separating the display from viewing a traditional screen or 2D-surface. As outlined in the previous subsections, Stereopsis is a physiological requirement for achieving this. And as will outlined in the coming sections, it's convincing effect depends on several technological components working in unison to keep the software appraised of the user's movements.

The history of VR along with precursors for our current use of it dates back some time, but an important milestone was struck with the first tracked

HMD, as presented by Sutherland (1965).[36] Though tracked and able to turn, the structure was still tethered to the roof due to its size and weight. Since then, it has a been developed as a popular technology for simulators, but has also had industrial applications with the CAVE variant, in which a full room with multiple projectors and viewed by the user in 3D-depth using special glasses.

Figure 2.6: The Cave Automatic Virtual Environment at EVL, University of Illinois at Chicago (Wikimedia Commons).[6]

During the 1990s there was also an attempt to commercialize VR as mainstream entertainment, but several factors such as hardware performance and poor experiences diminished the interest, instead giving rise to academic, therapeutic and research use in the 90s and 2000s.[23, 37] In 2012, Oculus unveiled its desktop PC HMD Rift after a successful crowdfunding campaign, which is regarded as another important milestone for mainstream availability. Since then, desktop systems such as HTC Vive, Playstation VR for gaming console use and HMDs for mobile phones have been released.

Method

The primary means to immerse the user visually in VR, is to give the illusion of depth using some form of optics (glasses, headsets, screens) to focus two images with stereo convergence on the eyes. From retinal projection and via the optic nerve, the brain will process the image in several stages before the resulting stimuli reaches the visual cortex just inside the rear part of the skull. From these steps, the brain (and the user) is able to infer depth and distance of elements in the scene.[11] Several means to achieve this effect have been developed since VR was conceptualized. Most involve the player donning a headset containing the necessary screen technology to display one or two images to the eyes, along with optics to focus the images appropriately.

Figure 2.7: Oculus Rift CV1 HMD (Wikimedia Commons).[7]

Sensor-technologies and 6 DoF

Headsets have built in accelerometers, gyros and other components in order to track the player's head orientation in very high resolution, which in turn is transmitted to the software. In order for the experience to be comfortable, reviewed research and vendor guidelines all state that delays in any part of the technical side must be minimized. This includes readings from the inertial measurement unit (IMU) and units that tracks the HMD orientation and movement, software rendering stages, positional tracking, CPU-bound operations that may cause rendering delays, and displaying the rendered image in the HMD. [38] Stutter, latency or inconsistencies that are perceptible may cause discomfort during play. Modern HMDs therefore have built-in high-frequency precision hardware to address these needs. By a measure referred to as motion-to-photon-latency, there should be no more than 20-60ms delay before a motion is registered and then reflected on the screen, optimally less than 20ms.[39]

Several means exist to achieve 6 Degrees of Freedom (DoF) tracking for room-scale VR. Some mobile headsets have traditionally relied only on head movement and acceleration detection to change the orientation of the scene camera, omitting positional tracking altogether. Various techniques have been used over the course of VR history, but in the current generation of desktop- and console-powered consumer-hardware, a combination of Infrared (IR) emitting LEDs and sensors are prevalent.As examples, we consider the tracking systems of the two most popular consumer hardware vendors: Oculus and HTC Vive. Oculus Rift has named its variant 'The Constellation' system, which are basically cameras that can detect LEDs.

Figure 2.8: Oculus Rift Constellation Sensor Tower.[8]

The basic configuration consists of only one sensor, able to track the HMD, but will not always be able to accurately track two hand controllers due to potential occlusion issues. The system scales, however, and seems restricted primarily by the number of available USB-ports, bandwidth and processing power at the software's disposal. Using two or more sensors, the Touch controllers can also be tracked and distinguished between while visible to the towers. Room-scale/360 degrees tracking can be achieved with two (placed diagonally in the area's corners) or more units, allowing the user to face all directions without tracking being lost.

On the tracked objects, small LED lights are placed below the headset- and controller surfaces, emitting fixed frequency lights that are registered by each

Constellation tower. The data from all towers is then sent to the computer and software for processing, resulting in positional data, also recovering orientation.

The HTC Vive takes a slightly different approach to this step, using the Lighthouse system, consisting of two laser-emitting towers, and sensory surfaces located on the HMD, hand controllers and peripherals.[40, 41] In other words, in this configuration it is up to the sensory-fitted devices to calculate their respective positions instead of the base stations, recovering their position and orientation as the light sweeps hit each sensory unit. The devices then transmit this data to the computer and software for processing and use, with similar precision to the Rift, but noted by one study as imprecise for research purposes.[41]

Figure 2.9: HTC Vive Lighthouse Base Station.[9]

As per manufacturer's recommendation, the base towers should be placed in two corners of the play area, facing the center along the diagonal, to facilitate room-sacale positional tracking, which is similar to the Constellation configuration for two sensors, but affords a greater play area.

Positional tracking extends to the hand controllers, and this enables the player to move within the designated tracking volume while using the hands/controllers to interact with the VE. Experiences can be categorized as seated or standing, depending on the game design and locomotion paradigm.

2.3 | A note on gamification

Gamification is the application of game design principles and game mechanics outside the scope of entertainment, through digital means, to facilitate motivation for people to reach goals. In this thesis, use of video games arguably falls somewhere in between a serious game (video game used for other purposes than entertainment, such as training and simulations), simply using them as is (entertainment), and a *gamified approach* of exercises used in a gaming context. Related research does, however, justify and classify this approach in therapeutic contexts as *gamified*.[42]

2.4 | Game Engines

Games and technology-heavy application can make for costly development efforts depending on their size and complexity. Interactive multimedia applications also require an interplay of modular software components to function. Game engines are complex development environments that often solve some of the more elaborate software problems such as hardware abstraction, low-level API handling such as input/output and graphics rendering etc. They have become increasingly popular and feature-rich with flexible licensing models for all actors. The trade-off between having full customization at all layers of the product, and the framework of components ready to use that commercial game engines afford, is one that seems to predominantly fall in favour of commercial engines. One special advantage of major engines is their targeting and support for deployment on multiple game platforms, such as PC, Playstation, X-Box One, mobile platforms, and notably increasing support for VR.

2.4.1 Notes on rendering pipelines for VR

By necessity, rendering a generated 3D-image for two eyes instead of one involves more steps than single-display viewing. One image is slightly shifted for natural convergence (like the second eye in real life), thus requiring separate geometrical processing for the images of each eye, with the additional draw calls and shading-pipeline steps added on top. At first, complete stereo rendering had been comprised of processing the entire camera- and scene view in two separate stages, essentially doubling or quadrupling the workload of both the CPU and GPU. Any and all steps to save on rendering costs have been popular in developing for VR, such as choice of the forward rendering path, since deferred rendering involves more than one stage of scene processing to populate the G-Buffers. Advances have been made, however, to makes the rendering process more efficient and cut down on draw calls, geometry processing, scene graph traversal, by way of instanced draw calls.

Additionally, since there are two frames, whose combined resolution on the HMD used—2160x1200 pixels total (1080x1200 per eye) @ 90 Hz—can exceed or match large 2D-displays, the pixel-throughput per second is significant in VR, where demands are high for a consistently high frame-rate to avoid discomfort. Techniques such as Asynchronous Time Warp (ATW) on the Oculus Rift can compensate for a lack of rendering power by reprojecting frames, thus requiring half the frames per second, but this is also comes with certain caveats that discourage complete reliance.[44]

The engine ultimately selected for the project will be briefly described next.

2.4.2 Unity

Unity is a popular game development framework for all tiers of ambition, being favoured by single-person teams and AAA studios alike. Since it's start in the mid-2000s, the engine and organization have grown steadily to become a major player in today's markets, situated among other veteran actors that have dominated the games industry. It is noted for its popularity among independent developers (”indie”, smaller studios or teams without support of major game publishers), but has in the recent years increased efforts to rival actors like Unreal Engine and CryEngine in terms of graphics capabilities and scripting. C# is the supported programming language used to implement game functionality and extend the framework. As is common, the developer environment is heavily extensible but offers a selection of game template and functionality, both through the editor and the Asset Store, a marketplace for Unity-specific content and third-party game assets.

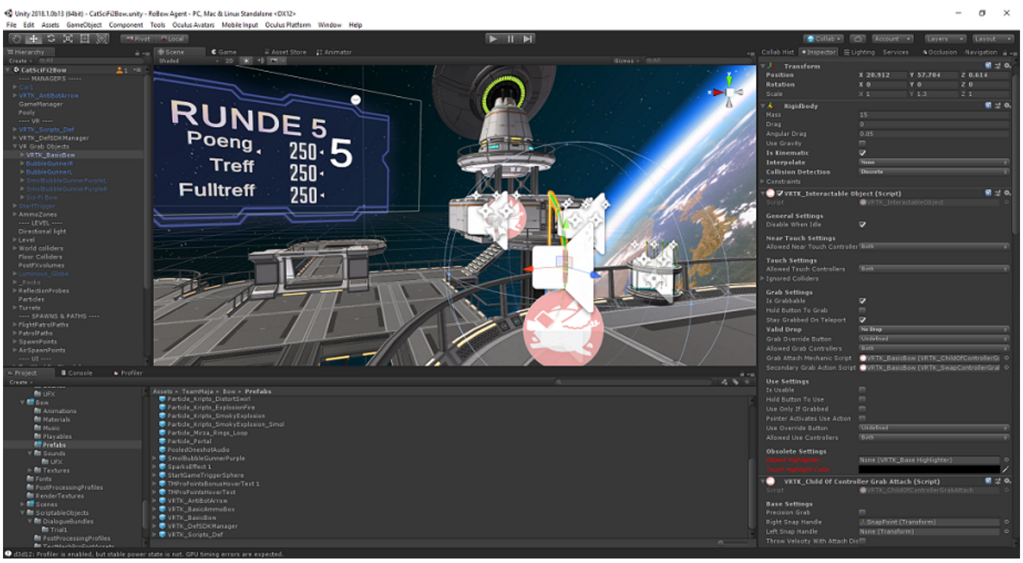

Figure 2.10: The Unity Editor and Scene View

Having reviewed relevant background topics and introduced the framework of development, the next chapter will describe designs and implementation, following a section on the clinical trial.

Chapter 3

Research description and methodology

This will describe the methodology and process going from the specifications set by Sigerseth & Fersum, investigations into VR games, through the prototyping stages, to the implementation that was used for the clinical trial.

3.1 | Single-subject patient study and background

The trial method chosen for the study is Single-Subject Experimental Study (SSED), useful when evaluating treatments or research that is not necessarily suited for a randomized trial and without a control group. [43] The null hypothesis is that there is no statistically significant change in *pain catastrophizing* and fear of pain in NSCLBP patients after being exposed to the VR sessions. Variables of the study are the training sessions (independent), and various daily measures and measures/questionnaires administred at the beginning and end of the interventions (secondary dependant variables and outcome measures). Full description must again be referred to the separate publication, including all medical considerations of inclusion/exclusion, data sources, methodological considerations and analyses. For the sake of contextual clarity about how the trial was carried out, a simplified protocol of the patient interventions will be recounted here, but omissions may occur, and should be.

Notable inclusion criteria at the start of the project were: *LBP, more than 3 months; age 18-65; patient is enrolled in waiting list in primary health care; localized pain from T12 to gluteal folds, provoked with postures, movements and activities; pain intensity greater than 4/10 on Visual Analog Scale (VAS), lasting more than 14 days; and a specified rating on the Tampa Scale for Kinesiophobia.*

Exclusion criteria: *Not sick listed for more than 4 months; no ongoing treatment from physiotherapist, manual therapist, chiropractor, osteopath, naprapath etc.; specific LBP diagnosis; acute exacerbation of LBP at time of testing; visual disorders, dizziness or Paroxysmal Positional Vertigo (BPPV); other conditions*
(Any low limb surgery in the last 6 months; Surgery involving the lumbar spine; Currently pregnant or less than 6 months post-partum; Diagnosed psychiatric disorder; Widespread constant non-specific pain disorder; Active rheumatoid arthritic disease; Progressive neurological disease; Serious cardiac or other internal medical conditions; Malignant diseases; Contradictions to general exercise.)

Intervention protocol, first session:
- Patient is given thorough information on the trial and VR equipment.
- Administering of questionnaires and background dialogue, with clinical assessment by researcher.
*- Patient is given a demonstration of the VR experience with the **First Contact** introductory game provided by Oculus.*
- Questions and further scheduling of sessions.

Intervention with exercise session:
- Patient is greeted, clinical dialogue and questions.
- First exercise game (HoloBall) is played for 10 minutes.
- Short break and questionnaire (VAS)
- Second exercise game (RoBoW Agent, prototype) is played for 10 minutes.
- Short break.
- Final game (HoloDance) is played for 10 minutes.
- Questionnaire is administered. Clinical evaluation, dialogue and session scheduling.

After completing all interventions, patients also undergo a follow-up session with additional health-related data collection and evaluation, which is described further in separate publication.

3.2 | Prototype Design

3.2.1 Initial conceptualization

The initial requirements and vision were presented after meeting with Sigerseth and her supervisor in the spring of 2017. The desired technology would encompass an immersive VR experience that allowed for a tailored exercise regimen to use in clinical practices. Examples were given of existing games being used to motivate patients for training, using reward and feedback systems. Wishing to use a similar product to tailor an approach to NSCLBP, the group requested a prototype game allowed a therapist to tailor an intervention with exercises and experiences from a toolet that was generalizable enough to fit the needs of many NSCLBP patients. Two main module designs resulted from the first sessions, including the flying prototype described below and a larger environment featuring adventurous activities with functional tasks, exploration and cognitive challenges. This prompted investigations that are also described as follows.

3.2.2 Research into VR-technology, -games and -experiences

The research process began by rounding up the existing VR-HMD technology available to the team locally, namely an Oculus Rift and an HTC Vive set. Both had solid Development Kits in circulation among developers already, and major engines like Unity and Unreal had integrated support.

The list below contains brief descriptions of games that were particularly useful in exploring the interaction designs and -paradigms for the prototyping. Since no one in the team were versed enough in the less obvious details of designing for VR, we spent quite a bit of time playtesting commercial games to gather impressions of what best practices and design paradigms developers were themselves using, ”misusing” and innovating to create entirely new ways of playing in VR. Also examined were various *best practices* formulated by HMD-vendors.

Oculus Best Practices [44] is an evolving set of examples, guidelines and design patterns recommended by Oculus, and is informed by both research and experiences garnered from commercial releases through their markets, including desktop- (Rift) and mobile VR (Samsung Gear). Prominent topics include optimizations that ensure a high framerate rendering (90Hz) and navigation/locomotion methods that are at low risk for causing Vection and motion sickness. It is noted that tolerance is build over time on this point, but for our trial this posed some risk, which is elaborated on in the coming sections and next chapter. Many forms of locomotions are outlined

Noteworthy game titles and features:

Eagle Flight is a 2016 UbiSoft title, made with Unity for multiple VR platforms. It lets the player experience high-speed flight through a VE as an eagle, but at reasonable comfort levels, making it a particularly interesting case study for motion in VR. Members of the development team have given several talks [45] on researching and prototyping this interaction paradigm, including citations as [46] , and elements of their design have influenced current *Best Practices* recommendations from Oculus. [44] According to the talks, developers spent a good amount of time on researching ways to make the experience a low-threshold, relatively comfortable means of locomotion without inducing motion sickness. Control of the eagle is done by way of using the HMD's orientation, and its flight path is directly forward relative to the camera and its orientation.

Though innate to any sort of real flight experience, there is no angular velocity apart from a simple camera rotation in the eagle's in-game flight, due to the likely onset of Vection as the inner ear expects a centripetal acceleration during turns (banking). Instead, the motion is given by the rotation around the Y-axis, magnitude of which is determined by the tilt angle of the player's head with a smoothing step (up to 25 degrees). This establishes a relationship between the player's head movement to the resulting rotational velocity, [45] which can significantly reduce the perception of acceleration. As with other experiences involving "involuntary motion", graphical motion-cues (elements as indicators for the direction and magnitude of motion) can help create an understanding of one's bodily situation in space. To further emphasize this, the main Head-up Display (HUD) uses linear particle system elements, arranged to produce a tunnel-like effect, along with ambient auditive cues. A sensation of moving forward in the air results, while actually remaining stationary in real life.

Traditional flight simulator experiences have often required the user to wear some form of head-gear, such as a helmet, and in general, visual input through the eyes will expose some facial features that are static relative to bodily motion, but in VR games, the view to any outside visual reference and facial features is blocked by the HMD. To give a stable reference point in relation to the player's head and orientation, the game fixes an "eagle head" to the main camera, including a nose/beak, and a centered reticle. Similar to viewing the world through human eyes in real life, this "grounds" the player with sufficient reference points to maintain a stable enough orientation during flight (especially banking).

Figure 3.1: Screenshot from Eagle Flight showing a phase of flight in close proximity to the ground and other obstacles, including occlusion and motion indicators. ©UbiSoft

An important countermeasure against motion sickness in VR is limiting the speed and flow of objects and pixels in the player's peripheral Field of View (FOV). Humans and many animals share the trait of being acutely aware of such motion outside their foveal vision, which is known to induce Vection. Experiencing abundant stimuli in the periphery of a virtual FOV can, therefore, be distracting and discomforting. To address this issue, Eagle Flight routinely *fades out* whole parts of the FOV whenever the eagle flies close to large static objects or flies at low altitude above the ground, using a screen-space post processing effect similar to masked Vignette. While flying through particularly narrow spaces, this reduces the FOV to about one third but is otherwise dynamically weighted by which region of the screen is affected and how close the object or ground is to the player. See figure 3.1.

The insights gained from these design elements were stepping stones for the project in deciding what type of motion would be risky for first-time users in the clinical study. Weighing the desired wow-factor of free flight in VR with potential risk factors ultimately led to this aspect being pulled from the first prototype design, reasons for which include potentially triggering motion sickness in particularly receptive patients, fear of heights, and the possibility of discomfort from motion triggering pain experiences in the same manner that Kinesiophobia might, though likely to a lesser degree. Mitigation strategies for this aspect were considered, such as a keeping the altitude at comfortable levels, limiting speed and motion cues, and using a mode of interaction that includes bodily input from the player (see alternative locomotion section of this chapter, NinjaRun) – "keeping the brain busy", as the developers put it.[45] Tolerance is feasibly gained over few sessions in this type of experience, but that can also be a limiting factor for other time-sensitive outcome measures in a short-term trial. In concluding this case study, the

Figure 3.2: Screenshot from Eagle Flight showing a phase of flight in high altitude, no occlusion, and UI-elements indicating areas of interest and landmarks. ©UbiSoft

author notes that motion-oriented game experiences for VR are trending in consumer marketplaces, and great potential for creating immersive scenarios that require additional cognitive processing (which may increase sensory distraction to pain and other discomfort). The game also evokes emotional engagement through it's art direction, storytelling, audio design and game mechanics, making for an effective motivational, sensory-distracting experience. It underpins the importance of considering various psychological as well as neurological mechanisms that are involved in the brain's perception of self within a virtual world, and how the vestibular system's functions must be respected to minimize conflicting sensory cues. Modern techniques have also been explored in academia that allow for sophisticated visual comfort designs, particularly in the FOV occlusion.[47][48][49] Eagle Flight relies mostly on the head-orientation for controls, along with a few select buttons on the hand controllers, but active bodily motion beyond this, as an interaction paradigm, can be enhancing for immersion, and can more importantly decrease discomfort. Relationships between acting neurological-/motor output and the tolerance for motion in the visual field is further explored in the next case study.

The Climb is a title developed by CryTek in partnership with Oculus VR.[50, 51, 52] The gameplay is centred around rock climbing activities in various large outdoor environments, and it's control-/input-scheme is a particularly interesting case of locomotion in VR. Progression through a climb is achieved by *grabbing* "holds" on the rock face in succession, eventually reaching checkpoints and, finally, the mountain top. Early versions of the game was controlled through a combination of gamepad or console controller and gaze targetting through the HMD; the player would center the view at a nearby hold, then press a button, prompting the hand to grab hold. Eventually an expansion was released that included support for the Oculus Touch controllers, bringing hand controls into the player's tracked 3D-space. Once a hold is grabbed, the player uses a dragging-motion to move the camera as desired (toward the next hold, interesting viewing locations on the route etc.). This is similar to games that feature full freedom of 3D-movement with freely anchored dragging-motions, usually by pressing a controller button, while in *The Climb*, a climber anchors this movement on each hold as it is grabbed. VR-designs using this type of locomotion are bound to involve

Figure 3.3: Screenshot from the launch trailer of The Climb. ©CryTek

both moving and accelerating the camera in whatever way a player moves the

controllers, and this found to be comfortable.[44] The question arises - why can this be done at reasonable comfort levels, but accelerating the camera through other inputs, such as simple button presses, immediately poses a risk of discomfort? A possible key observation lends itself to the player's bodily awareness (Proprioception). During this form of locomotion, the player uses his or her own hands to trace the path through tracked 3D-space, maintaining a one-to-one mapping between the hand- and camera motion. A disconnect is therefore seemingly not inferred by the vestibular system as the sensory-motor information from the limbs are taken into account.
The movement is expected and understood in cognition, and is less likely to trigger the illusion of being in motion (Vection), perhaps due to the world seemingly moving instead of the player.

In terms of game mechanics and flow, **The Climb** offers an experience based on strategic movements and placement of hands (no footwork), while also experiencing the compelling rush of an otherwise dangerous, adrenaline-filled activity. The risk-aspects are well represented, amplified by depth and scale in VR, also including the fact that the activity done in-game resembles free-solo climbing rather than sport—if the player lets go of all holds or is overly fatigued, there is no rope or belay to arrest the fall, resulting in what is presumably a fatal drop. Though the screen is faded quickly and resumes at a checkpoint to continue playing, with no violent effects or impact shown, the duration and screaming sound effect are ample to impress a deadly outcome. This deduction of viability for therapeutic use is discussed later in the chapter. Beyond awarding points for progress, flow and technique, other reward-aspects are arguably amplified as well; when the climber completes an ascent, a grand 360° vista becomes viewable before the player. High-end graphical representations can be seen of scenic nature and/or civilization, airborne vehicles, fireworks and celebratory effects etc. appearing close to the player, whose victory shout echoes in the distance. These elements are all well suited to experience through VR. They also arguably meet the need of players feeling a sense of achievement, progression and eventually mastery after performing a task outside their comfort-zone.

As a case for Exergaming use, **The Climb** was found to have pros and cons, but was nevertheless an enlightening game to research for locomotion, interaction, visual design and spatial representations in VEs.

After researching these and more titles, the author and Sigerseth eventually came to test the two commercial titles that were used in the clinical study: **HoloBall** and **HoloDance**.

Figure 3.4: Screenshot from the launch trailer of The Climb, showing one of the canyon vistas that can be seen from the mountain top. ©CryTek

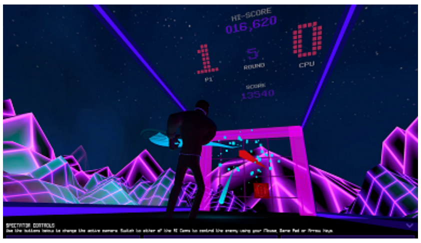

Figure 3.5: Screenshot: HoloBall gameplay.

HoloBall is a title developed for VR by *Treefortress Games.* It features a retro arcade-style (seemingly inspired by 80s sci-fi culture) sporting experience resembling that of the ball game *Squash* with a few key differences. The play area is a rectangular "court" of varying size depending on the setting, no-gravity ball that can bounce off the area walls that surround the player, and an AI-controlled opponent in the main campaign. The goal of each round is to score points by smashing a ball past the opponent and into opposite court wall using the paddles (rackets). Special bonuses are awarded through various game mechanics that reward the player for fast and accurate hits. Boundaries, court size can be adjusted through settings or are set at discrete levels on a particular difficulty selection (easy/medium/hard/extreme). Progressing through each campaign round will also increase some values for the opponent AI, making each round a slightly more demanding of effort. Paddles are attached to the virtual hands provided by the VR software from tracked motion controllers. No button presses are required to hit the ball, and this allows for the player to experience the core game mechanic with their her hands almost immediately as the ball is put into play.

Primary motivations for selecting this game are the sports-like exertion levels that the player undergoes to complete goals, and the nature of the sport that encourages movements in the low back area, through various flexing motions of the back. More importantly, game settings can be set such that the balls bouncing back towards the player can be directed into a customizable zone centred around the solar plexus. Allowing the researchers to set area size based on the range of movement ensures relatively safety and challenge level for the patient. In addition to the discrete difficulties for easy/medium/hard/extreme play, a progression can be laid out that is customized by taking the patient's pain level, fear of movement into account, along with the physiotherapists goal for the session. Besides a main campaign, custom scenarios and a more relaxed "Zen" mode is available for play, affording some additional opportunities if for reason an active sporting session against an opponent is too strenuous or otherwise uninteresting. HoloBall is also simple to appreciate, easy to learn or jump right in and start playing, which is beneficial. For the motivational side of the needs, rewarding effects and score-keeping can be found and heard throughout any session, easily observed in the play area. All these benefits considered, the game seemed cover many of the trial requirements.

With this is mind, Sigerseth and the author made contact with the developer and obtained permission to use HoloBall in the study. A custom build was provided that allowed for numerical adjustment (width and height, given as a percentage value) of how far off-center the balls can bounce back towards the player, or be targeted by the opponent/AI. This was deemed beneficial and important for safety and motivation, as an over-exertion that might naturally occur in a real sport similar to HoloBall or Squash could be overly difficult, trigger pain, be detrimental to the intended effect of the exercise, or even be medically inadvisable for this patient group. The second commercial game, HoloDance, was given the same consideration.

HoloDance is 2016 VR title for the HTC Vive and Oculus Rift, developed and published by *narayana games*. The game is themed around rhythm/music and dancing movements for interaction. Through varied gameplay mechanics, the main objective in a play session is to use the hands to interact with dynamic elements in the scene that are in sync with the music track. An example of a basic interaction is "catching" spheres that are fired towards the player at the same time that the "beat" represented by each sphere is heard. The timing can be determined by tracing the path of each sphere towards a semi-transparent grid that is presented in front of the player, indicating where the sphere should be caught. This grid is customizable in size and vertical positioning, which is useful to personalize the challenge level to each player. As it is a 360-degree experience, spheres can be launched from many directions, and the player must anticipate and face the appropriate direction during gameplay, though most sessions that were tested will cover a 180 span to maintain optimal tracking.

Figure 3.6: Screenshot: HoloDance gameplay.

HoloDance is split in two main modes of play, "Story Mode" and a custom mode. Story Mode is a kind of campaign or progression where each level is a "dancle challenge" in style of sphere-catching described above. The "story" is told in friendly manner, almost whimsical, by a character (a dragon-esque creature), whom also acts as the challenger. Spheres are launched by the dragon from its current position, but often repositions both horizontally and vertically such that the player will have to face many directions to catch all spheres. Both hands are often needed to catch those that impact opposing regions of the grid in rapid succession. Additionally, the adjustable grid position can encourage lumbar flexion and targetted muscles groups to be used. A progression of levels for each session can be set in a similar manner to HoloBall's campaign mode, making this game also ideal for use in the trial.

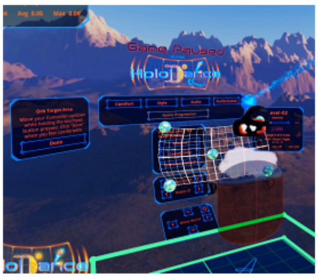

Figure 3.7: Screenshot: HoloDance grid-height adjustment.

In summary, HoloDance is a game that emphasizes enjoyment, a range of beneficial movements, intuitive interaction, coordination and music, and was chosen as the second commercial game–discussion to follow.

3.2.3 Re-selection for clinical trial

Due to the aforementioned delay of the project, it was decided that the author's prototype suite—that was originally intended as the sole product—would be scaled down to three sub-parts: a ball- or racket-sport game, one based on casual/simple archery, and a motion-game for hand- and body-movement exercises. This was further scaled to one of these designs, in addition to two hand-picked commercial games. Having conducted the research into design patterns for VR-experiences and commercially available titles in the project preliminaries, discussions led us to set aside prototypes based on flying and climbing, leaving the development efforts focused on the archery/target-shooting prototype.

Searches for usable titles was done on the marketplaces for commercial games in addition to news and other web searches towards commercial or research-specific VR software tailored for therapeutic use. The latter did not turn up any viable options, which prompted another browse of the Steam- and Oculus-platforms, having also done so early on to familiarize the team with VR. HoloBall and HoloDance seemed the most viable candidates at that stage, and the group reached out to the developers, who were happily willing to allow us usage. Consideration was given to the fact that larger studios and publishers may have an attractive selection of software on the consumer market, but obtaining rights for usage can be difficult for several reasons: the titles are offered, optimized and licensed for personal use only on consumer stores; rights to the titles could be shared between developers and publishers, making it laborious to obtain special dispensations; and compensation might be required even if the studio is willing to allow usage. Smaller studios and indie developers may be more approachable for such requests, as was the case with developers contacted before the study. Besides being generally friendly and willing to help, indie studios could benefit from additional exposure if the games are used in successful projects outside their market. As discussed previously, these two games were found to be sufficiently motivating, encourage relevant back flexion movement, be customizable to safety margins and comfort, and generally fun to play in a manner that encourages patient adherence to the study. Variation of activities and virtual environments was a requirement given in the project specifications, and as such, the two selected games needed to fit into a progression which made room for the prototype game.

In the following section, prototype designs will be outlined that were considered for development, but were either not initiated or completed in any functional sense, before the project's timeframe allowed for the archery prototype (RoBoW Agent) to be developed. The designs are also given for purposes of methodological transparency, research and future work considerations, and did yield insights that were valuable in the project's qualitative evaluations.

3.2.4 Designs and concepts

Sensor technologies were discussed early in the project, specifically which, if any, would be suitable for recording sets of more comprehensive and quantifiable data on body movement (e.g. back flexion, joint tracking). Such data could be used in later analysis and as a part of game mechanics or interactions, where capabilities of real-time data acquisition into the game engine exist. The Kinect, for example, was available for use, and found its way into a select few prototypes, but was generally used as a secondary means to record poses and animations where needed. Combining the Kinect with a VR-setup that included positional tracking was certainly an attractive possibility, because tracking the position and rotations of limbs and joints on the player's body would allow for a more fully animated in-game avatar by using Inverse Kinematics (IK). One concern noted before testing this was noise from either system, as both use IR lighting—the Kinect emits light towards the player's body and inferring structure from it's reflection, and the VR units emit lights in the case of *Oculus Rift* or sense light emitted by the Lighthouse base stations in the case of *HTC Vive*. Using Cinema Suite's Motion Capture plug-in for the Kinect & Untiy Editor (see appendix), output from the Kinect's raw camera and IR layering was used to test this combination. Despite some noise, which was unsurprisingly prominent where the HMD and touch controllers were held (and LEDs on the Oculus Rift), the unit was able to detect the player's silhouette and key joints useful for representing an avatar.

Though the Kinect was not used in the final prototype suite, the potential of inexpensive body tracking should be emphasized, and was pointed out as an interesting prospect from the physiotherapists involved in discussions. Data resolution and noise elimination were not expected to be medical- or research-grade, but was pointed out as a tool for recording/presenting a general movement profile of a patient during an exercise routine, for example, or afterwards to demonstrate patient progress. This led us to question what data sources would be ideal to capture high-resolution data fit for analysis and possible real-time application. One such option available to us at the time of development was Motion Capture.

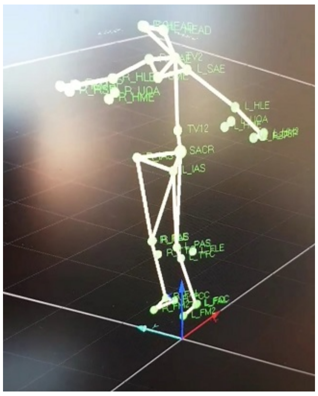

Figure 3.8: Qualisys testing session with mapped skeleton.

Qualisys is a research-grade *motion capture* solution[1] based on cameras and markers for recording and analysing motion data. Cameras are arranged around a space where one or more actors perform movements while wearing markers. The precision needed for medical- and research use is high, and the Qualisys system available for the author and Sigerseth to use has sub-millimetre precision (greater than that of VR-sensors), owned by the *SimArena* research group.

Some recording sessions were done early in the project to establish a pipeline for bringing recorded animations from the proprietary framework into Unity or a 3D modelling suite with animation editing capabilities. The format used by Qualisys was found to be exportable to **C3D**, an open format frequently used in medical- and research fields. An intermediate step through suites such as AutoDesk 3DS Max or Maya was feasible, where the animation could be processed and exported in a common format (FBX), which can then be used directly in Unity. Another possibility was capturing data piped directly into Unity via the Qualisys integration SDK [53], via which a real-time connection can be established with the motion capture software and the Unity editor. This allows for animation of 3D-characters directly, using IK provided by the solver included with the plugin, or other solutions such as *FinalIK*, a comprehensive solution for IK available via the Unity Asset Store (the author did own a license for this during development). Joints that are marked on the user can then be tracked in the virtual 3D-space, and the IK solver will animate the whole character as best as possible depending on how many markers are used.

Potential use cases envisioned for the project include:

1. Animation of a 3D character mirroring the movements of a player as they perform exercises.
2. Recording an animation sequence of a player as they perform exercises, allowing for post-session analysis and
3. Fully tracking and animating an avatar representing the player's own body in the VE. This can presumably increase immersion and presence by having an accurate representation of the player's physical movements (if the user looks down, there's an actual body present that

[1] https://www.qualisys.com/applications/human-biomechanics/

moves as expected, instead of either nothing or an avatar that only has solvable tracking for hand/head positions).

4. Representing a physiotherapist or instructor role as a 3D character, as a guide for demonstrating movements/activities. This can be pre-recorded (as examples, aerobic-type sequences, dance- or rhythmic movements), but using an external sensor such as Qualisys, or a Kinect, or a separately tracked VR-set, a real-time instruction is indeed possibly introduce in a session.

5. In the case of marker-based motion capture, marking physical objects in the real world that can be represented as a 3D-model in the VE, that the user can physically interact with, both in the real world and in VR.

Two prototype concepts included motion capture in some form, though as will be discussed later, larger systems such as Qualisys aren't necessarily feasible or available in most clinical settings outside large institutions, and the Kinect unit has the difficulty in maintaining tracking at all orientations. A possibly limiting factor was the requirement of a full USB 3.0 connection being maintained to transfer data during a session, which added significant load on the motherboard/USB controllers, as the Oculus Rift was configured to maintain 3 USB 3.0 connections—one for the HMD and two sensors. This was indeed the case during test runs, as connections would periodically drop. To mitigate this, one could force a USB 2.0 connection for one or more Oculus sensor towers, though accurate tracking is preferable in large play areas. Presumably, the HTC Vive might have smaller problems due to fewer USB/HDMI connections needed to operate. A dedicated PCIe USB controller card would also alleviate this, and is indeed recommended by Oculus for enthusiasts looking to use more than 2 sensors tracking with USB 3 links.[8] Programatically, one could also separate the Kinect hardware connection to a separate PC and periodically stream tracking data over a less strenuous network connection, though more software modules and the possibility of latency are introduced.

Movement-tracked Prototype 1 had intended for the inexpensive Kinect unit to be used for real-time integration with the VR game, in a movement-based exercise session. Primarily, the integration goal was to ensure the player could observe their own body during play. The possibility for reviewing recorded data along with the patient was considered, especially the joints/bones associated with back flexion, even though the data would be coarse and prone to noise.

Prototyping this was also considered for use at a demo-stand where we would present our project and the associated technology to groups of children. Game mechanics were built around matching the movements of an avatar assuming body poses in a preset or generated sequence (in the style of Guitar Hero, Singstar, Dance Dance Revolution etc.), which the player would then match as closely as possible. Points were awarded when each orientation of the player's joints (as reported by the Kinect) matched those of the displayed pose within a threshold. While the player was positioned properly inside the Kinect unit's proximal tracking zone, this worked generally well, but was problematic in the group setting it was intended for. When more than one person stepped into the zone, the unit would infer several human silhouettes and therefore infer several skeletons/individuals, all prone to noisy data and tracking. For individual use, however, the idea seemed promising still, but would be a demanding effort at the time of its conecption, requiring time spent on recording animated sequences or developing a proper system for animating transitions between poses. To meet the criteria for the clincial trial, one would also need to design, choreograph and vary a selection of tracks or "songs" that would be fun and motivating for the patient groups, while being paced for difficulty as well. It was at the time considered overly demanding to continue this development and meet the deadline of trial commencement, which followed shortly with the selection of HoloBall and HoloDance.

The joint comparison algorithm found in the Kinect Demos v2 Asset package was purposed for the game mechanic, and code was modified such that rotations could be stored in a Scriptable Object scripted by the author for each pose. A random pose would then be selected periodically for the player to match, but no transitions or speciel effects to blend between poses were present at this demo; rather, they would skip quickly or disappear before the next one was selected.

Movement-tracked Prototype 2 was a design involving the Qualisys motion capture lab setup, but was halted and not developed or coded for reasons pertinent to the availability of such a system in clinical environments. Accurate data for analysis and review is a positive outcome of such an experimental design, however, and was thought to be useful for validation purposes. It wasn't immediately clarified, either, whether the system was available full-time for the clinical trial, which resulted in backlogging this concept for development. It remains an exciting technology to apply in future works where an extended availability of high-precision tracking can be applied at least once for each test subject.

Developing of the Archery mini-game was the primary effort resulting from the design phase towards the clinical trial. A description of development phases and methodology will follow.

3.2.5 Hardware

The Oculus Rift consumer edition was used to develop and test the software, with accompanying Oculus Runtime and SDK suite. Versions ranged from May 2017 to current Some functionality to test cross-compatible modules was used on the HTC Vive consumer edition, and the Samsung Gear mobile VR HMD, powered by a Samsung Galaxy S7 mobile device (Android OS). Specifications for the development and trial machines are listed in the appendices—all software tested herein were found to run smoothly on the minimum requirement as given by the HMD vendors.

3.3 | Development Framework and Middleware

A majority of development time was spent inside the Unity Editor, Microsoft Visual Studio for C# scripting, and some select 3D modelling software as needed. It was decided to continuously update both Unity and the Oculus SDK/Runtime as beta versions became available due to advantageous functionality and error fixes being pushed. Both Unity 2017 and 2018 cycles were used, final version being Unity 2018.2. The Editor environment was a default setup with Pro license functionality (collaboration, repository/versioning, cloud build)[2] and a selection of external tools acquired from the Asset Store or open source initiatives—for a full list of plug-ins, customizations and technical specifications, see appendix or external references. *SteamVR* [3] plugin and runtime were used in cases of functionality from Steam, SteamVR or HTC Vive-specifics relying on it, and one frequently encounters asset packages that include scripts that at least optionally uses SteamVR as a layer.

[2] https://store.unity.com/

[3] https://steamcommunity.com/steamvr

Besides Unity, which was the primary candidate engine, some testing and conceptual design was done for use with Unreal Engine, but no actual prototyping aimed towards use was done in this framework, and is therefore excluded from review. Familiarity, experience and disposition of a Pro license for the engine, flexibility of rapid deployment to both Gear VR & Oculus/Vive, and author's existing library of game-ready assets at the time of development, led to a choice of using Unity.

3.3.1 Oculus Rift setup

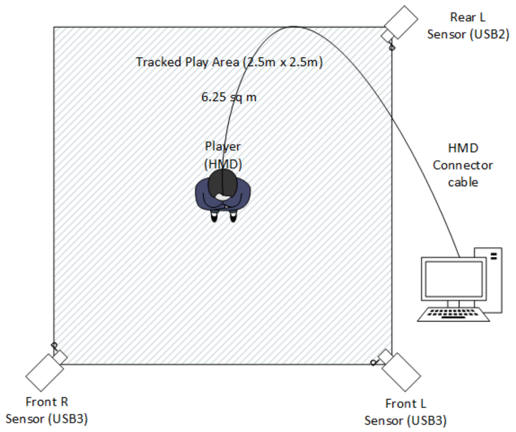

Figure 3.9: Diagram of play area and apparatus placement.

Areas available for use in the trial- and major playtesting events was always in excess of the recommended size. According to the specifications, optimal range is between 0.5 m and 2 m, stating that an *ideal* tracking distance of touch controllers is within 1.8 m—tracking is presumed to be lost when exceeding 10 feet (approx. 3 m). Following the recommendation for setting up room-scale, 360° tracking VR, the play area used for testing and trials was between 2.1 m-2.35 m preferably in width and length, but was reduced to 2 m or below along one side if needed. Two sensors placed on each side of the diagonal is recommended for a two-sensor configuration.[8] As three sensors were available, however, two sensors were used in the front position, with the third sensor at the rear diagonal being the peripheral unit (USB 2.0 connection). This setup satisfies all guidelines for comfort and safety, and ensures at least *good* tracking in all orientations, with an unlikely exception for occluded touch controllers where the user faces the empty corner and holds both controllers close to the body.

Having a clear space of at least 2.5 m was deemed helpful in instilling a feeling of safety and freedom of movement prior to play. Indeed, a few occurrences of overstepping the boundaries during intense play-sessions underpinned the importance of this—see the next chapter for discussion. Before the trial commenced, the group was aware that sessions would alternate locations between a large, spacious rehabilitation lab, and a smaller poly-clinical examination room, the latter being approx. 2.5 m-2.8 m wide. Players would be standing in the play area centre most of time, in all games, but still had ample space to extend their full arm span while moving around.

Flight

In discussing and considering Eagle Flight's appeal and mechanics, we briefly touch on the vision of having a certain "wow-factor" for motivating users from the start when starting with VR. Naturally, not every player will "dream of flying free", but the appeal for of motion that is generally enticing in video games, and was thought to foster potentially useful game mechanics with immersion. Conceptually, the initial idea was to have the patients complete their familiarity introduction with the VR and its control scheme, then introduce them to a stunning environment in which they would take flight and complete exciting challenges. This would need to be gentle enough, however, that risk of motion sickness was minimal, and the likelihood of becoming disoriented, trigger fear of motion, heights etc. would also need to be addressed. A small introduction after seeing the environment would ensure that the player would be fully aware of what was about to happen and how the HMD facilitates directional control.

Eagle Flight introduces the player to steering while flying high above the city to be clear of obstacles, but this can become problematic if the player is uncomfortable with heights, and this did indeed occur during playtesting with a few users. Conversely, starting off at lower altitudes reintroduces the possibility of striking obstacles—this requires special handling in VR, usually a pre-emptive screen fade; simply passing through solid objects or suspending motion due to a collision will be disorienting, and break immersion. A relatively linear sequence of fly-through-rings with aptly paced explanatory cues was thought be the most appropriate solution. This could either be over a smooth terrain, seaside, or above a cloud/fog layer to give a "ground-height" for reference without the fear of impacting it. Also in Eagle Flight and similar games tested with Oculus/Samsung Gear VR, speed is either constant, boosted through a bonus, or altered by pressing a controller button. Bonus boosts are attractive for awarding points, speed and stimulus, but does not necessarily facilitate and additional flex or movements besides the increased speed. NinjaRun, an external Unity asset pack available for purchase, or similar was considered to provide modulation of speed via body posture, specifically wingspan-extension and forward leaning—and from this combination, lumbar flexion. Positions of the hand controllers and the HMD

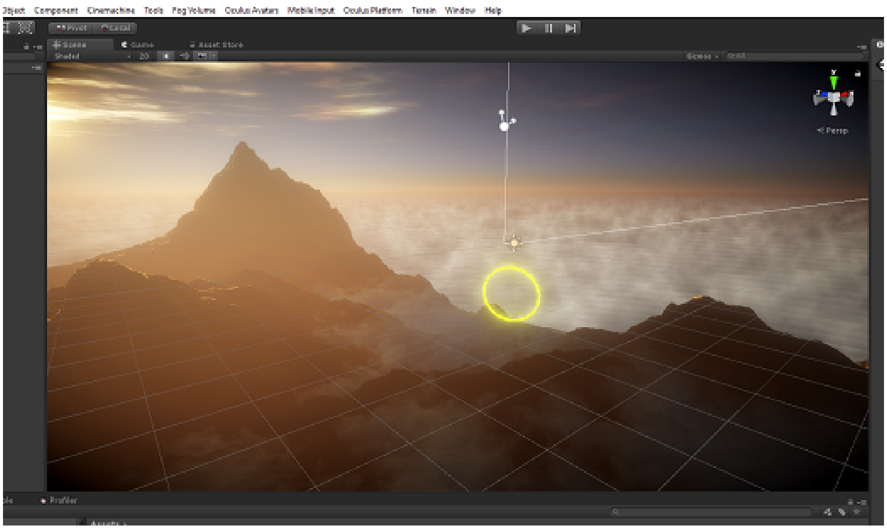

Figure 3.10: Cloud layer from the Fog Volume 3 asset pack.

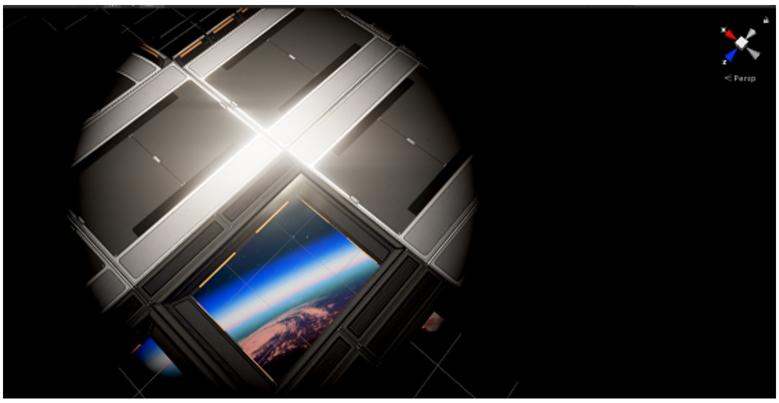

Figure 3.11: Illustrating the partial occlusion using masked vignetting as a post-processing effect (Unity Post Processing Stack).

are considered as a triangle, and forward speed of the player is increased or decreased depending on the calculate area of that triangle. According to the asset specification, using bodily movements to manage the acceleration lessens the onset of cybersickness, to which similar findings exist in CryTek and Oculus' research into comfortable locomotion techniques. Further addition of comfort was thought to be possible using a masked Vignette screen-space effect that was shifted during banking.

The script developed for testing before discontinuing the prototype featured a similar rotational scheme as Eagle Flight. Testing was done partly in high-fidelity environments on the Oculus Rift, but also some minor testing was done on the Samsung Gear VR HMD.

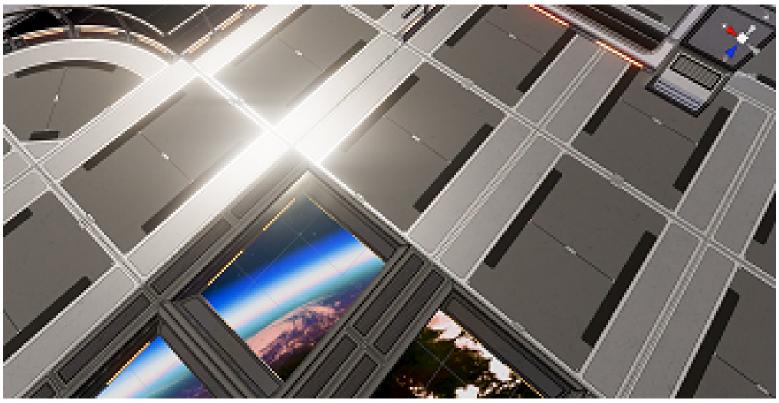

Figure 3.12: The same image with no vignetting

.

Environments used for brief testing were from a few external environment packs, prominently Manufactura K4's Pirate Island. Due to high rendering costs in some of these, the author also created a scenery and island using the World Machine software and Geoglyph plugin, both of which the author had licensed prior, for height-, normal- and splatmap authoring. This was populated using foliage and environmental assets also found in the appendices. This environment also incurred a high rendering cost due partly to third party shaders, Unity's internal terrain system and incompatibilities with the most optimal rendering pipeline in Unity that were unresolved for the flying game. The island saw two iterations with experimental ring targets, and was also populated with a climbing route as shown in the next section. A third iteration would likely use a lower-resolution environment and stylized as "low-poly", while trying to match fidelity with other modules of the prototype.

Climbing, exploration and obstacles

Geometry-wise, the north cliff face of "Mt. Prototype" was a slopy mountainside that was augmented with rock-face 3D-models and foliage. A climbing route using VRTK-supplied demo holds established along these formations—seen as the glowing, yellow glyphs. This was intended as the first easy climbing challenge for the players, where a sense of height would be instilled from surrounding terrain and sea but never require being in a dangerous-seeming free fall situation due to several terracing rock features below for landing. Challenge and encouraged lumbar flexion were attributable to cleverly crafted routes, where such movements would be necessary in order to progress. It

Figure 3.13: Screenshot: Prototype Beach level, flight & exploration environment.

Figure 3.14: Screenshot: Prototype Climbing route

was also thought to rely on smaller ravines and river crossing, where such short climbs would have a safer feel and provide exploratory opportunities in the terrain.

The above designs were either partially developed or scrapped, so we now detail the prototype that was used in the patient interventions.

3.4 | RoBoW Agent

Figure 3.15: Splash screen.

Figure 3.16: An arrow bucket the player draws from using a grab-interaction.

After suspending development of the above prototypes, the archery mini-game ***RoBoW Agent*** was brought to light. Its setting and theme take some inspiration from the retro sci-fi and arcade themes set by HoloBall (and HoloDance, to an extent). Since it was known be second in the sequence of stimuli, it was reasonable to assume the subject would be warmed up from playing HoloBall for the first third of the total duration. Some flexion and targetted muscle movement would therefore be desirable, but with flexible pacing given the 10-minute duration. Sigerseth had initially requested a stage of play where the user must bend and flex to pick up a bow, for example, and then do some less strenuous movements to pick up arrows or shots. Early designs was built from the interaction samples supplied with VRTK using the scripts and Prefab set provided. The bow is a simple model put together by primitive shapes and colliders, using the VRTK API for interaction. The SteamVR API examples also include an excellent implementation of archery, and would in retrospect be an ideal choice, but since more of the VRTK functionality was intended for use in the prototype, a choice was made to use the more lightweight bow implementation and avoid a comprehensive rewrite/port of the SteamVR example scripts. Examples provided with the VRTK library demonstrate a grabbing functionality for both the bow and simple arrows composited in the same way. These scripts were modified slightly and then carried into the prototype scene that eventually came to be the trial scene.

Arrows could be either picked up from a spawner or drawn from a quiver (given by a simple collider and a behaviour/script) that followed the HMD, allowing the user to reload by using a grab interaction close to the shoulders—this resembles a normal movement to what one would expect if using a shoulder-strapped quiver in real life. Given the desire to have a user pick up munitions from either an adjacent side position or directly in front, this was omitted and replaced with two "arrow buckets" (see figure) placed on either side of the user's starting position. This was the main form of exercise mechanic as of the first prototype playtesting (later expanded). For targets, the VRTK primitives were replaced with hovering variants of robots found in the Angry Droids (Bad Bots) asset package. Default Artificial Intelligence behaviours associated with the droids were replaced with simple movement paths, though parts of the scripted functionality was kept in line with the animations, health/damage etc., and modified with apt response to the arrow projectiles. The necessary scripting was put together,

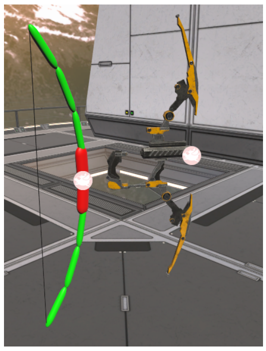

Figure 3.17: In-editor reference shot of the two types of bows: the VRTK example with unaltered look, and the sci-fi bow considered as its replacement.

Figure 3.19: Interviewee draws bowstring (left) and arrow from the bucket (right) during interview & playtesting.

visual effects and audio sources included to perform some testing, and the scenario was put to a simple reduction of an environment obtained from 3D Sci-Fi Environment Vol. 2, consisting primarily of terrain elements. The main level elements were also adapted primarily from the 3D Sci-Fi kit. A subset of the exterior base structures were arranged on either side of the player's position, which was raised to a platform situated above the "archery range" area—the motivation for this was to encourage forward leaning motions during play, especially when aiming for moving grounded targets[4] that were approaching the platform. Primitive collision cubes as targets were replaced with the hovering droids and given origin-centred basic parametric/sinusoid path motion.

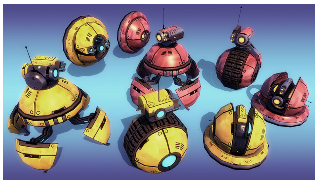

Figure 3.18: Excerpt from the Bad Bots product image, featuring several variants of the droids, including the Walkers and Wall-mounted droids used for hovering targets.

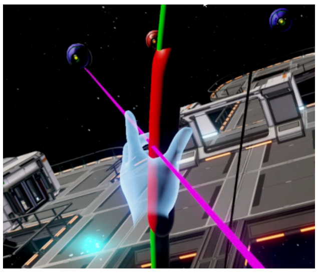

Figure 3.20: In-editor reference shot of the two types of hovering droid targets.

Playtesting This setup affirmed that we were on the right track; back flexion was indeed prominent when the motion to pick up munitions was instigated. Aiming was also found to be ok with a variance in the horizontal arc and short span of distance tracks. The testing revealed, however, the importance of having some dynamic element or variance in the arrow-source placement, such that the player would not remain as static. The author and Sigerseth were also agreed that the height from which the arrows should be drawn had to be adjustable (at session start and/or runtime) due to variances in player heights, their varying level of pain, and their desired exertion intensity for that wave.

One playtesting session in particular[5] reaffirmed this need, and several game

[4]Using the term *enemy* is favoured vernacular in games with combat elements, but author proceeds with using *target* for clarity and simplicity. The game is more like *target practice* despite the use of animated robots, explosions etc., and this was the style reflected in verbal briefings given to the trial patients/players.

[5]My bravest supervisor Remy had the misfortune of playing on an overly difficult setting that put some additional stress on the lumbar region, and paid the price for several days

mechanic adjustments were implemented, to be described below. Some stylistic choices were also established from these sessions and guided the look and feel towards their final forms, and the audio design was revamped to increase the sense of immersion and presence in the 3D environment.

3.4.1 Level Design

The active play area of the environment was designed to be approximately situated within a 180 degree arc from the raised platform. This would be in line with the desire to ensure full continuous tracking of both hand controllers from the front sensors and not have players face the side or rear edges for long periods of time (thus introducing the possibility of tracking loss due to occlusion in 2-sensor configurations). At the time of development, only 2 sensors were in use and this seemed an ideal placement. The open area in front of the platform/player was a semi-large surface platform on which target agents could roam freely when grounded via the surface Navigation Mesh or hover above. Some structures/buildings are placed adjacently to enclose the space and occlude each surface-level Spawn Point. A platform segment was also extended directly away from the player, to provide extra room for depth sense and -cues. The level was tuned and simplified, especially with regards to

Figure 3.21: View of the main play surface, as seen from the player's viewing height.

visible geometry, and intended as simple, stylistically approached (similarly to the other game elements and theme), cheap to render, and easy for players to be oriented within. Since the player was unlikely or unable to move beyond the raised platform, all geometry was fixed statically where possible, locking in the appropriate Level of Detal (LOD) level. Keeping the thematic but

following the test. His sacrifice is remembered.

simple approach was thought to be optimal for both performance and enough occupied space with depth that wouldn't distract the player while aiming for targets.

Spawn Points for the grounded units are found on either side of the main platform–one on the left, and one inside the right tower structure–as well as the far platform in the distance. Grounded targets appearing on any side will converge on the centre area by their defined "patrol router" behaviours. Units moving from the distant platform will therefore afford the player an opportunity to aim deep for extra challanging shots.

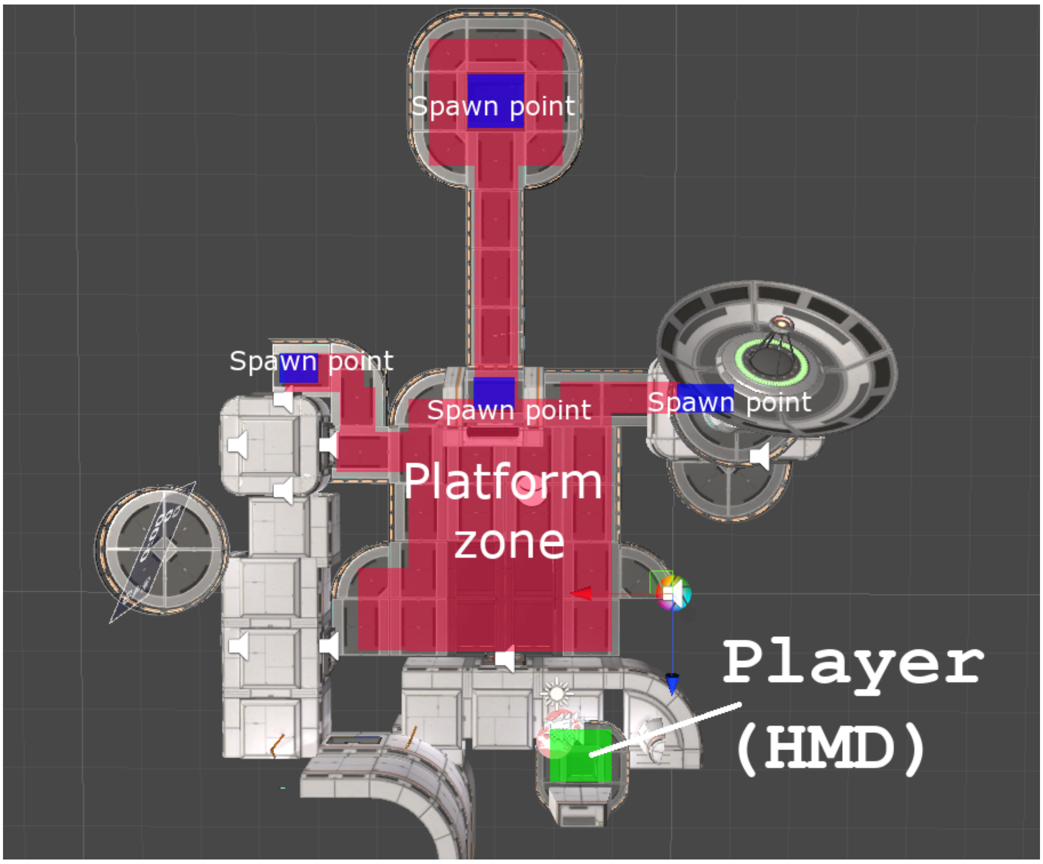

Figure 3.22: View of the main play surface, as seen from the player's viewing height.

3.4.2 User Interface

Interface solutions went through iterations with Unity's native components. TextMeshPro is a comprehensive 3D UI text plugin, a replacement for the native 3D text components, that Unity officially acquired during the development time, and was also put to use in the project. One drawback encountered was the lack of support for the Single Pass rendering path with instancing, though regular single pass was ok (see background). The final look was composited from the UI samples project from Unity, TextMeshPro and CurvedUI (appendix link).

As distances, focus, size and placement are important when presenting information in VR, guidelines from Oculus, Unity and their sources were examined for directions, frequently encountering Mike Alger's thesis project and "VR Interface Manifesto" on UI in VR.[6]

Dialogue and instructional information was confined to a large canvas directly front-facing from the starting platform. Some optional elements appear occasionally in close proximity to the player, and some free-floating elements, but for the most part, this is the main interface for text. A score-keeping and metrics panel was placed above a structure on the left side of the main platform, where it could easily be examined, but would not distract during a wave.

Figure 3.23: Panoramic view of the UI canvas placements

3.4.3 Game Mechanics

Archery is the main activity included in designs from the beginning, and therefore, the bow and its interaction methods have the greatest focus. However, playtesting also led to questioning the full 10-minute duration with

[6] https://vimeo.com/116101132

the arrow-drawing flexion being near constant in each wave. It became quite strenuous to repeat this exercise, even when the game was divided into waves, with brief respites between each. It was decided that some variance to this would be beneficial, and the author included two small hand-held ”zappers”, weapons resembling futuristic energy-based pistols. These are held as such, and fired by squeezing the trigger button, which launches small glowing ”energy beams” in rapid succession. Each weapon has an ammo capacity and must be recharged (unless set otherwise) by touching recharge batteries that appear in front of the player when needed. Both the batteries and arrow pickups in this mode are spawned in a ”field” (an area in front of the player, spanning roughly the same area as the bucket moves within), in which their spawning positions are randomized, such that the player must reach differently each time. Allowing the use of a weapon that merely requires holding in front and pointing to aim provided a different means to muscle engagement, even if notably easier than the full bow-firing motion. The reloading also encourages brief leaning and back flexion when the player reaches towards the batteries.

Figure 3.25: Zappers come in contact with batteries and trigger the reload/recharge effects.

3.4.4 Post Processing and shading

Some post processing (screen-space effects) was used on the scene camera. Primary motivations for using the natively developed Post Processing Stack by Unity was its comprehensive support for the recent versions of the editor, ease of use and optimized shading pipeline, and perhaps most notably, an extremely efficient suite of Anti-Aliasing effects. A modern color-grading solution, ambient occlusion, screen-space reflections etc. are also available from the stack, though the latter two were seldom switched on due to increased cost and largely inconsequential results. o Submorphological and Temporal anti-aliasing effects from the stack were used, favouring temporal Anti-Aliasing (AA) towards the end once a few bug fixes were awaited, and proper support for single pass stereo rendering were implemented.

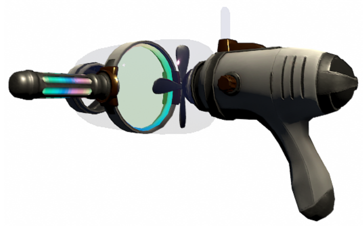

Figure 3.24: The Bubble Blaster, from which the Zapper gun was appropriated and modified.

Beautify, a post-processing effects plugin, was also used in combination with the stack due to its stylistic colour grading and bloom/flares implementation. This made it easy to achieve a look that was cleanly in line with the theme and setting, with a higher appearance of quality.

These were used as provided and not modified by the author.

3.4.5 Scripts, components and plugins

VRTK was a central component to the SDK integration, facilitating the bridging between the SDK and game code. Support for both HTC Vive and Oculus Rift HMDs were desirable. VRTK also handles direct interaction between the hand controllers and "physical" game objects in the VE, including the bow and "zappers". Scripts attatched to the zappers were by the author,

The game is divided into *waves* or rounds that each entail hitting targets until a timer runs out or a pre-set number of targets have been hit, though in the trial, only timed waves were used in order to preserve the 10-minute session goal. Seven pre-configured waves were the most used, lasting from 1 to 1:45min:

1. Hovering targets, slow moving. Moving arrow bucket and VRTK-bow for shooting.
2. Hovering targets, slow moving. Randomized arrow field for pickups, and VRTK-bow for shooting.

3. Ground/wheeler targets on the platform. Moving arrow bucket and VRTK-bow for shooting.
4. Ground/wheeler targets on the platform. ”Zapper” guns and batteries for shooting.
5. Hovering targets, moving slightly faster. ”Zapper” guns and batteries for shooting.
6. ”Reaction time” wave. Stars with VRTK-bow and no arrows. After random wait period, one hovering target appears and randomized arrow appears. The faster the player hits the target before 5 seconds passes, the bigger the bonus given.
7. Final wave. VRTK-bow as weapon. Both arrow bucket and random arrow field available. Wheeler droids on platform are the targets, but also spawns to turrets on either side of the field that periodically launches an innocuous projectile towards the player. No dramatics are

Wave configurations that defined parameters and which weapons, droids and ammo modes used are stored in Scriptable Object form.

3.4.6 Program flow

Due to prototyping schedule, a single GameManager class (singleton) scripted by author manages the flow and main loop of the game, feauring tight coupling with other systems in the scene. According to the wave length or specified win condition for each wave definition, each game starts with a ”cutscene” or dialogue information, followed by a wave that continues until time runs out or other condition is met. Dialogue bundles are defined in Scriptable Object assets.

3.4.7 Sound

Sounds is important in VR, but would not be overly emphasized spatially due to lots of stimulus present with background music.[37] A pooled audio clip solution was eventually implemented ensure spatially blended effects from arrow impacts and droids. The effects used were short blasts and impacts, with a few droid sounds, so as to minimize violent thematics.

3.4.8 Summary

Figure 3.26: In-editor scene hierarchy.

A summary of author's own work in the scene: scene layout, implementation of spawn points, UI helper scripts, game manager object, modifications to behaviour scripts on droids, modifications on behaviour scripts on bow, zapper gun scripts, minor scripting on audio, and Scriptable Objects.

The research, designs, methods and implementations have been given in this chapter, applications and results of which will be outlined in the next chapter.

Chapter 4

Results and discussions

In this chapter we discuss the project's results—what was conducted, achieved, discovered. Its goals and scientific questions have guided all efforts and aspects of research towards our conceptualizing, designing, developing, testing and reflecting on the thesis.

Results thereof are a superset of the particular ones that are relevant for the author's thesis goals. Sigerseth's project executed a vision of applying a consumer-grade VR-technology and -software on a trial group of chronic pain patients with Kinesiophobia. From the therapeutic side, the outcome measures of those efforts are primarily concerned with whether there is a beneficial change in pain experience, fear of movement, psychological factors (beliefs?) pertaining to long-lasting chronic pain conditions, and statistical variance in self-reported ratings on a per-patient basis, grounded with a baseline that is measured at the beginning (refer to said thesis when published). The author's goals were supportive to these desired outcomes, and are grounded in research into the space of VR technology; VR experiences and games; design, methodology and application of *best practices*; attempted gamification of parts of a therapeutic treatment regiment (exercises); data obtained from domain expert interview; and observed, subjective measures grounded in UX, *Design Science*, and HCI. Parts of the questionnaires applied by Sigerseth are relevant, of course, such as open feedback, and partly, subjective comfort reporting[1]—results from the clinical data set, however,

[1]One should keep in mind that with regards to measuring comfort levels in games for VR, NSCLBP patients are likely to experience discomfort not necessarily inherent to VR, the HMD and games compared healthy individuals, and that not all discomfort/pain is bad or dangerous in this type of exertion-based intervention—it is to be expected when exercising and pushing beyond the maladapted comfort zones related to Kinesiophobias.

are forthcoming at the time of writing.

An important part in starting off discussion of results is the lack of specific, relevant data sources on the author's part. Examples of desired sources include:

- Questionnaires (Game Experience Questionnaire (GEQ), UX) and patient interviews pertaining to the user- and game experience.[54, 55]
- More specific sources on the comfort and physiological response to VR, though, as mentioned, these must factor in medical considerations.[34]
- Video recordings with motion capture. In a larger project, this could be beneficial to therapists and patients alike for review.
- Recorded (structured) demographics on technological/gaming/vr proficiency for each patient. If using particular niche products, such as sci-fi themed games, it is of interest to chart users' preferences and disposition towards those thematics.
- Forms of interviews that structure both the researcher's protocol for observation and what questions or feedback are required for the patient. Rigid structure that allows for more generalization across patients, and each subject's baseline.

A factor with considerable weight in the exclusion of such sources is the time-frame that resulted from the author's health problems after joining the project. Since the extent of participation had become unclear, Sigerseth's and Fersum's application to the regional ethics committee for research (REK) was finalized, and was largely unaltered in relevant parts before the trial begun—the regulations are strict to the absolute on each step of the medical intervention protocol (to protect the integrity of the study, including the safety and privacy of patients), and the chain of responsibility for all personnel involved. There were discussed reasons, of course, for not pushing an extension of the protocol, and that this was largely in the best interest of all parties. Motion capture, for example, could introduce data that was not easy to correlate with other findings in the absence of high-precision data, which as discussed in **chapter 4** (and following post-trial interviews in this chapter) was problematic, and would therefore not necessarily be as beneficial towards the primary outcome measures. Similar considerations were given for video recordings, that might possibly lead to overly complex analyses with regards to the primary (health-) goals. One could, of course, argue that the value of these data would be discoverable after the fact, but would still be demanding in terms of medically or therapeutically qualified analysis. They are certainly interesting for future work considerations—in patient education, session reviews, UX/HCI research etc.—and as reference material for observational studies, which could be separated from the health effect studies. The expert interviews posited the trade-off between high-precision tracking with markers placed on multiple body points/-joints, and the lessened comfort of no or little clothing worn due to bare-skin contact points (advisors did suggest tailored clothing similar to ski-suits or those worn in cinematic motion capture). They also pointed out that these markers had a tendency to move, slip or be displaced from joint movements and dermal elasticity during sessions, which would render them unstable or prone to inaccurate positioning in a prolonged exercise session. The likely scenario of interest considered for the project was a set of reference sessions at the start and end of the intervention set to compare a subject's ranges of motion. Further separating this from a virtual environment to the allocated lab space available to us with Qualisys could provide the advantage of having a subject do movements outside the confines of a VR tracking volume (affording a short walking-/jogging-distance etc.). Given non-trivial downsides to the approach, and the lack of alternative apparatus that matched the desired data precision, no motion data was recorded per protocol.

In choosing a single-subject experiment, aspects of the trial were also expected to be varied for each patient. This includes special adjustments made during each intervention based on the patient's pain level, for example, and would prompt the physiotherapist to adjust protocol or parameters during play, or the patients themselves wanting to play a particular mode, level or difficulty. All in all, there are many varying factors inherent to the form of intervention used: adjusting the experience per-patient per-session, game experience/engagement will vary by pain level[2], enjoyment, patient's own situational sense of engagement with stimulus/immersion. And these are, of course, influenced by qualities of the game design, its immersive factors, degree of comfort designed for, challenge level, comfort afforded by apparatus, and motivating elements (all of which we would ideally want to measure). With stimulus likely to vary as much over the patient group, a general analysis across all participants seemed less feasible. Instead, the author elected to focus on the motivational benefits provided by both the game experience and quality of the part played by the prototype game in the interventions. An assessment of this was deemed to be best given by the physiotherapists as expert users, providing the greatest value of data with the time that remained. One should also consider the volume of data sources that each patient had

[2] which sometimes would require skipping parts of or a whole game if the movements involved were particularly problematic for a given patient.

to contribute to if more were used, which could be slightly overwhelming over time, break the motivational factor of enjoyment/play, and could also introduce some analytical distractions for each patient if they were continuously asked technical questions about the experience they were undergoing, keeping in mind we want the user as motivated and closely engaged with the stimuli as possible. A subjective measure of engagement, interaction proficiency and enjoyment could be partially observed by the researchers and collected from unstructured feedback requests or unsolicited comments given by the patient (frequently given as they were eager to contribute), which is a broadly used form of observational study.[56] Changes in behaviour and thus data-quality as a result of observation-aware subjects is usually modelled as the *Hawthorne effect*, though there seems to be some dispute as to its validity when discussing empirical evidence.[57, 58, 59, 60] Regardless, we should give some consideration to a misalignment with other goals if data sources become intrusive, even if a HMD affords significant distractions to the surrounding environment.

Pursuant to the project goals, we sought a consumer-grade VR experience that is potentially usable in clinical practice. The behavioural changes and exercises that clinicians may deem critical to the successful intervention in treatment of NSCLBP patients often occurs outside the physical bounds of the clinic, such as when exercising, performing everyday activities made difficulty by the condition, and pushing past the discomfort and fear that is inherently not dangerous.[3] The case for consumer VR in both clinical settings and for home use—possibly a tool for patient education—has some justified merit that further discussion will attempt to establish. Motivation remains a keyword for success and patient adherence.[4][42] We start by discussing some observations from the trial, and will cite the expert interviews further along in the chapter with specific discussions on motivation.

[3]This is emphasized by an expert interview discussed in section 4.2. During a line of questioning about the prospects of using VR with wearable sensors and data-collection capabilities at home, indicating that data on how much a patient is moving when *not* doing prescribed exercise can be the most interesting measure.

[4]Meaning adherence to a clinical treatment- or exercise regime (which is traditionally low in treatments of NSCLBP patients) as prescribed by clinician(s).

4.1 | Clinical study

4.1.1 Participants

A total of 10 patients were recruited for the study (n = 10, 8 male, 2 female). 9 patients completed all or most their interventions as scheduled, with some adjustments and max. deviation of 3 sessions; 1 patient attended more than half before withdrawing for medical reasons. Age span was 22 to 63—a good sample range, though a balanced male to female ration would be ideal. With reference to Sigerseth's publication, some inclusion criteria were modified before startup due to a shortcoming in patient numbers that met the criteria. Primary adjustment was the fear of movement, measured on the Tampa scale. Approx. 9 sessions were allocated to each case (nearly all of which were attended by the author), averaging 1 hour each including $\tilde{3}0$ minutes of VR time, not including preparation, rigging and calibration time. Session data and daily measures were collected by the clinician at each. Again, role in the trial is noted be assisting and to provide technical assistance and advisory on the game experiences and their settings. All final calls on parameter adjustments were medically qualified per protocol.

Only two participants were familiar with desktop- or console gaming VR (though not extensively), while a few more had tried a mobile HMD briefly. The project's inclusion criteria screened for factors that could be potentially problematic to the VR technology, such as fully functioning stereo vision, inner ear conditions (vestibular) etc.

Observations were noted per patient, but the author must concede to finding it difficult to maintain sets of observations for each patient. When evaluating interaction by repeatedly observing motion and gameplay in a clinical setting (albeit neutral), some focus tends to shift towards observing ranges of motion, expressions of (dis-)comfort—the clinical dialogue also influenced how observations on gameplay were qualified, as intended. This did become a pattern of observation due to the clinical focus of the trial, and author regrets not maintaining consistent notes on specific interactions from each session. It is certainly tempting to observe and discuss how health conditions specifically modulated gameplay interactions, but while interesting to the observer would not necessarily be sound arguments grounded in this thesis' domain. Unless otherwise noted, the basic patterns of learning, adapting to and playing the games, however, were repetitive, and largely uninteresting to dissect per-user (unless sometimes considering individually health-related information). The observations detailed below will also describe deviations from the norm. When references are made to **pain ratings**, this indicates the values reported by patients on the VAS, which is recorded twice per session, and on the *daily measures* forms filled out by the patient at home.

4.1.2 First encounter

This experience is the "tutorial" app provided by Oculus and familiarized the user with HMD use, tracked controllers and interactions within the VE. Its second module is a VE populated with interactable objects that are handled in ways relevant for the Touch controllers, and also features a friendly robot character that guides the player.

All patients as observed completed the **First Contact** experience without problems. There were no sudden movements or far reaches/flexion encouraged therein, and none of the users found it to provoke unusual discomfort or pain. For the researchers, introductory sessions were interesting to observe, being for most of the users their truly first contact with fully immersive VR that allows for room-scale movement and object interaction using familiar hand gestures. Not all participants fully grasped the subtle instructions given, so some verbal assistance was needed occasionally, but the important process of joyful discovery was left to the user, and the experience of which was often expressed verbally during play, though still seemingly immersed in the experience.[5]

We noted that the grabbing interaction, which on the Oculus Touch controllers are located along the grip-positions (see Figure 4.1), took the most time to get right, where users would often enclose their entire hands around the controller and squeeze the trigger button as well—not necessarily problematic, but some interactions in **First Contact** are sensitive to open-close gripping, and is relevant to grabbing bows, zappers and arrows in RoBoW Agent—and the grip button would sometimes be constantly gripped (which actually does achieve a grip interaction in some cases, including RoBoW Agent, since the code may only check whether a grip is being performed when the hand

Figure 4.1: Oculus Touch controllers. The grip buttons are located along the handle. (Image: Oculus VR)

[5]The researchers were often prompted for help if the animated visual cues were insufficient to advance the tutorial. For example, the correct hand-waving motion or how/what to pick up.

touches/collides with an object). By encouraged design, virtual hands pass through solid objects rather than collide and not follow the continued movement of the player's physical hands.[44] It is therefore not obvious that the grip should be released before touching the object without further feedback, especially if the player unknowingly grabs continuously.

Having observed all the patients through this first encounter, it seems reasonable to conclude for the trial that having an introductory experience that covers all the interaction mechanics relevant for the trial games was beneficial. In addition to an enjoyable and motivating start, it presented users with the "wonders of VR" in a safe environment that fosters playful interactions (and some social contact with the friendly, cautious robot).

4.1.3 HoloBall

All patients were able to have a varied experience while playing **HoloBall** in their sessions. The game's variance in difficulty and game modes was found to provide ample opportunity for the patients to perform the training even when their daily self-reported pain-rating was in the higher end. *Zen* mode (no opponent) was always used as first gameplay encounter to engage safely with and gauge the patient's response to the paddle-ball gameplay. Little instruction was given or needed apart from how to enter each mode, assume the centre-position to ensure visibility of the ball (frequently strayed from, requiring a look-around to find the ball again). This game was the first experience entered after First Contact, and how fast or easy a player is able to start playing does speak to a strength in simplicity. After the game is loaded, only a few seconds is needed to step towards the correct menu choice, push twice, and appear in the ball court/play area. Pressing the trigger button to spawn a ball and hitting it is all that is needed afterwards to begin. In order to tone down the sci-fi theme and plot of the campaign, so as to not put off players who would find the theme unwelcoming, little explanation was given by the researchers concerning the underlying "plot" or theme when briefing patients, unless specifically asked for. One of the experts (health professionals) interviewed also indicated to being estranged by the theme. Trial participants gave mixed feedback on the visual style, some being positively predisposed from gaming experience or the visual style, but most enjoyed the effects that are given in response to in-game events, and questions on the style were not routinely asked.

The setting for horizontal/vertical range was, on average, set between 70%-80% and 20%-35% respectively. A starting setting of 70%-20% was found to be cautious for all patients and conditions, not leading to overreaching or overstepping, unless clinician indicated additional risk to a particular case. This was established throughout early sessions.[6] Patients that were eager to be challenged had these values adjusted, but seldom above 30-35% vertically, as increased game difficulty provided more than sufficient increase of exertion and health-wise benefits without risking overly antagonizing pain-sensitive areas. Conversely, cases with good ranges of motion could increase these values, but keep a lower difficulty setting, to elicit broader movement patterns with less emphasis on speed/power etc.—less significant muscle/joint loads during exercise—but the former strategy was prevalently chosen. On average, pain levels in the upper range of the scale would default towards playing *Zen* mode, especially at a 7 or above pain rating, and *easy* campaign mode. In the average and lower ranges of pain level, the clinician would instruct or recommend settings per case. The patients' wishes, if any, were factored into these decisions, and deemed important to engage them as players. A useful observation was made when testing horizontal ranges of 65% or below: the setting would often require either sidestepping, rotating the body to a more side-facing stance, reaching forward or swinging downwards towards the floor (similar to a smash) in order to deflect the incoming ball, since the ball would likely move towards or near the solar plexus area. Once adapted to a shallow range, however, movements tended to slow down as predictability increased. Experimenting in the vertical range was given the most situational judgement, as this was likely to elicit more back strain. Lower vertical ranges had more of the intended benefits to movements, while the higher ranges that resembled those in regular play of **HoloBall** were significantly harder, with full body movement. High vertical range combined with high difficulty was never set during the trial. See Figure 4.3 for an example, where the author had to leave the ground several times and aggressively reach in all directions to catch while playing *hard/extreme mode*. Increased power is also needed to beat the opponent. Not all test-players outside the trial were as mobile, but the exertion required to win at such settings was found to be much greater.

Three patients who were often in the higher ranges of the pain scale would sometimes during early sessions elect or be instructed to play without an opponent for the full duration. While repetitive and foregone of the 5-round progression, these patients still indicated an effective exercise experience, as observed. One patient even found a competitive element to bouncing the ball

[6] Adjusting range values more than once during a session was done a few times only, where the initial settings did not have the intended effect or deemed unsafe. Since the setting was made in a .ini file outside the game, adjustments would also require a restart to take effect.

Figure 4.3: The author plays HoloBall on high difficulty setting with no restrictions on vertical/horizontal range.

as long as possible without missing any returns, which in regular play would mean a victory point for the opponent—the game does indeed display this count in the UI. In *Campaign* mode, there is also a brief respite between a round victory/loss, but while in *Zen* mode the ball is continuously bouncing until the player stops or misses a return. Those who played with an opponent in the regular mode reported both to be captivated by the gaming aspect, or motivated personally to engage in challenging gameplay. One stated that he was likely to *overexert* once there was a game objective to win, score to beat etc., and this carried into the other two games as well, despite a clearly worded anticipation of pain-response.

The Artificial Intelligence/opponent would, as described previously, become progressively more difficult to beat. Generally, this provided a steady increase in challenge at a pace that was motivating due to each round's average duration. Since each play session was set to 10 minutes, several such progressions could be played, allowing time for second or third tries after a win or loss. The highest intensity of play were conveniently observed at the last rounds where the opponent's speed- and power-increase are at their maximum for that difficulty setting. The last rounds were therefore an element of unpredictability and

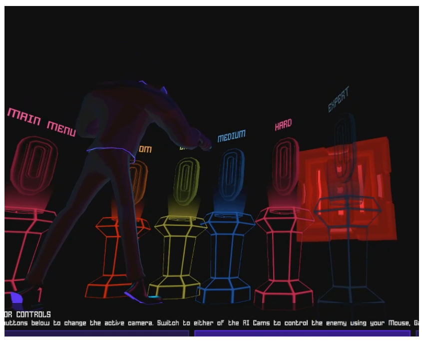

Figure 4.2: HoloBall main menu.

excitement that challenged even the players that easily beat the previous rounds.

Besides gameplay and visual style, the audio design did not yield many specific remarks or feedback. Patients did at times adjust the "headphones" in order to communicate with the researchers, snapping them to a position close to but not in direct contact with the ear. This applied to all the games, not just the first, and since clinical focus took precedence over maximized sensory distraction (risking discomfort or negative affect anyway), they were not *instructed* to maintain full attention to auditory stimuli from the HMD.

We suggest that the game was a valuable experience for the trial goals based on the sessions that were observed, and met the requirements for safety. Not all aspects of the game appealed to all users, but the experience was adhered to, presumably by a combination of exercise motivation, sensory distraction and motivated adherence to the treatment session. Patient remarks concerning their perception of how useful the game mechanics were as exercises tended to be in the positive, but also varied as the sessions progressed, and were often compared to the two other trial games. This can be seen as natural, since the progression introduces some variation to both gameplay and motion behaviours. Difficulty progression as defined by protocol/clinician and a patient's beliefs about their own condition could also influence how relevant or useful they perceive the exercises are. *HoloBall* as partly a warm-up game could also have some influence on this because of its place in the sequence. While it would be interesting to discuss these remarks and observations towards more definite conclusions, this would require more meticulous record-keeping of the remarks than was accomplished.[7] Following a warm-up and several more minutes of challanging gameplay, the next stage of the protocol is a short break for a questionnaire before starting the developed prototype game.

> "Today I'm going to beat him!" (Patient, female, 40s, close call in difficult match)

4.1.4 RoBoW Agent

Observations pertaining to gameplay of the prototype are divided into the categories listed below. In reiterating the design goals, we sought gameplay that keeps the players engaged and motivated, facilitation of exercises

[7] And probably clinical training.

that are physically demanding and elicit some lumbar flexion, and sufficient stimulus to facilitate pain-distracting cognitive activity.

Due to the demand of technical assistance in the early sessions, significant attention by the observer had to be diverted towards safety assurance, assisting the clinician and patients, noting performance issues, bugs, design flaws and smaller improvements that could be corrected while maintaining gameplay consistency to future sessions.

Instructions with visual cues was found to be one of the most improvable areas of the prototype. Only a few changes to the technical side of the interface were introduced, and some text clarified. Feedback and verbal queries during sessions were mainly concerned with what the current objective was and how to interact with the "weapons". Once accustomed to after the first time, however, less feedback or instructions were asked for in the following sessions.

Gameplay

An improvable game mechanic for firing is the implemented laser-aim which was kept as a linear line renderer, from which some confusion was felt by players as the parabolic arrow trajectory became apparent. Adapting to the gravitational effect was not seen as problematic, and a modified aim was immediately adopted. By the verbal remarks recalled it seemed to be a moment of comical discordance, but both the author and several players agreed that either a curved aim guide or less pronounced straight-aiming laser was desirable. Possible frustration must be noted as a counterpoint to an "added challenge". Following this, the players were made aware of the function that switched off gravity for the arrow projectiles. There was some variations on the preferences of a small added challenge associated with the modified aim or the speedy aiming that the no-gravity with linear aim offered. By default the gravity-influence was switched off during the first sessions of the final two patients; they would habitually prefer that it remained such. Extending the renderer with predictive path rendering, based on the bowstring pull distance, is expected to have provided better starting intuition.

Motion

Two primary interactions occur during gameplay: picking up arrows or batteries; and firing one of the weapons. The researchers attentively observed patients during these interaction phases and noted the following findings per motion type.

General Reaching, observed randomly to either involve stepping or performed from stationary centre. Not consistent across sessions, but seemed habitually consistent per patient, unless otherwise suggested. Response was noted to the researchers' verbal encouragement to "use the room" and "move freely" if they seemed stationary during play. This cue was given sparingly, aimed at users that signalled painful sensations when being overly still and reaching far for an item, and to those in lesser pain that could benefit from increased exertion relative to how they were playing the game.

Bow grab Per default settings, the bow spawns at a position to the rear left of player's origin. Patients would often take some time to look around at the start of a session and notice the bow, but often a verbal indication as to its location was necessary at introductory sessions. Then, depending on the player's handedness, they could initiate either a turn and reach, turn and walk, but usually defaulted to a far reaching motion for the grab. In almost all cases (sessions), some rotational movement was used for the grab. In subsequent bow-waves, bow spawns near its last location before de-spawning, which occurs at the end of each wave. This was initially thought to be an undesirable side-effect, and a code routine to restore its origin transform was implemented; however, during the following sessions, patients were observed to initiate another searching scan and subsequent rotational movements that were sometimes interesting. A small, but useful trait of the unpredictable appearance of the bow. Re-spawning code was therefore kept intact for the remainder of sessions. In hindsight, randomizing its location with a visual indicator could have greater value, or even animating with a Bezier-Tween along the guardrail. The bow's hand-switching function sometimes required a verbal instruction but was not problematic, and was often discovered by accident or inference. It was actually patients in lesser pain that were not so stationary that took steps forward towards the weapons in moving freely, and grabbed them with less strenuous flexion. This could probably be a setting for calibration or difficulty.

Secondary weapon grab The "zappers" did return to their origin because a random rotational transform resulted in a bit more unnatural appearance on re-spawning (due to the straight-forward aiming involved in their use). A randomized pickup would again elicit more movement and scanning, but due to their intention of being a ”pause” from the strenuous bow motions, the return to origin was implemented. Their positioning close to and above the guardrail was found to have even the freely moving patients do a forward-leaning reaching movement, possibly so as not to get ”too close” (particularly one patient with a fear of heights)—mostly by rotational flex due to the zappers being slightly above the deck (at a ”neutral” height), but two in sequence. This would still be considered as beneficial.

Arrow bucket and -field The two-bucket configuration was removed as noted previously, and an animated single-bucket setup was implemented with Tween animation as of the third session. Height above the deck was set to be adjustable in increments by a keystroke, but in the final month of testing this became prone to some bugs because of intricacies in the *DoTween* library. Several patients asked where the boundaries of grabbing begun, and visually clarifying this is thought to be a candidate future improvement. It can also be made more dynamic and visually enticing by animating the arrows within the bucket for dynamic cues or, if the physics impact is sufficiently low, grab individual arrows instead of spawning one within the grab volume. Subtle animations were introduced but noted aloud by only one player. Grabbing munitions from the moving bucket was a simple but observably effective way to elicit varied flexing motions during play. The same was reported and observed in the volume that spawned floating arrows at random locations. Raising or lowering the bucket on command was deemed to be an extremely

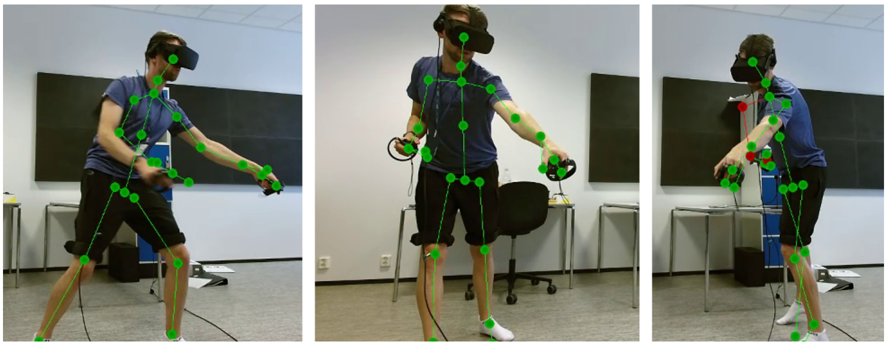

Figure 4.4: Illustrating arrow-bucket grab-interactions with different reaching motions and Kinect overlay.

useful feature as it enabled the clinician to assess patient responses during exercise and prompt for a less strenuous reaching motion. There were some technical problems with this function in the later stages of the trial that were presumably due to caching of the Tween animations.

Bow aiming and firing A shallow firing-stance was observed even in the first patient, whom had initially presented with a high pain rating. This patient had a "benign" stance, however, and there was significant variance observable between users. The bow script/-model used was neither flexible nor scalable in its form, which allowed for players to draw the bow string far shorter than the full span that their body-build allowed for. The short draw and hand being positioned close to the chest at maximum results in a body rotation that is more forward-facing, relatively, than the side-facing posture associated with an archery shot. Generally, we sought more rotation on the simple basis that increased movement is beneficial, though this particular stance is not necessarily associated with a design goal for targeting the lower back. Due to the relative height above the targets, however, forward-leaning aiming stances ranging from subtle to clearly pronounced could be seen occasionally when aiming for the platform-bound wheeler-droids. Encouragement was given verbally to the participants to draw the arrow further back, sometimes qualified with a conditional – *"if you feel like increasing the pace, or if the motions feel to easy, try drawing further back"* etc. While no specific remarks of it were recorded from sessions, it would seem that it could be an element of a strategy for rapid firing, and thus a lower threshold for adapting a technique for releasing an arrow as quickly as possible. Rapid fire does allow for a higher pace, observed frequently when trying to get in the best possible points before time runs out. The higher pace in such cases entailed more rapid and aggressive movements—increased exertion followed.[8] Leaning over the guardrail was sometimes observed here also, so as to get a good aim for targets that were occluded by the roof structure that spanned a section just below the player's platform. Though it would technically be possible to cross through the guardrail without much consequence, apart from the possibly unsettling sensation of "walking on air", this was not observed during play, and was by design positioned towards the play-area threshold.

Motivation We can only infer results on this point based on the patients' own feedback and the researchers' perceived goal adherence, enjoyment and engagement with the experience as influenced by the health-related factors. This must also be balanced by factoring in the sacrificed objective rigidity in the absence of control groups and possibly biased analysis, personal encouragement via patient dialogue (dynamics in the clinician-patient relationship). The point of motivation would be particularly interesting to infer based on forms on a per-session basis, as this could potentially speak to measures of

[8] And an exclamation of disappointment or success if the target was hit or missed at the last moment.

progress, adherence and UX related to positive or negative affect. Arguably, there are elements of intrinsic and extrinsic motivation associated with the trial goals and the technologies applied towards them. If successfully tailored or adapted, the experience should be intrinsically motivating by way of providing motivational bases through game mechanics that are interesting to the player, and supporting to their health-related goals and interests. By way of assisting the clinician and providing a framework of rewarding stimuli, the extrinsic motivational aspect should also be present, or at least facilitate assisting dynamics to the intervention goals.

Inference from the patient's verbal responses is the most valuable data acquired in this aspect. In the cases where patients seemed engaged and "motivated" following a session or particular game, or reported this, was observed. Again a notable element to this was the urge to beat previous score values.

Audio Few feedback elements were recorded on audio. Those who remarked the music, for example, indicated that it was upbeat, engaging, but did not remark as to taste or preference. Sound effects without spatial blend were noted on occasion to be confusing, and overall audio design is an improvable aspect of the prototype, particularly in auditive cues that accompany instructions and information.

Software stability Bugs that caused crash and instability were unfortunately encountered, likely due to scripts that were affected by upgrades in the SDKs and Unity versions, and some physics optimizations. The post processing stack also had some unexplainable problems, so a switch was implemented to turn it off at will. Other crashes were worked around to the best of our abilities.

Level Design and Environment

Level design will be further discussed in the expert interviews, but author/observer notes that the design should be interchangable with other environments, which some patients remarked as well. The environment was generally navigated and oriented around comfortably by all players, though as expected, the settings, colour profiles and thematics were not to everyone's liking. Despite this, stylistic consistency is suspected to have retained some positive engagement. The author has noted that a variation in the hovering targets' altitudes could be an interesting mechanic for the player's movements. A larger open space for ground targeting that spans equally around the centre is also thought to be a positive contributing design, should a 360-degree experience be desirable.

The structure of challenges/waves seemed to have the intended effect of varying the game mechanics and short breaks due to the aggressive flexion-motions seen during development, though the 1-2 minute durations may have led to an impression of being abruptly stopped when playing for the first time.

Comfort Having resolved some latency-causing issues, the software seemed to mostly be consistently rendered. Most other aspects of comfort were observations related to exertion and pain responses. We also observed one patient with acrophobia (fear of heights [23, chapter 6]) display discomfort as the sudden transport into the RoBoW Agnet environment occurred. Since the intitial design was implemented using a simple scene loading that immediately beings without a fade-in or similarly gradual onset of visual stimulus, the patient in question would sometimes "appear" in the VE close to the guardrail. This was later mitigated by introducing a splash screen and fade-in (which didn't always work), but was initially addressed by reminding the patient to take an extra step or two backwards as the game loaded. This is comparable to the patient's response to a VE in HoloDance where the dance takes place significantly high above the ground; the environment was adjusted to and accepted by patient, but again, the shock of suddenly appearing sky-high even with the virtual dance floor was observably, and verbally reported as, unsettling.

Further discussions will follow in the domain-expert interviews. Following a short break, the final session game was launched.

4.1.5 HoloDance

HoloDance was observed to elicit motions primarily with extended arms, and some rotational movements and flexion. With the added challange of incoming spheres, additional hand-eye coordination challanges were prominent. Remarks of surprise and challenge were observed when the pace was high, starting with joyful surprise and concentration. Cognitive distraction seemed prominent. Overall, rhythm- and music-based play facilitated significant engagement, even if, at times, the narrative, characters and songs seemed a bit or weren't to their personal liking. This is not strictly necessary to elicit engaging gameplay-experiences, which was frequently indicated as net result.

Ability to adjust the grid height was found to be quite useful, and tailored the difficulty to patients of varying height and pain levels (or desired muscle exertion). The observations made here are brief, but suggest that the goals set for using HoloDance were met, and it features game mechanics, immersive qualities and tailorable elements of exertion.

4.1.6 Hardware and Software

Hardware stability (HMD units and sensors) was generally good during trial and development, but occasionally low software stability yielded some unfortunate events. HoloBall generally performed consistently with the single version supplied for us by developer that enabled customization. For HoloDance we only noted a few bugs that required restarts and procedural adjustments, some being attributable to the SteamVR/Oculus runtime, and these were either worked around or fixed in updates.

4.1.7 Development

In assessing the development portion of the thesis, it is reasonable to ask to what extent the selected hardware, game engine/Framework, plugins, SDK and assets performed when compared to the specifications. The prototype ultimately featured in the trial was rushed in order to make the trial start, and as such suffered most of the developmental- and performance flaws that such workflows produce. Prototyping involved mostly relying on fragmented code and assets provided by other publishers, such as VRTK for inter-SDK bridges and additional interaction mechanics for VR, along with its supplied demo-prefabs (archery included). On top of that, interoperability and dependencies quickly became an issue in the lack of time to write or fully re-write the functionality in S.O.L.I.D. style. Components in projectiles, for example, directly interacted with behaviour scripts in their intended target objects, rather than message- or event-based data propagation of such interactions.

Code-wise, the same can be said of the coding principles and the agile methodology. Overuse of the Singleton-pattern is often encountered in Unity projects, mainly due to the way that MonoBehaviours and Component/Entity patterns are more prominent that a pure Object-Oriented scene-graph structure in Unity.[9] Many demonstrated best practices for this type of game was found sporadically during development. Revision and generalization of prototype modules stands as a strong desire for future work and applications of the designs discussed in this chapter.

4.2 | Domain Expert Interviews

4.2.1 Premise

Two interviews were conducted after the clinical trial. Both interviewees were categorized as experts in the health domain, specifically physiotherapy, and were affiliated with the Faculty of Health and Social Sciences at Western Norway University of Applied Sciences (HVL). Four were initially considered for interviews, all physiotherapists, but the remaining project time did not allow for this. The narrowed selection had some influence on the interview form that was used. Ideally, a UX- or motion-test with numerous users would be used for gameplay evaluation. However, with the time remaining, and the limited coverage gained from background research, the most value was thought to be gained from an evaluation that focused on the health-aspects of the prototype. Potential users for such a trial would not be in the target patient group, either, as this would've required a similarly long preamble to the clinical trial. With health domain experts, one could discuss relevant observations made during the trial and reflect on the use of VR, consumer-technology and video games in the physiotherapy domain. A play-through of the trial games was also considered so that the experts could form an opinion and be familiarized with the trial protocol, gaming-wise.

The book *Interaction Design* by Rogers, Sharp and Preece [56, chapter 7] was consulted for an overview of interview forms and other data collection methods in the project. A semi-structured interview form was decided to be the most appropriate for the collection intent and the pool of experts available by convenience sampling. Since both were researchers and connected with the project, an overly neutral and strict, objectively formulated approach was not thought to be the most productive use of the conversations—objective evaluation was of course asked of the subjects. An open-ended interview format allows for the interviewer to maintain a script, reference or set of topics/questions, but also allows for conversation to flow freely around these,

[9] This is addressed with significant changes in the 2018-cycle of the engine.

both ways.[56, chapter 7] A structured interview, on the other hand, is beneficial for comparative analysis of answers and generalizations across respondents, but allows for less exploratory venues to be pursued without sacrificing rigidity. Given the parameters and experimental nature of the clinical trial, and the interviewer being a student in one of the two domains to be covered, and having limited experience with this form of data collection, an open style of conversation would likely yield the best frame of discourse. Datasets from this form of collection are mostly qualitative. Depending on the interview length and depth, they can also be sizeable and difficult to assess.[56, chapter 7] As the expected yield was high for this stage of the project, and given the limited experience of the interviewer, spoken interviews were amended with a recording of the play-through sessions and the GEQ in order to better qualify the discussions. A GEQ value-set was also thought to lessen the tendency towards biased analysis in addition to video recordings for observation and *think aloud* tasks. For clarity's sake, the experts were not asked to evaluate the clinical approach to the patient trial, but to reflect on game experience, game designs, game selections, technologies used and implementation of the physical exercise mechanics with respect to the trial's goals.

The first expert interviewed was Associate Professor and researcher Bård Erik Bogen, and the second was Lars Peder Vatshelle Bovim, University College Teacher, master's student of Health Sciences, and researcher affiliated with SimArena. Though not entirely disconnected from the thesis research endeavour (which was assisted by SimArena), their roles are sufficiently neutral for conducting an evaluation of the stimuli and project efforts in the same manner that one would have customer expert roles evaluate other software or products. Neither were directly involved in the prototype design decisions apart from their advisory contributions during supervisor meetings and early playtesting sessions (which was mostly contributed to by Bovim).

Formulation of the interview topics was grounded in the research questions, prototype design goals, goals set by Sigerseth for the clinical trial, and methodology for UX evaluations. In the absence of user groups able to do testing rounds for UX- or motion analysis, the primary goal for the interviews was set as an assessment of the prototype's value for the clinical project goals. Secondarily, some measure of its *game experience* was sought, with focus on domain-knowledge and applicability to general NSCLBP patient groups. Tertiary topics include future uses of VR and consumer-gaming technology in clinical practice.

Interview questions were designed beforehand, but the author was not able to do this in collaboration with other experts as the thesis advisers had recommended. As such, the questions were in a prepared, topical form, but loose enough so that a conversation could flow freely around them. This was thought to be the best conversational style that allowed all parties to think openly on each topic with follow-up remarks or questions, and also for the author to bring observations and experiences from the trial for possible commentary. It was also thought and decided based on this to order the line of questioning differently for each expert, to bring a slight randomization to each session, with a basis on how the expert would visit the topics during conversations. This decreased predictability for the interviewer, but was not found afterwards to have been problematic apart from a few short pauses to recompose after exhausting a line of enquiry. A selection of heuristics from evaluation methodology [61, 56] was considered for grounding observations and discussions, but ultimately not emphasized as data points due to their reliance on the absent UX-expert role. Some heuristics may be useful for questioning or evaluating how exercises and activities were presented, angled comparatively to how health-expert role would present or prefer the information through UI to a patient.

Topics formulated for the conversations, developed with considerations outlined, were as follows:

- Clinical approach to diagnosing and treating NSCLBP patients.
- Experience with patient group. Opinion on the consensus on treatments, exercise regimes and best practices.
- How quickly are experimental treatments and technology applied in clinical practice?
- What behavioural changes or psychosocial factors are important when assessing prognosis and quality of life?
- What measures or metrics, if any, are used by clinician to track progress?
- Is there a set process to routinely determine whether to initiate exercise interventions, home training, cognitive functional therapy, cognitive behavioural therapy etc.?
- What is the expert's experience with technology, games, VR, sensor devices, consumer technology in academia, research and everyday situation?
- What is expert's experience with technology in clinical practice? How does new technology find its way into the clinic, whether from experimental research or commercial actors?

- Clinical impression of exercises used in the intervention, with specific focus on prototype.
- Are the exercises translated well from clinical specifications to how they're performed in the game?
- Are the correct/relevant muscle groups engaged as intended?
- How well are the methods chosen to regulate difficulty suited for the patient group, given our protocol and games?

4.2.2 Questionnaire

Recorded below are results of the GEQ administered during the two interviews.

Questionnaire Scale:
0 (not at all) - 1 (slightly) - 2 (moderately) - 3 (fairly) - 4 (extremely)
Legend: **E1 (Bogen)** **E2 (Bovim)**

Game Experience Questionnaire – 2. Core Module			
#	**Question**	**E1**	**E2**
1	I felt content	3	3
2	I felt skilful	3	3
3	I was interested in the game's story	2	4
4	I thought it was fun	4	4
5	I was fully occupied with the game	4	4
6	I felt happy	3	4
7	It gave me a bad mood	0	1
8	I thought about other things	0	0
9	I found it tiresome	1	1
10	I felt competent	3	3
11	I thought it was hard	3	0
12	It was aesthetically pleasing	3	3
13	I forgot everything around me	3	3
14	I felt good	4	4
15	I was good at it	3	3
16	I felt bored	0	0
17	I felt successful	3	4
18	I felt imaginative	2	4
19	I felt that I could explore things	2	4
20	I enjoyed it	4	4
21	I was fast at reaching the game's targets	3	4
22	I felt annoyed	0	0
23	I felt pressured	0	0
24	I felt irritable	0	0
25	I lost track of time	3	3
26	I felt challenged	4	3
27	I found it impressive	4	3
28	I was deeply concentrated in the game	4	4
29	I felt frustrated	1	1
30	It felt like a rich experience	3	3
31	I lost connection with the outside world	3	2
32	I felt time pressure	0	0
33	I had to put a lot of effort into it	3	3

Table 4.1: GEQ: 2. Core Module answers

Game Experience Questionnaire – 5. Post-game Module			
#	**Question**	**E1**	**E2**
1	I felt revived	2	2
2	I felt bad	0	1
3	I found it hard to get back to reality	0	0
4	I felt guilty	0	0
5	It felt like a victory	3	3
6	I found it a waste of time	0	0
7	I felt energised	3	2
8	I felt satisfied	3	3
9	I felt disoriented	0	1
10	I felt exhausted	0	1
11	I felt that I could have done more useful things	0	0
12	I felt powerful	2	3
13	I felt weary	0	1
14	I felt regret	0	0
15	I felt ashamed	0	0
16	I felt proud	2	3
17	I had a sense that I had returned from a journey	2	4

Table 4.2: GEQ: 5. Post-game Module answers

Using the scoring guidelines [54] of the questionnaire, the following results were produced:

GEQ Scores: Core Module		
Component	**E1**	**E2**
Competence	3.0	3.4
Flow	2.7	3.5
Tension/Annoyance	0.3	0.3
Challenge	2.0	1.2
Negative Affect	0.3	0.5
Positive Affect	3.6	3.8

Table 4.3: GEQ: 2. Core Module Component Scoring

GEQ Scores: Post Module		
Component	**E1**	**E2**
Positive Experience	2.5	2.8
Negative Experience	0.0	0.2
Tiredness	0.0	1.0
Returning to Reality	0.7	1.7

Table 4.4: GEQ: 5. Post-Game Module Component Scoring

4.2.3 Summaries

In this section, summary and discussion is given, along with transcript line- and page-number references to the appendix. Best effort has been made to not be selective in the summaries, but reference to the full Norwegian transcript in full is encouraged where possible. When references are made to health services, this is by interviewer's understanding to be the national Norwegian health services, but research and consensus is understood as internationally relevant.

All translations and interepretations are the author's, who is not an expert in the health domain. Author also notes that the product Oculus Go was wrongfully stated to have 6 degrees of freedom and room-scale tracking (it has 3, comparable to other mobile HMDs), but Go was mistaken for another Oculus product (Quest) that is under development at the time of writing.

Legend: Transcript reference given as (L(line number), page number)
Roles: (Author/interviewer, Expert—Interviewee)

Interview 1

Demographics from the question list: *experience with technology through academic work, has tried immersive VR (including one of the trial games) but is not involved with use on a daily basis, does not play video games on a daily or weekly basis. Does research in kinematics, primarily with elderly patients, but also does part-time general clinical practice, in which NSCLBP group is encountered.*

The first interview (Bogen) started when the expert had finished the HoloBall session, which in the grand scheme would be the equivalent of a warm-up.

Expert immediately notes that although he does not have any ”relevant” pain experiences, the level of exertion and immersion is such that no thought is given to the back, knees etc., but an easier experience would conceivably suffice in cases with more pain. (L9, p. 111) Some discussion followed where the lab setup, proprioceptive aspects and spatial awareness were mentioned. The fact that a racket/paddle was felt as an extension of the player's arm span or range/reach is an interesting detail with regards to *embodiment*. (L98, p. 113) *Author's present comment: This is a key focus in how platforms like Oculus and SteamVR/HTC Vive facilitates carrying the player's sense of self into the virtual world through a familiar concept of embodying avatars, providing rich customization options and social services to further personalization.*

Discussion on the topic of game mechanics was given after the trial games. (L248, p. 117) Expert noted some difficulty translating racketball-moves to HoloBall's mechanics scheme, suggesting skill or short time to adapt as likely causes, probably resulting in some negative affect. For HoloDance, right after the play session ended, it was noted that the player's movements are well facilitated both in HoloDance and RoBoW Agent. The rhythm-based movement is again emphasized as highly relevant and interesting, which the trial participants did also report. (L133, p. 114) Expert reported a sense of ease in relating to the environment and that it was obvious what the player was supposed to do. This was generally the case with trial participants, who quickly adapted to the game mechanics.

The prototype game was reported as being enjoyable in the immediate comments after play, followed by quick reporting of a glitch occurring in a particular wave. More specific were discussed later in the interview. Firstly, the aspect of facilitating the forward flexion and activation of relevant muscle groups to maintain balance were mentioned by Expert as beneficial. (L646, p. 126) Rotation from the bow-interaction and more prominently in HoloDance was also included in the assertion. As discussed from the trial observations, increased rotation during archery activity was more prominent in high-pace situations with aggressive movements and more side-facing stances; this was not caught or experienced by the interviewee and not observed during play. Regarding concrete exercise-benefits, Expert points out that thus far a limitation to the VR experiences as an exercise scheme is the lack of extrinsic resistance to a movements (e.g., weighted or elastic, author's interpr.) to increase load and facilitate muscle overload, exemplified by the ”zapper guns” that are held up high when aiming by activating neck and shoulder muscles. (L684, p. 127)(L776, p. 129) Targets bound to higher altitudes is also suggested to keep the posture longer.

After finishing all the trial games, more attention is given to discussing immersion and distraction from the clinical situation. (L190, p. 115) It is noted that this form of treatment (presumably referring to games and relevant technologies) is not broadly used in physiotherapy and not known first hand to Expert. A surprising level of immersion was indicated, and interviewee suggests this may be key to therapeutic application—the distraction away from back pains and the tailored but indirectly encouraged facilitation of beneficial movements while forgetting time and place. A need for more research to determine approach and effect is again noted. The elements of tailoring and customization are carried further into discussion (L209, p. 116) where environment and style come into play; Expert suggests that distraction from the clinical setting is particularly relevant, following up with a discussion of how a patient's personal tastes and preferences should be heard in order to maximize this effect. Patients in our trial were not presented with any options outside the internal variances of the three games, and some estrangement due to incompatible tastes with the games' thematics and environments has been affirmed previously. Parameters exposed for adjustment in HoloBall and RoBoW Agent mainly reflect difficulty- and challange profiles, but would not be cause notable changes to environmental stimuli, color profiles, music selection etc., and Expert suggests that a degree of neutrality in their design is warranted. HoloDance is an exception, where the choice of music and environment brings significant changes to the experience, but not the core game mechanics (at least for the game modes used in the trial). Author follows up the point of neutrality by suggesting ”variation”, to which Expert notes that the prototype game could just as well be set in a more neutral environment, and further exemplifies with the underwater levels of HoloDance and an estrangement from the look and feel of HoloBall. (L221, p. 116) A suggestion is further made by Expert that a task or game mechanic variety is just as useful. Trial observations on the point of thematics, environment and preferences also vary on this point, as discussed earlier in the chapter. Video games and VR can facilitate presence, flow and playful interactions in another world, with environments that may seem fantastical or foreign but still draw the player in. But as the Expert, patient feedback and design principles underline, there is always a risk of non-concordance or disconnect between the activity and setting, player's tastes etc. This becomes important to address when considering therapeutic use, where diverse groups of players are the end-users, and off-putting stimulus could be detrimental to clinical goals. A sobering counterpoint (by author, at time of writing) is that distraction from pain, immersion and facilitation of exercise does not seem strictly dependant on aesthetic appeal, however preferable, the lack of which can be offset by immersive qualities, sensory distraction, cognitive challenges, *fun* and gameplay. See results from the GEQ for metrics.

Over the interview, several questions regarding clinical applicability and use were posed, in addition to some questions regarding home use for mobile equipment. Primary use case is thought by the Expert to be usage in a clinic or an institution for rehabilitation, focusing on specific patient groups. Possible thresholds for widespread use are suggested to be limitations as a generic tool due to costs, hesitation among clinicians to adopt new experimental technology, the need for additional clinical tailoring and research indicating effectiveness. (L329, p. 118) The prospect of supplemental exercise in VR at home is then posed to the interviewee in two forms: either tailored software developed for clinical use (with capabilities of logging etc.), or a selection of consumer games that are available to the patient through generic platforms (similar to the Spill Deg Bedre project[10]). Both are suggested by Expert to be viable, though a tailored solution is noted to be preferential in aiding the clinician to focus on a particular case. Motivation, enjoyment, relevance for Kinesiophobia and the likelihood of a patient actively wanting to engage with the experience are pointed out as favourable qualities, and is noted as an improvement to exercise plans sent home with a patient that are not as likely to be carefully followed.(L541, p. 123)

Logging, performance feedback and data collection (motion metric) aspects were explored further in the interview. On the topic of wearable sensors that provide information on patient movements, Expert responds favourably to the idea but cautions that there is a large set of definitions and terms that must be researched, established and agreed upon—good/bad movement, what type of flexion is relevant, what constitutes "progress" in each patient's case, gameplay progress and so on (L496, p. 122)—and that at this stage, primary outcome objectives should consider whether there is less fear of movement, less pain and an acceptance of the VR experiences. A possible future work element was posed in the response, related to the Kinematics, that "smoothness" of a movement. In the project we explored whether to use Qualisys or other motion capture technology for data collection, and the question was posed in the interview. Expert accounts for pros and cons for marker-based capture, pros being a high degree of usefulness for a select few patient groups not necessarily related to NSCLBP and precise under ideal conditions, cons being time-consuming work to set up and acquire data, markers shifting position due to elastic skin, and subject required to wear little clothing to ensure solid marker placements. (L432, p. 121) Expert suggests that other forms of wearable sensors are preferential to this project's

[10]urlhttps://www.spilldegbedre.no/

use-cases. The points made are in line with findings made during the project development with exception of some additional pros of object tracking and multiple actor support, as discussed in chapter 3.

Interview questions on the state of research and topics within the physiotherapeutic domain, approaches to patient care and diagnostic process were given, but will not be discussed at length in this thesis' domain. Much of the preconditions that patients have are known from the background- and project literature, and as such will not be elaborated on. Reference is again given to citations in the background chapter and Sigerseth's publication for qualified therapeutic discourse on the project. Expert does reaffirm that the VR interventions with motivational benefits may be most relevant to patients that are not presenting with a specific pathological finding (from clinical examinations, x-ray etc.) without an improvement over time and have developed a fear of movement (Kinesiophobia) despite attempted reassurances of safety. (L541, p. 123) Also reaffirmed, following a question from the author on where a threshold for such interventions should be, is the need for further study and evaluation before considering deployment to clinics. The patients in our target group have tried multiple approaches to treatment/screenings already and may therefore be candidates for tailored exercises outside the established "best practice" set. (L573, p. 124)(L606, p. 125) Further descriptions of the exercises used in treatment are reminiscent (author's perspective) of graded exposure principles; mapping out ranges- and quality of motion, selecting movements that can be brought into the daily life of the patient, and working gradually towards the individual tolerance level, which in turn can be influenced by pain, stiffness and fear of movement.(L658, p. 126)(L684, p. 127)

Interview concludes thereafter.

Interview 2

Demographics: *Second expert user (Bovim) also has some experience with technology in research and academics, including strong knowledge of Qualisys, motion capture systems, various sensors through physiotherapy and an industrial background, brief clinical experience. Strong familiarity with VR through research project (walking simulator with a HMD and treadmill), academic use and gaming interests, both recreational and for therapeutic contexts. The aforementioned entailed an advisory/supervisory role in the development of a VR-experience, concerned with UX aspects, quality of therapeutic exercises.*

Video transcript is provided in the appendices (p. 130) as Expert gave verbal remarks during play. During HoloBall gameplay reported to being well warmed up when asked by Author and followed up with describing the increase in pace and difficulty as beneficial—or possibly ”cool”, by translation of vernacular—when the player progresses by winning.

In the second video, gameplay of the prototype game, RoBoW Agent, Expert reported exertion after a short period of time. (p. 131) Also discovered without prompt from the Author was the shallow, forward-facing firing stance as described earlier in this chapter, which Expert then demonstrates, but remarks that the main difference is felt in the shoulders. It is suggested by interviewee that this can be corrected with verbal instructions from the researchers, and that either way, increase in exertion is more important. After some time passes, interviewee remarks that one of the sounds effects emitted by the was confusing, which is noted, followed by a clarification request for a written instruction given before the third wave (to ”draw the bowstring a little faster in one movement”, author’s loose translation) and a suggestion that game objects described in such text are displayed on screen. A final query and observation was whether the bow can be locked to either the left or right hand such that the nocking is unmistakable, in addition to where the interaction boundaries of the arrow buckets are. Both points noted for further consideration.

Voice interview (p. 132) starts with questions pertaining to familiarity with technology, games and VR. After establishing the background questions, Author asks of how frequent new technologies are encountered in Expert’s research and academic work. Interviewee suggests, based on the technology they use, that health personnel prefer working with devices that are easy to start/apply/use and are facilitating to the clinical objectives. Exemplifies with a patient’s appearance as safe/confident or scared, freedom/range of movement (uncertain translation), and that such clinically relevant terms must be present in the software rather than technical terms not known to therapists. (L854, p. 133) Specialized institutions with a prominent interest for experimental technology are stated to be less demanding on this point, where technically inclined personnel facilitate such use. This is followed up by remarking on user-perspective that for these three VR experiences and the tutorial, information through the HMD described in normal language what was going to happen, and patients would not have to concern themselves with technical details.(L864, p. 133) Moreover, when suggested by Author for use at home as supplemental to clinical therapy, Expert suggests that even if there are some technical barriers such as sensor calibration, it can still be cost-effective to have a therapist do this step and have the patient carry out exercises at home. This is qualified with the expectation that demand on health-services is ever increasing, with more elderly patients in need. (L891, p. 134) Expert also notes beforehand that a therapeutic approach to such VR experiences should be angled towards usefulness to clinicians, instead of just something patients can discover on their own leisure. (L879, p. 134)

Following this line, Author asks Expert if it is difficult to give an exercise-based treatment regime and have NSCLBP patients follow it up both in the clinic and at home, as literature on adherence and the previous interview suggested. (L904, p. 134) Patient motivation and the therapist's ability to adapt to the given case is focused on in the response. Furthermore, Expert affirms the focus of the VR interventions on distracting from the patient's back and associated pain, with indirect motivation for exercise through play, even if some pain is felt afterwards. Then the clinical focus can shift to what was achieved and experienced in VR/gameplay in following patient dialogue, rather than the therapist observing while the patient performs movements that they likely expect in advance will be painful. Expert follows up on the motivational aspect and notes that a short-term goal with this group can be getting any form of activity and ameliorating intervention started, which again leads to focus on motivation. If the patient group is susceptible to gaming experiences, this could be a solution, suggests interviewee. An example is given of the arrow bucket in the prototype game, as a dynamic element, which elicits a variation in movement that is difficult to achieve in other therapeutic exercises. (L920, p. 134)

On the question of encountering this patient group, Expert notes having brief clinical experience, but also that patients from this group are quite common. Following up, it is suggested that the VR is not necessarily something that can help everyone, but an important addition to the clinical toolset that can help the right person(s) that find the experience enjoyable. (L933, p. 135) Interviewee notes not being an expert on the particular patient group, but is familiar with discussion within the academic- and clinical environments due to the lack of a given treatment that is effective for all. The general existence of experimental interventions that claim success is further noted, exemplified by Expert through the Biopsychosocial approach; that both patient and clinician must identify patient's situational goals and desires, in which motivation is prevalently key, rather than presenting a fixed, mechanical recipe as a cure. (L963, p. 135) Further exemplified that as motivated, determined patients in the relevant category have likely been exposed to treatment interventions without improvement, the approach focused on gameplay elements and fun could be more facilitating than something a patient might see as "correcting" a previously presented treatment. (L974, p. 136)

Discussion follows on how interviewee experienced the grade of stimulus and distraction (no existing pain condition was reported). Expert noted they were analytically inclined as an experienced user of the technology, but still experiences significant distraction and playful engagement in VR. Author gives a short follow-up remark to see if Expert has any suggestions as to development guidelines for these experiences, to which Expert makes one note that it should be adaptable to the individual who is playing. Example given as our 10-minute gameplay durations, noting that pauses happen when the individual feels it is appropriate, and we can then explore why that happened. (L1016, p. 137) Author noted that during the trial we did observe expression of pain when immersed but seldom in the order of needing to stop immediately—no further discussion followed at this stage.

On the topic of home use and portable units, Expert indicates to know about forthcoming mobile HMD units that do not require external sensors to operate with positional tracking. Author poses a question on the possibility of having patients bring such a unit home with a pre-programmed exercise set and logging capabilities. Interviewee makes a comparison to an existing Exergaming project (Nordstrand, possibly related or comparable to [62]), described as being instructed exercise with feedback afterwards. (L1073, p. 138) Further discussion is given on what type of data collection is of interest, with an example of wearable activity tracker (which typically measures steps, sleep patterns etc.), which does demand willingness on the patient's side to be monitored. Expert notes that in such cases, data on how they perform when they're *not* doing exercises is the most interesting, and that the storage scheme would involve remote synchronization to clinician for activity review. This would also allow the clinician to monitor sets of patients with such equipment in use and follow-up with individual patients as needed.

As a tool for clinical use, Author estimates current consumer- and enterprise costs associated with operating relevant VR hardware, e.g. Oculus Rift/HTC Vive for stationary deployment, and asks if such costs are feasible. Expert suggests that in the short term (coming years), this should be considered for specialized clinics. (L1115, p. 139) Author again poses the question on where the threshold likely is for patients to come in contact with such interventions, given their chronic condition, screening processes, ruling out pathologies and other treatments ("quick fix") before meeting trial criteria. Expert references the organizational complexity of health services in the response, presumably indicating that this is presently difficult to establish, and again suggests that in the short term, specialized use of VR interventions for NSCLBP/Kinesiophobia is more realistic than rapid widespread adoption, along with the need for further development and research. (L1131, p. 139)

Interviewee again indicates a belief or inferred likelihood that many experimental treatments exist, especially with a lack of consensus and patients willing to try such treatments.

The final portion of the interview covers game mechanics in the trial games. Interviewee is asked how the exercises were experienced, again focusing in response on motivation and players being encouraged to move their back without explicit instructions, and that the movements instigated are beneficial even if the "solution" (to the patient's condition, author presumes) is not known. (L1163, p. 140) Variation in the activity is emphasized, particularly with the range of motion facilitated in HoloBall. (Portions of audio is regrettably missing from this response. *Also note that HoloDance was not played in this session but is familiar to interviewee*) Both follow up on mechanics of the prototype game, where Expert asserts that the arrow bucket should move even more, suggesting multi-directional movement including up & down, maybe even behind the player, preferably with an untethered HMD. (L1174, p. 140) At this point, the shallow stance observed when shooting arrows is brought up, which is described as problematic. This is conceded to, and suggested by author to be an object for calibration, such that patients could set the difficulty by their current comfortable range of motion per session. Expert further suggests that this can then be adjusted by the software as an increase in difficulty after 6-7 minutes, and that it becomes especially relevant if played at home—the need being to balance the desired upper body rotation and the level of comfort. (L1211, p. 141) Author recounts playtesting with a supervisor whom had a painful reaction to prolonged archery exercises (static bucket at low height), and the reasoning to include the bucket motion and "zappers" for varied gameplay. Response by interviewee again notes the immersive properties of the VE and gameplay, differing from viewing through a 2D-screen. Author noted that Expert did not display much movement or flexion when playing with the zappers, which both agree is influenced by player's experience and ease of adapting to the situation. This adaptive behaviour is exemplified with being present and stepping towards interactive objects, but it is suggested that proper placement and an obstacle would prompt the desired movements and forward leaning. (L1257, p. 142) (L1257, p. 142)

The interview is concluded afterwards.

4.2.4 Conclusion

In the preceding sections, arguments, observations and citations have been summarized. The observational data and interview responses have accumulated many valuable points for a *pro et contra* evaluation. Results collected herein are used in the concluding chapter to discuss what findings answer the research questions and fulfil the thesis goals. All the technologies and game experiences tested were found to display applicable strengths and weaknesses, which in sum has yielded qualitative data for further consideration. The interviews also has GEQ response measures that are not generalizable but may be used in evaluation data from the citations given above.

Chapter 5

Conclusions

In this thesis, we have presented contributions towards using consumer-grade technologies and experiences for VR as clinical tools in the treatment of NSCLBP patients. Contributions were made to a clinical trial that aims to test this, and gathered observational data throughout its duration in addition to some patient interaction and technical assistance rendered. A game was developed that featured tailored interactions specified by clinical personnel to be beneficial in use for the relevant patient group, and was observed to facilitate the desired targeted movements in addition to being customizable in their difficulty of execution. Observations were made in the discussion about participant feedback regarding UX, motivational aspects and enjoyment of the gameplay, thus drawing some preliminary conclusions as to the efficacy of game design principles applied during development. For an evaluation of the game experience and exercises from within the health domain, two health-domain expert interviews were conducted after conclusion of the clinical trial, including administering the GEQ for supplementary measures to discuss the citations. These interviews posited an impression from the health personnel that the clinical affordances of the VR interventions can indeed serve as beneficial tools, especially when clinicians can tailor the parameter of difficulty and exertion to each patient with ease. The experts noted that there is likely a high threshold to adapt new experimental technology as proposed unless clinicians can confidently relate their clinical goals for each patients to relevant parameters exposed in the technology, and these must be easily set. This is noted as an emphasis for future work. Motivation was a key focus in experts' opinions regarding both trial outcome and an important focus area when considering experimental interventions or technological applications in treating NSCLBP patient groups. This was partly related to Biopsychosocial factors; how to work with the patients' own interests, goals, life situation, motivations and existing clinical history. An enjoyable challenge was indicated from the prototype game, that elicited movement in the correct lumbar region for the patient group, which was discussed in the previous chapter. Observations from the clinical trial have also been made and discussed by the author that have highlighted strengths and improvable elements in the VR games, including the prototype that was developed. In the analytical phase of development, various interaction paradigms were examined through commercial games and experimental work referenced by previous research or HMD vendors. Some considerations of comfort were theorized to be overstated during research and design of the prototypes described in chapter 3, but I conclude that for a relatively short trial duration, they were apt in ensuring the best patient care vs. testing experimental designs and risk compromising health- and motivational goals. In larger studies, or as observed in consumer markets in general, plenty of motion-based games and games with experimental locomotion are usable, and would probably, as discussed, provide additional stimulus for sensory- or cognitive distraction from pain.

In summary, findings have been made that are in line with the research questions:

- observational results from the trial, corroborated and amended by two interviews, suggest that VR technology and appropriate experiences can be beneficial clinical tools in the treatment of NSCLBP patient groups;
- the trial games, including the prototype contribution, facilitated movements that were considered beneficial for the trial objectives and its participants;
- the interviewees noted that while thresholds may be high for adapting new experimental technology such as VR games in specialized clinical practice, the trial games are potentially useful tools in treating NSCLBP patients, so long as the games were sufficiently adjustable to a variety of cases. Clinical goals must easily translate to game settings and parameter adjustments given in therapeutic vernacular.

While the observations are encouraging, more research on all points is needed for more decisive conclusions on general applicability.

Sigerseth and I were able to experiment with therapeutic assessments translated to game difficulty settings, as outlined in the project goals and described in chapter 3 and chapter 4. I note that the clinical assessment dictated these considerations, having been tempted as a "surrogate game designer" to make uneducated suggestions in either side of the average, based on opinion and situational feedback from patient rather than proper clinical reasoning and considerations of the steady progression of exertion that the games would actually take. I was correctly overruled by the clinician, of course, the reasoning of which was understood and observed afterwards to the best possible extent in every such case. Close collaboration with therapeutic domain experts for experimental game mechanics/-technology thus stands as a strong recommendation based on experiences from the thesis project, especially when playtesting during development. Rather than or in addition to discrete difficulty profiles (easy/medium/hard/etc.), as was first intended, parameters should be adjustable by clinicians at runtime, or properly organizable beforehand. NSCLBP and Kinesiophobia are complex conditions that can influence individual variations in both game experience and pain levels for each player, as observed, and needs qualified evaluation even when positive outcomes are noted for the trial games.

The existing research from the last decades, discussed in the background chapter and related work, has already established that VR provides the means to modulate pain experience and facilitate sensory distractions applicable to therapeutic contexts.[23] I found this to hold true from the trial based on observations, feedback and expert interviews, but must again refer to the forthcoming publication for any conclusive findings from the trial regarding pain modulations over time and whether sensory distractions afforded by VR can break maladapted patterns from Kinesiophobia.

Exposure therapy, while often found useful and effective, can be a costly and time-consuming intervention, requiring not only of qualified personnel and time but also the environment or conditions of the Fear-avoidance (FA)-behaviour.[30] Full-body interaction within a VE provides engaging stimuli that can both present information and engage patients in activities that are relevant to their condition, but may hopefully yield benefits from generalized (and functional) exercises that target the lumbar region. This completes a beneficial link between education, motivation, *gamification*, serious games and *gameful design* in the thesis' context. Possibilities for motion metrics as an assisting data source and interaction examples have been discussed; VR session reviews can be useful for demonstrating progress with or without motion metrics.

5.1 | Future work

First and foremost, conducting a trial with similar or new parameters over a longer time period is immediately interesting. Many patients from the trial remarked that they would have liked to extend the intervention period if possible, and the researchers agree that an up-scaled scope, greater than that of a master's thesis project, would allow for a possibly valuable data on lasting effects of the interventions. Results of the health-domain data analysis will, of course, likely influence this opinion.

In concluding the thesis, I argue, by currently available results in this cross-domain project, that patients may benefit from using VR-exercises at home, but caution against any off-the-shelf experiences that have not been evaluated by a clinician (to minimize risk). I also argue from observations and interviews that the ability to adjust game- and exercise-difficulty is crucial to the successful adaptation of clinical VR games, which underpins directives in previous works.[63, 64, 30, 65] Moreover, another point that is up for discussion is patient-adherence to VR at home, and how a customized software would need to adapt or be adaptable to progression, pain levels and short-term goals. I propose that extending the previous works in implementing a fuzzy-based adaption mechanism as well as a relevant domain-specific taxonomy is a useful endeavour. In the clinical trial we have encountered patients that have stood the test, carrying out a full $\tilde{3}$0min. exercise regime, despite severe before and after a session (which they anticipated). An experimental clinical trial, with twice-weekly an daily measures, after multiple therapy instances, screening procedures etc. might instil a greater call to adherence, and more formal framework around the exercise intervention than VR-exercising at home. Clinical guidance is noted as important, with an emphasized possibility for remotely monitoring progress outside clinical hours. Previous works highlight the importance and need for specific simulations of the stimuli a patient has FA-responses towards, congruent with general exposure therapy methods.[30] However, I also humbly suggest that a general approach that weighs gameful aspects has been observably effective, and supported by citations from the expert interviews that imply general activities with correct postural loads may be effective in getting the patient active again following longer periods of inactivity, pain and switching between treatment institutions. Indeed, fully leveraging larger gaming experiences as opposed to small simulation-angled, trial-focused stimuli is a prospect that lends itself well to tailoring game selections based on gamification frameworks or insights from studies of affective response in pain patients while gaming. In the context of research, some ecological validity may be sacrificed by erring on the side of entertainment and motivation versus strict adherence to graded exposure therapy simulations. A sobering counterpoint is inferred by considering the NSCLBP patient group and their arduous journey through different diagnostic- and treatment options, a point to which the interviewed physiotherapists remarked that adhering to almost any useful, relevant activity is desirable at that stage. Health domain experts do, of course, have the final say in how this approach should be focused, if at all. Motivational aspects may be arguably important for adherence to home-interventions as well, hopefully with an effect that can be expectedly greater than existing interventions.

The prototype games designed and/or developed in the project can certainly be expanded upon in their viable areas, having gained new insights from the project. In particular, the RoBoW Agent game can be amended with new challenge types, better UX and clinical tailoring towards external testing or deployment. Internal interest in maintaining a working version also motivated this.

Application of commercial consumer games should be noted as potentially useful in clinical settings or research. At the time of writing, exercise-promoting games like **Beat Saber**, a rhythm/music game, have taken the consumer marketplaces by storm. Often referred to as a novel exercise game, this particular title has seen rising popularity also due to modders inserting custom "beat maps" to other songs than those included. Again I note that recommendations of consumer games that facilitate beneficial exercise can be an important tool in itself for clinicians where the relevant platform or hardware is available to the patient at home.[1] In the absence of clinically adjustable difficulty parameters, a protocol can be made that specify which existing game modes are beneficial and safe for use per patient.[2]

From an earlier uncompleted thesis project of mine, I am also predisposed to having an interest in exploring this application of VR in other contexts of games research, particularly Affective gaming that incorporates *psychophysiological* measures/analysis of play and biofeedback [66] into gameplay, game design or analysis. Trost et al and gamification approaches that categorically tailor gameful designs to players' game interests, personality types, motivations etc. Arguably, frameworks of gamification, such as [67], can be applied

[1] https://www.spilldegbedre.no/

[2] Licensing terms, obtaining rights and associated costs remain likely prohibitive issues for using consumer games in clinical rehabilitation, the institutions of which are considered enterprise actors that do not necessarily have access to consumer markets.

when evaluating the Biopsychosocial factors of patient history, and relevant game experiences identified that would be more engaging than simply basing the selection of experiences solely on which exercises are recommended by the therapist.[3] For example, players inclined towards social gaming experiences could benefit from multiplayer games that encourage social interactions through gameplay, possibly reinforcing the patient's motivations. Lasting disability and FA-behaviours can foster isolation, to which social gaming could be an effective amendment. With ubiquitous mobile HMD technology (capable of room-scale tracking) coming to market at very affordable prices, using VR experiences on outside the clinic as supplementary means of exercise and distraction was found by the experts to be an interesting prospect.

On a subjective note, as a master's student, games enthusiast and chronic pain patient myself (though not specific to low back), assisting in the trial has fostered a greater understanding of how clinical research is conducted and the nuances between working with health patients and working with subjects in a strictly observational or interview trial that is more often encountered in computer science and UX. Some rapport is intrinsically built between clinicians—that have expertise in both scientific research and therapeutic domains—and patients, who benefit from this in ways that were only partially understandable from an uneducated point of view, but did layer in some additional observations during sessions. After all, patients who try a new therapeutic approach, such as stepping into a virtual world, to exercise and pain distraction that has them exclaim "Whoa!"[4] and be increasingly motivated to work towards their goals, can be *breakthrough-moments*. These are caught by the clinician as possibly important occurrences to be understood, repeated and amplified, but can be relevant in both domains of research, as we also want an engaging game experience that supports the same goals. Ultimately, it is the clinicians and patients who work together towards their common objectives, but it is an encouraging reflection that these technological tools foster playful interactions in a context that directly assists the clinical personnel in engaging with the patient's own motivations. Developers of these tools and UX designers can likely benefit from domain-specific insights into how clinicians work to accomplish this, and a reflection on how the tools can deliver an experience that distracts from pain, and speaks to the individual's motivated desire for a better quality of life. The infancy of VR will eventually come to and end; I hope that despite the specific patient group- and therapeutic focus considered for this thesis, the vision and results

[3]Applying *psychophysiological* measures during novel research into seriousVR games is an interesting venue to explore in its own right.

[4]often accompanied by tasteful profanity.

of Sigerseth's project will be a stepping stone towards lifting some burdens off of the NSCLBP-suffering patients, dispelling myths about back pain that is prevalent by sociocultural dissemination, and also ease burdens on the public health care systems that have to keep up with ever-increasing demands.

"Games are testbeds for new technology."

Lennart Nacke, Ph.D.
Pioneering researcher into affective gaming and gamification

Appendix A

Hardware

A.1 | Specs

Specs	
Manufacturer	Komplett ASA
Operating System	Microsoft Windows 10 64-bit
CPU	Intel Core i7-6800K, 6 cores @ 3.40 GHz
Hard Drives	SSD (OS, Unity, Executables); HDD (project, cache)
RAM	32 GB
Motherboard	MSI X99A RAIDER
Peripheral connectors	6xUSB3.0, 2xHi-Speed USB3 (10Gb/s), 4xUSB2.0
GPU	
Model	MSI NVIDIA GeForce GTX 1080Ti
VRAM	11GB
Connectors	2xDisplayport, 2xHigh-Definition Multimedia Interface (HDMI)

Some activities and demonstrations planned within the project phase required a mobile solution; a laptop with a VR-ready Graphics Processing Unit (GPU) was also used:

Specs	
Manufacturer, model	ASUS ROG GL702V Notebook
Operating System	Microsoft Windows 10 64-bit
CPU	Intel Core i7-7700HQ, Quad core @ 2.80 GHz
Hard Drives	SSD (OS, Unity, Executables); HDD (project, cache)
RAM	16 GB
Motherboard	ASUS GL702VMK (U3E1)
Peripheral connectors	3xUSB3.0, 1xUSB-C Gen. 2.1
GPU	
Model	ASUS GeForce GTX 1060M (Mobile, VR-Ready)
VRAM	2GB dedicated + shared
Connectors	1xHDMI

For limited testing on mobile VR, a Samsung Gear VR HMD (which is connected to the Oculus Platform) was used with an Android-driven Samsung Galaxy S7 phone.

Appendix B

Assets and plugins

B.1 | Unity Assets

Assets and asset packages from the Unity Asset store[1] that were already available to or acquired by author, and used in some capacity (mostly partial usage of select components during the project. Not all assets listed were used in the final prototype game). All credits to the original authors.
Bad Bots/Angry Droids, by Gravity Box Studio. Used extensively in RoBoW Agent.
3D Scifi Kit Vol 2, by Creepy Cat. (3D Sci-Fi environmental assets and effects)
Beat Detection, by 3EY3Net. (Solution for detecting "beats" and cues in audio. Used when prototyping pose-matching music for the Kinect)
Beautify, by Kronnect. (Post-processing effects and shaders)
Blend Modes, by Erlingus.
Cinema Suite.
CurvedUI.
DOTween Pro. (Prominently used in RoBoW Agent for Tweens)
Epic Positive Game Risers FX.
Everloop.
FinalIK, by RootMotion. (Inverse Kinematics solution. Used during testing and prototyping)
Pooly, by Ez. (Object pooling solution. Used in RoBoW Agent)
FastLineRenderer.
First Person Lover weapons pack, by ISBIT Games, that was modified for

[1] https://assetstore.unity.com/

the zapper guns.
Cartoon FX, by JMO Assets.
Laser Construction Kit.
Realistic Effects Pack 4, by KriptoFX.
Particle Mega pack, Mirza Beig.
Objectify.
Oculus Platform SDKs.
OpenVR SDK.
Sci-Fi Bow, by Glitch Squirrel.
Sci-Fi Battery pack Free, by 256px.
SCT Scriptable Text.
TextMeshPro.
NinjaRun VR Locomotion, by Trapped Inside Games. (Tested during prototyping for experimental locomotion and considered for Flight prototype)
UI Controller.
Sample assets by Unity Technologies.
Texture packs by Artificial Creations.
ADG Texture pack.
SpeedTree foliage and Tree packs.
Manufactura K4's environmental packs.
Big Environment Pack 3, by Phillip Schmidt.
Tools by Procedural Worlds (Gaia, GeNa, CTS).
GreenStash Mesh plants.
Enviro and DeepSkyHaze.
Tom Stobierski's terrain shaders and tools, and UBER shader pack.
TextFX and TextMeshPro.
VR Panorama Camera tools.
Universal Sound FX Pack.

B.2 | External and open source

AudioBlocks.com service for royalty-free sound effects and music tracks.
https://www.audioblocks.com/
World Machine Pro, procedural terrain authoring software. Used with Quadspinner's GeoGlyph plugin suite (Pro).
https://www.world-machine.com/ - http://www.quadspinner.com/geoglyph/
Substance Suite, for texture adjustments and procedural materials.
https://www.allegorithmic.com/

Virtual Reality Toolkit: https://vrtoolkit.readme.io

Appendix C

Interviews

C.1 | Interviews

This section of appendices contains the questionnaire results and interview transcripts of the domain expert interviews covered in chapter 5. The conversations were held in the author's and experts' native language, Norwegian, and is therefore transcribed herein without translation. The clarifying remarks written into the transcripts (legends given below) are given in English to assist the reader.

Consent Form

Signed by each expert before the interview session commenced. *Text in Norwegian Bokmål. One spelling error was corrected before reciting here.*

Samtykkeskjema ved intervju

Forsker: Thomas Fiskeseth Larsen, studentnr. 131204 HVL
Masterstudent, Programutvikling – HVL og UiB
Veiledere: Harald Soleim, Atle Birger Geitung, Remy André Monsen (HVL)

Overnevnte student (Forsker) gjennomfører ekspertintervju—intervju med en som regnes som domeneekspert og fagkyndig innenfor et av intervjuets tema og rammer—og vil i denne forbindelse gå til datainnsamling i form av skrevne notater, lydopptak som transkriberes, evt. videoopptak og evt. skjema til utfylling.

Undertegnede deltaker/ekspert er gjort kjent med og samtykker i at innsamlet data vil bli kunne brukt og sitert ved publikasjon fra prosjektet, inkludert masteroppgave, der hele eller deler av transkripsjon kan bli gjengitt. For grundighetens skyld vil Forsker kunne forespørre å navngi Ekspert i publikasjon (for evt. conflict of interest osv.).

Deltaker/Ekspert deltar på helt frivillig basis, kan når som helst trekke seg, og kan trekke samtykke til bruk av innsamlet data i forkant av at masteroppgaven ferdigstilles, eller at gjengitt data anonymiseres. Ekspert bekrefter å ha bli informert om dette. Hvis ønskelig kan data som aktes publisert bli oversendt Ekspert for kontroll i forkant.

Bergen, . .2018

Deltaker/Ekspert

Forsker, Thomas Fiskeseth Larsen

C.2 | Domain Expert Interview 1

C.2.1 Premise

Interview session with Physiotherapist and Associate Professor Bård Bogen, Faculty of Health and Social Sciences, Western Norway University of Applied Sciences.
18.6.2018.
Referanser fra Interaction Design boken.
Location: Neutral chosen (small poly-clinical examination room, 2.5x2.5m play area, used in clinical trial).
Goal: Ascertain value of produced research and cross-disciplinary observations used in supporting the thesis' goals. See Chapter 4.
Stimulus: All 3 clinical trial games. Full run of RoBoW Agent.
Apparatus: Same Rift setup as used in trial.
Method: Unstructured interview and mixed conversation, playtesting (Author's observation and video recording), GEQ. **Data collection:** Voice audio recording (transcribed, quoted). Video-recording of play session (screenshots provided).
Premise of conversation, as decided beforehand: See Chapter 4.

C.2.2 Transcript

Part 1

Session begins with a very brief introduction, signing consent form, mounting the HMD (straps, Interpupillary Distance (IPD) adjustment). Expert is given the First Contact experience from Oculus (as the patients were), including more than half the second FE part. Author then loads HoloBall with 0.8/0.8 settings on horizontal/vertical span (see chapter 4 on HoloBall), where Expert plays one round of Easy, and two rounds of Medium campaign. No significant remarks recorded during play. Voice recording of post-play conversation follows.

Legend: (E)xpert (A)uthor (Clarification/comment in english).

E: Det gir liksom ikke noe sånt billig intrykk. Altså, det føles om at det er...

det føles veldig levenede. Klart, man kan diskutere, sånn, i en pasientsammenheng, hvor egnet det er med lyden, men fargene. Og så merket jeg det at det skulle litt tilvenning til. Så det blir nok en bedre prestasjon om man har gjort det noen ganger da, vil jeg tro.

A: Absolutt.

E: Nå har jeg ikke spesielt vondt noen steder, men jeg merker på en måte at jeg blir varm. Så jeg bruker jo uten tvil kroppen... og det er så oppslukende at jeg ikke tenker jo ikke noe på rygg, eller knær, eller noen ting. Om jeg hadde gjort det hvis jeg hadde vondt i ryggen, det er vanskelig å si. Men jeg innbiller meg det at det går jo an sikkert å begynne med enda lettere ting enn det her hvis man er virkelig plaget da. Ting som der du skal... kanskje du skal stå på samme sted, men at du kan likevel kan ... der du gjør det bedre i spillet hvis du beveger deg da, ikke sant? La oss si at du hadde hatt... hvis figuren din i spillet var en robot, med stråler som kom ut fra kroppen. Så er det da om å gjøre at du liksom skal vri seg slik at strålene treffer visse punkter, ikke sant?

A: Akkurat, ja.

E: Sånn at du liksom... Og det kan man jo gjøre med små og store bevegelser, tenker jeg. Men du verden for et potensiale. Det er jo ikke ubehagelig. Det føles veldig lite ubehagelig.

A: Ok, ja, det er godt. Jeg kommer til å spørre deg litt mer i ... etterpå når vi ferdig.

E: Ja.

A: **(inaudible 1 sec.)** På grunn av den tilvenningsbiten da, så det vi har gjort er at vi spurte utvikleren om vi kunne justere på en måte hvor disse ballene kunne komme i retur da, for om en en ekte, eller om **(inaduble)** så måtte du kanskje hive deg og bevege deg såpass som du nettopp gjorde. Så det... vi fikk da heldigvis tilsendt et bygg der vi kan definere at ballen kun kan sprette tilbake i et viss prosent av et sånt spenn i bredden og i høyden ... og det vi for 90 komma noe prosent av pasientene ... det er var det vi hadde kun 20 prosent i vertikalen sånn at de fleste fikk kun returballer et eller annet sted rundt solar plexus og allikevel fikk bevege seg ganske mye. Så i bredden da gikk vi .. der varierte vi litte grann på de som måtte begynne kanskje smalt da, og da blir det at de sto mye i ro og... fikk slått men ikke fikk disse her strekkene noe sted. Og så gikk vi til de som tålte det da, var vi vel oppe i 70 80 prosent – at de kunne få litt sidebevegelse, men det begynte i hvert fall at ... som du sier, at de må stå litt i ro, men de får brukt sånne rolige slåbevegelser, at vi da instruerte de i å heller gå over i sånn easy/medium/hard hvis de... men ja, det kan vi kanskje ta litt etterpå.

E: Men det virker ikke som farten på ballen avhang veldig av hvor hardt jeg slo.

A: Ja, litte grann, det kan stemme. Det skal litt til at ... sånn når du smasher og sånn, så var det ... **(lydeffekt)**

E: Men om det er min fart eller om jeg treffer bedre, det er vanskelig å si. Og jeg ser jo ikke racketen min noe godt her, ute i sidesynet, sant? Men det kan hende også det har med tilvenning å gjøre, at en som har spilt mer ville være ... ha øynene mer på, jet vet ikke ... jeg er ikke god i squash heller. **(inaudible)**

A: ... Det vil også variere på det ser seg mye ... det erfarte vi også på ... **(inaudible)** variasjon i hvor mye de orienterte seg i rom før de ... og til slutt virket det som de hadde full propriosepsjon i at de kunne bare **(lydeffekt, slå)** bruke armen sin, og det er jo litt det vi ønsker å oppnå i VR, at de skal bare kunne slå med armen eller ... noe de er vant ... de har forståelse av **(inaudible)** racketer, og de kan beregne sånn cirka hvor de treffer.

E: Men, når dere har vært der inne **(clarific: the large rehab lab where most of the sessions took place)** så har dere jo hatt litt større plass. På gulvet.

A: Ja.

E: For jeg merket jo det at jeg hadde de her kamerastativene litt sånn i bevisstheten. Sant?

A: Ja.

E: Men interessant nok, jeg merket det ... da la jeg også til racketen.

A: Ja. Riktig.

E: Kom jeg på nå. Ja. Sånn blir det jo litt ... **(inaudible)**

A: Det er litt sånn instruks vi gir også ... du så kanskje et blått rutenett sprette opp.

E: Mhm. **(affirmitive)**

A: Litt ekstra når du nærmet deg.

E: Ja.

A: Så det er jo den... sikkerhetsområdet som vi definerer på forhånd. Som er litt foran stativene. Så inne på rehab-laben hadde vi jo "carte blanche" med ganske mye område, så der kunne vi gå litt utenfor, men... Så er det også det at.. dette er fantastisk ... dette er den funksjonelle delen av sensorene. På LP sine kamerastativ. Så de har ... hvis to stykker ser deg, så kan de spore opptil tre meter før de begynner å miste litt sånn synet av deg. Sånn at...

E: Kommer de på sånne plater?

A: De kommer med bare sånne bordstøtter.

E: Så du har limt de nedi da?

A: Nei, hare bare skrudd de på.

E: Så de passet nedi de..?

A: Ja.

E: Ah, perfekt.

A: De er veldig standardisert altså. Veldig kult. Så vi sier ... cirka 2 og en halv meter, alle retninger. Det pleier å være sånn... da har vi optimal tracking og vi har godt spenn.

E: Mhm. **(affirmitive)**

A: De fleste spillene som HoloBall, eh... det virket som du var veldig bevisst på bakstativet **(clarific. The rear sensor tripod)**, men egentlig så var du aldri lengre bak enn cirka her. **(clarific. Indicating area just beyond the halfway point of an edge)**

E: Nei, det kan jeg godt tenke meg.

A: Men jeg ble litt nervøs når for da... **(clarifc. Indicating a wall column that protrudes from an edge of the room, just beyond the boundary of the play area, and that B almost struck it with a controller during play)**

E: Men jeg kjente jo... jeg kjente at jeg kom borti tråden. **(clarific. a retractable cord used to keep the wire to the HMD out of the way)**.

A: Ja.

E: Men det var veldig interessant at det gikk opp for meg nå at når jeg tenkte på rekkevidden min så hadde jeg faktisk racketen med. Ja.

E: Det er jo godt tegn.

A: Det er veldig interessant.

E: Ja.

E: Yes? Push on?

Interview paused at this point. Expert prepares to play RoBoW Agent. Author gives some instructions about which controller inputs are used and what the basic premise is. "No robots were harmed during the production..." Author explains that this is the same version of the prototype that was used as of the last trial patient. Play session starts ***(with some video recording)****.*

After RoBoW Agent. Brief comments.

E: Det var veldig, veldig gøy. Veldig gøy. Men som sagt, jeg merket en liten... på et av nivåene – jeg tror kanskje det var tredje nivået – så var det et lite "lag" **(delay)** mellom hvor tid jeg slapp knappen og hvor tid pilen gikk.

A: Riktig.

E: Men om det er fordi jeg var upresis med fingeren, det... **(inaudible)**

A: Du sto litt sånn at den ikke var helt trukket tilbake, men jeg tror jeg vet hvilken feil og det rett det. Men jeg er nødt til å begi deg ut på det som ble brukt med siste pasient. Så det buen er egentlig litt håpløs; du så kanskje at den vinglet litt sånn.

E: Nei, og buen er helt irrelevant i sammenhengen, sant, fordi at du gjør bare tre ganger, og så merker du liksom hva du skal gjøre, ikke sant. Det var ikke noe vanskelig å få pilen til å sitte eller noe sånt. Og da spiller det ingen rolle.

A: Mhm. Det var veldig gøy for de fleste; de ble veldig giret til slutt, til og med de som sa at "dette er gjerne et guttespill" og sånt. Vi hadde én dame... vi hadde to damer med i studien, én i 40-årene som sa at dette var et ”guttespill”, men jaggu etter tre-fire ganger... og akkurat samme reaksjonen når du akkurat bommet på den siste før tiden. **(latter)**

E: Veldig gøy. Ja men **(profanity)** bra.

A: Jeg spør deg litt etter om det.

Interview paused. Expert prepares to play HoloDance.

Part 3

Interview/convo about physio, VR, consumer tech, treatment strategies. Motivations for gaming, home use by patients and retention.

(recording starts right after expert begins stating impressions of experience after HoloDance)

E: ... per definisjon, siden de der kommer fra ulike retninger. Rytmen er ganske interessant der, altså, at du skal jobbe I rytme. Det er jo ... det fremmer jo, altså, for en ting er jo at bildet – verden – er **(inaudible)** men rytmen gjør det ekstra **(inaudible)**, ikke sant. Og her tenker jeg at akkurat som med det her buespillet altså, her... du fasiliterer bevegelsen her på en veldig god måte. Og det er også et veldig nøytralt miljø. Det her squash-spillet, det er litt sånn... det er litt fremmed. Mens dette her var egentlig ... det var veldig lett å forholde seg til, et behagelig miljø, tenker jeg. Det var ganske tydelig hva du skulle gjøre. Jeg merket at jeg hadde dårligere kontroll på venstre hånd; det var mindre... altså, jeg traff dårligere på venstre. Det var mindre risting på den venstre siden. Det var antagelig min plassering da. Men jeg hadde noen ganger følelsen av at jeg egentlig traff. Men jeg gjorde sikkert ikke det.

A: Kan være jeg som sto i veien for sensorene mens jeg filmet, egentlig. Kan være.

E: Ah. Ja.

A: Så ja. Jeg husker ikke hvor mange miljøer det er, men... **(total, in the game)** vi har brukt, altså, vi har brukt 4 forskjellige miljøer. Vi har en sånn strand som er ganske ”chill”–og ja, med en veldig ”chill” låt altså—så der begynner man å komme i godt humør i god rytme. Og så er det en oppe i skyene, og der... uten unntak, var det en som hadde høydeskrekk og så... sa ”åh, nå skal vi opp i skyene igjen. **(skrik)**” Så jeg måtte bare si fra at ok, det gulvet, at du prøver å se på det **(to maintain reference to floor-height/ground)**, altså. Og så var det ett sekund, og så var det greit, men... å komme inn der.

E: Ja. Det var en liten tilvenning da.

A: Ja. Så har du under havet og en ørken og det er de vi har brukt da. Så sangene – vi har hatt litt variasjon, fire fem forskjellige i tillegg til den du har prøvd.

E: Ja. Men jeg kjente nå at etter det spillet her nå, jeg vet ikke hvor lenge... varte det fem minutter eller noe sånt?

A: Ja.
E: Så tenker jeg at nå... da er det greit å puste litt og få samlet seg litte granne. Det var liksom en grei varighet. Mange tror jeg kanskje nesten ville syntes det var langt.
A: Ja, det har det **(inaudible)** ... Ja, så de fleste tok to sanger minst da, så var det noen som var sliten og måtte de ...
E: Ja.
A: stoppe der. **(referring to patients whom after one or two songs in HoloDance preferred to stop, which was usually close to the prescribed 10-minute mark)**
E: Ja. Men et veldig kult spill. ... **(pause)** Ja. Nei, jeg vet ikke hva det var, men det her squash-spillet, jeg fikk liksom ikke helt **(inaudible)** på det. Jeg synes de... jeg lurer på om det er noe med dynamikken der. At du mister litt kontroll. Altså, nå sier du det at du kan jo stille det inn da, med hvor han skal returnere **(adjustable ball-bounce directions/span)** ballene. Men her følte jeg at det var litt som at det ga spilleren litt mer kontroll, rett og slett.
A: Ja. Mhm. **(pause)** Ja, så hva skal vi si om stilen – det er jo nesten Tron **(popular sci-fi franchise from the 1980s)**.
E: Ja, litt sånn.
A: Vi har gitt de **(patients)** litt instruks på forhånd og forteller på forhånd; at det er en historie, "earn your freedom" og alt det der, det toner vi helt vekk. **(game plot)**
E: Ja. Game-aspectet tas vekk litt, ja.
A: **(inaudible)** begynner på den Zen, der har man ikke motstanderen.

Interview paused while GEQ is administered.

A: Du har svart på dette litt i sted, men som behandler, som kanskje bruker noen lignende øvelser og bevegelser, hvordan opplevdes dette for deg?
E: Ja. Alså, jeg kunne tenke meg å begynne med liksom si, dette er en måte å arbeide i fysioterapi som er lite utbredt. Ikke sant. Jeg kjenner jo til at man har brukt sånn skjerm-gaming; har inntrykk at folk synes det er "ålreit", også at de blir engasjert med det—lite førstehåndserfaring med det, men... for min egen del, jeg følte at jeg ble veldig oppslukt. Overraskende—mye mer enn jeg hadde trodd. Og det tenker jeg er jo kanskje det som ville være nøkkelen til å bruke dette i fysioterapibehandling, det er jo det at man... tar oppmerksomheten vekk fra.. måtte det da være ryggplager, eller hva det måtte være, over til noe annet. Og at man kan lure frem bevegelser som man ikke ville fått i vanlig behandling. Jeg tenker at det her ligger godt til rette, atlså. Tenker jo også det at der jo sikkert egentlig tidlig barndom i utviklingen av sånne behandlingsmetoder som dette, men det må jo være fantastisk potensiale. Jeg kan egentlig ikke forstå noe annet, altså. Veldig... hvordan man kan tilrettelegge det veldig spesifikt inn mot aktuelle, forskjellige pasientgrupper og brukergrupper. Men det er den oppslukende opplevelsen—det

er det jeg kanskje sitter mest igjen med; man glemmer tid og sted, altså.

A: Det vi bruker som design-prinsipp for **(inaudible)** distrahert for komfort hvis det er bevegelse—nå er jo dette stillestående spill, men... i flygespill og bilspill og sånn, så må du nesten... vi kaller det for ”keeping the brain busy”. Vi skal gi de rette depth- og motion-cues uten å forstyrre mye av sidesynet, og holde det vestibulære systemet fornøyd.

E: Ikke sant. For jeg tenker, hva skal alternativet være, sant, du har en pasient som har vondt i ryggen, gruer seg for å bevege seg, stive av, kaste ball, sant... oppmerksomheten er jo allikevel på at vi er i en treningssal, eller hvor det måtte være. Så det å skulle forholde seg til disse oppgavene som ”gaming”i et så oppslukende nivå, nei, miljø; veldig, veldig relevant. Så kan vi også diskutere, hvordan skal sånne miljø se ut, sant? En ting er jo hvis man er sånn ”game-kid” og går på butikken og kjøper et spill—det gjør man jo antagelig ikke, man bestiller et spill—så har man jo muligheten til å la preferansene sine styre om du vil ha musikk og farger og sånt som dette her, men her kommer det jo pasienter som der deres preferanser ikke er hørt i forkant, så det er sikkert om å gjøre at miljøene skal ha en viss grad av nøytralitet.

A: Og variasjon, kanskje?

E: Og variasjon, absolutt, sant. Det her buespillet på et romskip **(referring to RoBoW Agent and its setting/level design)**, det hadde også fungert om det var i et annet miljø, ikke sant. Glemmer jo fort at det er på et romskip, for så vidt, da. Det her under vann **(HoloDance underwater level)** er jo også sånn som jeg tror vil mange pasienter vil synes det er helt greit å forholde seg til. Men det her squash-spillet **(HoloBall)**, det var litt sånn fremmedgjørende. Litte granne.

A: Mhm. Ja. Det er tidlig i markedet, men variasjon kan være nøkkelen der. Det er et prinsipp der ...

E: Kanskje mest variasjon i oppgaver, ikke så mye miljø, nødvendigvis. Jeg vet ikke.

A: Ja. Det spørs litt hva hensikten med spillet er –

E: Absolutt.

A: – og hva tema er, da. Her er det ganske ”retro-arcade style”, så det er jo tilbake til Tron-eraen, og simplistisk... Det vi kaller for den grafiske shadingen er ganske målrettet mot den type opplevelser. Det er et trekk vi ser i mange av disse tidlige VR-spillene; det er enkel grafikk, for det kjører lett på billige maskiner, og derfor **(inaudible)** kan man bruke stilistisk variasjon i mest mulig grad, og det enkle miljøet plutselig begynner å lyse akkurat som... veldig sci-fi der.

E: Ja.

A: Du ser for deg at det er sånn at squash-greien, hvis man toner ned sci-fi elementet, så kunne man..?

E: Hm. Ja. Jeg tror at—helt personlig for meg, nå uttaler jeg meg på sviktende grunnlag da, men—jeg hadde kanskje syntes at det gjorde det mer tiltrekkende, ja. Det tror jeg kanskje.

A: Hvordan merket du at spillereglene artet seg? Altså, fysikken står jo til en viss grad, men bare en viss grad her, og så har vi stilistisk kontroll over hvordan ballene oppfører seg.

E: Jeg tror kanskje jeg måtte øvd litt mer. Det var... jeg følte det var vanskelig. Jeg følte at hver gang jeg prøvde å slå "back-hand" så traff jeg ikke eller så gikk den liksom i alle mulige retninger. Men det kan utmerket godt hende at det hadde med mine ferdigheter å gjøre. Mest sannsynlig så hadde det det. Nei, så, litt sånn tilvenning tror jeg sikkert hadde hjulpet. Egentlig sikkert på hele opplevelsen. For jeg følte at jeg mestret det spille dårligere enn jeg mestret de to andre. Og da ble jeg sikkert litt negativ på grunn av det. **(laugh)**

A: **(laugh)** Ja. Som du sier så har vi en variasjon der **(inaduble)**, spiller du med Lars Peder så bruker du disse store, klunkende, solide kontrollene **(referring to the slightly larger and weighty HTC Vive hand controllers)**, mens her har du de litt mer nøytrale grep **(referring to the lighter Oculus Touch controllers)** så du kan bruke fingrene.

E: Ja, rigktig. Det vil jo sikkert ha litt å si.

A: Så vi kunne kanskje tilpasse, at det ble litt mer behagelig hvis du fikk stille inn hvordan racketen var rotert?

E: Kanskje. Vanskelig å si.

A: Ja. Du har prøvd litt VR. Har du prøvd noen andre type VR-opplevelser? Med Lars Peder eller..?

E: Ja, jeg har prøvd med Lars Peder.

A: Mobil VR?

E: Kun Lars Peder sitt, egentlig. **(HTC Vive)**

A: Ja. Vil du si at du er en "gamer" til vanlig?

E: Nei, jeg vil ikke det.

A: Casual gaming, eller hva som helst?

E: Nei, det ville være å ta hardt i. Nei, gamer er jeg uansett ikke. Jeg har definitivt spilt **(inaduble)** på piltastene på tastaturet, men ikke erfaren. Bruker hverken VR eller dataspill.

A: Ja. Litt background. Ja, jeg tenkte å snakke litt om dette med tilgjengelighet. Dette oppsettet vi har her i dag, det er sånn såkalt "desktop-VR", at du trenger en litt småkraftig maskin, og så trenger du litt "real estate" **(free space for play area)**; gjerne noen sensorer—som riktig nok kommer i bordplassering—men du trenger litt åpent område, og det skal litt til med rigging, ledninger. Dette er jo veldig lett å sette opp helt nøytralt i en klinisk sammenheng. Hvis du hadde hatt en datamaskin, og ledningen var skjult, er dette ok behandlingsområde?

E: Ja, ja.

A: To og en halv meter? –

E: Ja, det virker jo sånn, altså, så lenge det buret **(Guardian System, safety grid in VR)** var definert. Altså, at... man føler seg trygg på at man ikke er på vei ut av vinduet eller noe sånt. Og det gjør man jo når et sånt perimeter er definert, ikke sant. Så det ville jeg ikke tenkt på at det var noe tema i det hele tatt.

A: Kjenner du til noen av disse nye VR-settene? Facebook, eller Oculus GO? Ikke hørt om det?

E: **(indicates no)**

A: Nei. Altså, det er bare forbruker-klasse da, men det er samme produsent, og Facebook har kjøpt Oculus, så det blir kanskje en sosial plattform etter hvert. Men... tenkte å dra diskusjon litt inn på forbrukerteknologi i behandling.

E: Ja.

A: Enten at dere bruker det klinisk, eller det er noe man kan sende hjem til pasienter da. Og dette her **(indicating the full Oculus Rift lab setup)** er ganske mye utstyr, men en liten telefon, og et VR-headset som ikke trengte noen sensorer eksternt, eller disse nye settene som ikke trenger telefon en gang ... Så kan du få hjem en liten pose, gå hjem og trene i stuen din, og ha seks grader av frihet, samme område... Hva tenker du om det som supplerende til behandling og intervensjon?

E: Ja. Det synes jeg er veldig spennende, for det er jo klart at, som behandler... Det første jeg tenker er at dette må være på en klinikk, der det på en måte er stasjonært utstyr, nærmest, ikke sant. Og det må også være... sant, det er jo et lite hint der, at det er ikke enhver klinikk du kan bruke sånt som dette her, fordi at mange fysioterapeuter vegrer seg jo for alt som er vanskeligere enn... ja, ikke vet jeg. Tekniske ting, da. Sant? Så det er en liten terskel der. Jeg tror ikke der er så mange, men noen vil det nok være. Men min første tanke er at dette er noe som skal stå på et sykehus, eller rehabiliteringssenter eller noe sånt. Men hvis det åpner seg muligheter for at du kan ha en tilsvarende opplevelse hjemme, på en enkel måte, så synes jeg at det må jo være fenomenalt... Så man trenger ikke sensorer da? **(referring to Oculus GO)**

A: **(author briefly describes tracking scheme of said HMD, inside-out tracking)** Det er noe jeg vil ta opp som fremtidig arbeid og potensial for at pasienter kan bruke dette, og at dere kan bruke det, at dette er enkle headset som ikke har noen ledninger, du bare lader det opp, og så putter det på deg. Ingen sensorer **(external)**, trådløse kontrollere som blir sporet i rommet på samme måte. Og dette er forbrukerteknologi som koster deg et par tusen å kjøpe i dag.

E: Mhm.

A: Kanskje en bedriftsutgave **(referring to enterprise licensing, e.g. Oculus for Business, HTC Vive Enterprise)** kan koste litt mer, men at den kommersielle lisensen er på vei da. Dette du har brukt i dag er jo også forbrukerutstyr, men det finnes og i bedritsutgave, **(inaudible)** rundt ti tusen **(approx. 10 thousand NOK or more at time of writing, roughly estimated)**. Så kanskje med en dyr datamaskin så er du oppe i tretti tusen, men det er sånn ”klinisk” pris da, kan du si. Så har du det du trenger for å begynne å spille og bruke det. Mens kanskje hvis pasienten har selv, eller hvis man kan sende et sånt Oculus GO for eksempel, disse nye mobile settene som ikke trenger eksterne greier til et par tusen, er det interessant å kunne sende hjem til de?

E: Ja, det synes jeg absolutt det er. Fordelen her er jo at hvis jeg lager et treningsprogram eller sender med et treningsprogram med hjem til en pasient, så kan jeg jo være ganske sikker på at det ikke blir fulgt opp nøye... **(inaudible)** av, eller.

Ikke sant. Men her har du noe som er motiverende. Man vil jo antagelig bruke det fordi det er morsomt, i tillegg til at det har en sånn rehabiliterende hensikt da. Så absolutt. Sånn fra mitt kjennskap til kommunalt helsevesen og penger som er i omløp der, så tenker jeg og at i første omgang så er det nok viktigst med ganske spesifikke brukergrupper, der man på en måte vet med stor sikkerhet at dette her er noe som hjelper, ikke sant. Det er liksom ikke et generisk verktøy i første omgang, tenker jeg. Det tror jeg blir for kostbart, rett og slett. Sikkert ikke på sikt, men... Det blir jo på en måte jobben nå da, å finne ut hva er liksom er det en... har pasienter en god effekt av dette her? Men hvis det det viser seg—jeg mistenker at det kanskje har det, altså—så vil jo det være veldig relevant. Så blir det jo da også en jobb som må gjøres med å liksom skreddersy miljøene og oppgavene veldig til hva som er pasienten sine problemer.

A: Ja. Jeg kan følge opp med et mini-spørsmål da, at når er VR-markedet blitt både ganske sprengt eller mettet i sin nåværende kapasitet, kan du si, eller det finnes i hvert fall mye. **(a slightly misaphrased question/reference on the flow of titles, many of which are indie titles, hitting the consumer marketplaces)** Er det interessant at dere kan sende de hjem med et sånt forbruker-sett **(a mobile HMD)**, og så kan de ta en del forbrukerspill som er der allerede, og sette sammen en skreddersydd kombinasjon av de? Akkurat som Sunnås har gjort med sin katalog av treningsspill.

E: Ja. Absolutt.

A: Eller ville du foretrukket å ha et helt skreddersydd opplegg selv der du hadde kontroll over kanskje loggføringskapasitet, eller..?

E: Jeg ville jo... Som utgangspunkt ville jeg jo tenkt det siste da. Men jeg tror det første alternativet er veldig fruktbart og. Men hvis du skulle liksom... jeg tror det hadde vært veldig stilig hvis det var... ja, og en logg hadde vært kjempestilig. Men nå nevner du Sunnås, og det er jo selvfølgelig et veldig godt poeng, spesialinstitusjonen, som driver med spesialisert rehabilitering, sånn som Sunnås og, som Nordås gjør, så vil du jo antagelig treffe mer spesifikke brukergrupper enn i vanlig kommunal praksis, der tredje-annenhver som kommer inn døren har vondt i ryggen. Du kan liksom ikke sende med de hjem, alle sammen, med den typen utstyr. Men i spesialisert rehabiliteringssammenheng, altså, tenker jeg der må det være kjemperelevant. Uten tvil. Så Sunnås har det? **(referring to the game catalogue)**

A: Ja, jeg burde kanskje sagt for tydeligheten sin skyld, jeg tror det er Sunnås som har det, en katalog av vanlige forbrukerspill til X-Box og sånt med de som har Kinect, eller Nintendo Wii—

E: Akkurat.

A: —så har de en oversikt over forskjellige ”exercise”-spill, og hvilken muskelgruppe eller mental trening de er nyttig for.

E: Nemlig, nemlig.

A: Det ville vært dyrt om de skulle kjøpe opp lisenser for sånne spill og brukt de kommersielt, men de kan jo lage en oversikt, og...

E: Ja. Anbefale.

A: Ja. Så vidt jeg forstår så er det det de har gjort. Skal ikke si bombesikkert.

E: Det er jo veldig interessant, altså.

A: Mhm. Så jeg tipper jo at kanskje en VR-plattform, eller en oversikt over VR-titler, hadde vært noe i samme bakgaten å bruke?

E: Helt klart. Det er om å gjøre å så prøve ut litt forskjellig. Og sånn som på Sunnås så tenker jeg der vil de jo ha pasienter med ulike motoriske problemer, sånn at noen trenger kanskje spill der de sitter, og noen greier å stå, og noen greier å gå, sant. Og at man da finner spill som egner seg for... vi har antagelig også unge folk som er kjent med forskjellige game-varianter. Ja! Så interessant. Det er veldig interessant.

A: Ja. **(pause)** Så vi har snakket litt om ulike motivasjoner for å ta i bruk forbrukerteknologi i VR, eller i det kliniske. Jeg skal bare spørre litt om hvordan opplever du nyvinninger i teknologi i forhold til din kliniske praksis, eller forskningen du driver med; hvordan kommer teknologiske nyvinninger til hos deg?

E: Ja. Det er jo... **(pause)** Nå jobber jo jeg litt med teknologi da, i hvert fall i forskningen, med sensorer og sånt. Så jeg har jo...

A: Kan kanskje si litt om det? Kort, bare...

E: Ja, jeg er opptatt av kinematikk under gangen, hos eldre da, og da måler jeg akselerasjoner i gangen med en sensor som de har på ryggen. Og da vil jo en sånn akselerasjonssignal, det vil være ganske rytmisk eller syklisk, ikke sant. Så da har vi statistikk for å bearbeide akselerasjonssignalet og se hvor like syklusene er til **(inaudible)**, rett og slett.

A: Mhm.

E: Så jeg er jo antagelig en av de fysioterapeutene da som har brukt teknologi litte granne i hvert fall. Jeg er ikke spesielt teknologisk kompetent, men jeg er ikke livredd for tekniske ting heller. Jeg prøver, og ser om jeg får det til, og hvis jeg ikke får det til, så ringer jeg til Lars Peder **(Bovim)**. Jeg tenker jo... nå må du bare minne på, hva var spørsmålet her igjen? **(laugh)**

A: **(laugh)** Ja, du var inne på det med teknologi og hvordan det finner veien—

E: Hvordan det finner veien frem, ja.

A: Ja. Så må jeg spørre også, har du erfart noe forbrukerteknologi eller noe som..?

E: Men hva legger du i "forbrukerteknologi"?

A: Noe som gjerne du finner i andre steder enn akademia, ikke "industrial grade" eller "research grade". **(referring to consumer-grade hardware, not necessarily precise enough for industrial, medical or research use)**

E: Ja. Sånn som du kjøper fra butikken, rett og slett.

A: Ja.

E: Ja. Nei, mobiler er jo en ting da. Sant, det er jo noe som mange forbrukere har, tenker jeg.

A: Er det noe som du bruker i forskning eller samler inn data fra?

E: Man kan jo gjøre det. Jeg har personlig ikke gjort det, men sånn jeg har forstått det når jeg har snakket med Harald og sånt **(one of my thesis super-**

visors at the Department of Computing, Mathematics and Physics), så er det jo antagelig ikke så krevende å lage sånne apper da, som du kan bruke til å registrere bevegelser og skritt og etc. etc., og kanskje også innebygget med noe slags feedback-system—”nå har du gått mye” og ”nå har du gått lite” og ”nå har du sittet lenge”, og at du får meldinger, eller vibrerer et eller annet sånn som det.

A: Litt som de nye FitBit eller mobil helse-apper, eller?

E: Ja, så det er jo ikke akkurat revolusjonerende lenger, FitBit-en har jo... Men jeg tror jo sånn, for å bli veldig teknisk da, så FitBit-en har jo noen begrensninger i og med at den er på armen, og en armsving tilsvarer jo ikke nødvendigvis ett skritt. Så i min verden så hvis jeg er opptatt av gåing, så ville FitBit-data og tilsvarende ha lavere verdi enn det som du for eksempel har i en baklomme. For det at det er nærmere på skrittene, enn bare på et armsving.

A: Mhm. Ja. Så her på bygget er det den Qualisys dere bruker når dere er avhengig av mest presis mulig data?

E: **(redacted a few seconds indicated to be ”off the record”)** Det er et veldig, veldig viktig hjelpemiddel for de veldig, veldig få pasientgruppene som der brukes mye, for eksempel da barn med CP **(? Uncertain transcr.)**, men jeg ville aldri drømt om å bruke det i forskning på eldre, for eksempel. Nei, skal jeg be en fem og sytti år gammel dame.. Ja, nei, men de må jo gå rundt i undertøyet, sant. Og gå frem og tilbake mange ganger for å få gode opptak og sånt. Så det hadde jeg ikke gjort. Og det tar fryktelig lang tid å få ut data i etterkant. Så det er en tungvint... **(short remark redacted as above)**. Men sensorteknologi tenker jeg er fremtiden.

A: En spennende ting er jo nå når vi kan begynne å sette på.. for eksempel HTC Vive, konkurrent til Oculus, som du har brukt i dag, de har et sånt helt grensesnitt for å koble på hvilke som helst pereferier, og de er begynt å lansere body-trackere som du bare setter på med ekstra ”dupeditter”, og så vil de bli registrert på sensorene på samme måte; da kan bruke bl.a. invers kinematikk **(Inverse Kinematics)** eller beregninger for å animere skjelett, eller spore flere kropsdeler, alt etter hva du vil.

E: Ja. Nemlig.

A: Og da snakker vi kanskje millimeter, eller sub-millimeter presisjon. Er det godt nok for ”research grade”? **(this question was explorartory, and not entirely accurate as put in hindsight, given the discussed reference in the background chapter that postulates that the HTC Vive Lighthouse sensor technology is not sufficiently accurate for research)**

E: Ja, det vil jeg si. Sannsynligvis så er det det.

A: Ok. Du må kanskje ha mange nok punkter da i forhold til..? Å måle nøyaktig fleksjon, for eksempel?

E: Hm, ja, jeg måtte nok sett på det da, men millimeter høres ut som det kan være akseptabelt.

A: Ja. På det ene punktet, riktig nok.

E: Typisk da, når du går, så flytter hoften seg fra side til side. Og det er cirka tre centimeter i hver retning. Så en millimeter der vil jo utgjøre... én prosent. Er ikke det riktig? Null komma tre prosent. I hvert fall. Du vet, selv med det Qualisys-systemet, sant, de sitter på hud, og huden glir over... Vi fester de liksom på sånne beinete punkter, men huden glir over de punktene, så det blir jo aldri helt nøyaktig, uansett hvordan man snur og vender på det. Og det er jo hele tiden et trade-off mellom brukervennlighet og nøyaktighet. Noen ganger tror jeg at den millimeteren, den lever vi greit med. Men dette er jo knapt en forbrukerteknologi, da.

A: Ja, vi tenkte på det, og hadde en liten diskusjon på det, om det fantes noen små **(devices)** som vi kunne spore kanskje to-tre punkter på ryggen og gjerne hoftene... hvis du hadde hatt, ikke nødvendigvis sub-millimeter presisjon, men noe i det området...

E: Ja, men altså kjøper man sensorer fra litt sånt respektabelt firma så får du god nok kvalitet, altså. Det tror jeg definitivt du gjør. Nå... jeg har ikke sett på nye sensorer på en stund nå, men det som jeg vet har vært en utfordring... En utfordring har vært å finne et nullpunkt i rommet. Når vi har prøvd oss med flere sensorer, så har de dataene driftet veldig. Fordi at den har, vi greier ikke å definere et godt origo da, hvor xyz begynner. Men det—

A: Det er ingen av de som har ekstern referanse eller sensorer?

E: Det er det du må ha, altså. Men det som Lars Peder sa **(Bovim)**, jeg diskuterte det med han her forrige dagen, det du trenger er bare en ekstra sensor, som er orgi, som du legger fra deg et sted. Og det høres jo veldig rimelig ut. Som jeg sa, jeg har ikke sett på sånne sensorer på fem-seks år nå, jeg bruker bare de gamle jeg har, jeg er helt sikker på at i sensorteknologien har de kommet betydelig mye lenger og det sikkert ikke er noe stort problem. Så ja, absolutt, men spørsmålet er jo da hvilken informasjon er ute etter da. Er på en måte en... For jeg vet at Maja **(Sigerseth)**, hun hadde jo dette som et kjernepunkt, at hun var opptatt av veldig presis informasjon om bevegelser i ryggen. Er det litt det du tenker på nå?

A: Ja, jeg tenker diskusjon på hvor dypt man måtte gå, hvis man hadde noen sånne forbrukersensorer på to-tre steder, og det kunne vært integrert i et sånt system fra før **(meaning something like HTC Vive sensors and tracked object within the SDK/Runtime, e.g. body trackers as mentioned)**, om det hadde vært veldg enkelt å kunne si noe, ikke sånn veldig presist diagnostisk, men fått en viss pekepinn om hvordan denne pasienten lå an ved start, **(inaudible)**?

E: Ja, det hadde jo vært kjempestilig om du kunne modellert et skjelett eller noe sånt som... Det er jo, den feedbacken du får nå, det er jo om du gjør oppgaven rett eller ikke. Men det er klart, det hadde jo vært kjempestilig om du kunne bygge inn i dette også feedback på bevegelse dine. Men det er jo en hel jungel av begreper som skal avklares der, på hva er en god bevegelse, hva er en dårlig bevegelse, sant. Er det bare fleksjon i ryggen? Er det det at man skal se i samme spillsituasjon over tid at man får mer og mer fleksjon i ryggen? Så man må lage noen hypoteser rundt det. Men ja, absolutt. Absolutt. Kanskje man også kunne sett på sånn, dette som vi kaller for ”smoothness” i bevegelsene. Som er... da trenger du for så vidt ikke mer enn én sensor, altså. **(pause, expert fetches some paper to illustrate)** Hvis du ser for deg at du har en som har veldig... sånn at nå går signalet her **(see illustr.)**, og her skal personen snu, og så er det en hakkete bevegelse, versus da en sånn glatt og jevn bevegelse. Det tenker jeg at det må man kunne operasjonalisere ganske greit med å bruke sensorer. Så det får bli PhD'en deres. Men jeg tenker sånn, for å selge dette her inn, så tenker jeg at et mer overordnet mål som er det viktige i første omgang. Har de mindre bevegelsesfrykt? Aksepterer de spillsituasjonen? Har de mindre vondt? Sant? Så blir det her, det blir ikke så viktig, føler jeg, i første omgang, som at det aksepteres, og at man på en måte jevnt over føler at man fungerer bedre.

A: Ja. Mhm. Det er veldig spennende.

E: Det er veldig spennende. Absolutt. Hvis dere går videre, så er vi med altså. Helt klart.

A: Det hadde vært kult. Ja. **(pause)** Jeg må også ha litt bakgrunnsresearch, ikke veldig mye, min oppgave er mye teknisk. Skal vi se, nå har jo vi, eller Maja har, veldig spesifikke kriterier for nøyaktig hvilke pasienttyper som skal inn. Jeg regner med du er litt kjent med de?

E: Sånn, roughly.

A: **(author presents an excerpt from the project plan submitted to the regional ethics committee, including the inclusion criteria that were actual before the later adjustments were made, of which Expert had some knowledge of. See chapter 5)**

E: Ja, de skal ikke ha spesifikk LBP-diagnose? Da blir det ikke så mange igjen. **(pause, comments criteria)** Ja, for forskningen, så gir jo det god mening, sant. Man vil ha så lite konfunderende faktorer som mulig, og så lite annet som kan påvirke som mulig, så man vil ha et homogent utvalg.

A: Men hvis du hadde møtt på en pasient som hadde bevegelsesfrykt, som hadde vært egnet for denne type trening—

E: Ja.

A: Først og fremt, hvordan blir disse pasientene møtt når de skal til en screening, eller om de i det hele tatt skal til screening... kan du beskrive kort hvordan deres vei blir?

E: Det er jo litt sånn varierende det, tenker jeg. Så akkurat de her kommer jo fra Nordås. Og da er det jo litt alvorlige plager.

A: Ja. Og så vidt jeg forstår har de prøvd mye og vært litt frem og tilbake? Og som ikke har noen veldig konkret diagnose som kan behandles?

E: Nei, i hvert fall ikke noe veldig tydelig funn da, sant, noe blodprøver, røntgenfunn eller tilsvarende. Men... De jeg møter som har muskel- og skjelettplager—ikke så veldig mange med ryggplager jeg treffer da, mest knær og hofter—som ikke har veldig spesifikk patologi, så er det mye snakk om bare avdramatisering, ikke sant, og understreke det poenget at det er ingen ting som blir verre av at de beveger seg og sånt. Og jeg tenker det at denne gjengen her har jo sikkert fått det rådet og, men de har liksom likevel ikke blitt bedre da. Og akkurat der et det jo at et tilbud som dette her **(referring to the VR-interventions)** tror jeg vil være ganske bra altså. Fordi at det er så oppslukende; det er morsomt, de vil bli mer antagelig eksponert for trening, sant fordi de oppsøker det aktivt, og frivillig, fordi det er morsomt. Pluss også at det er en treningsform som er godt rettet mot det de har av plager da, at de ikke tør å bevege ryggen.

A: Men de pasientene, de har... de som dette kunne vært aktuelt for, hvis dette hadde slått litt an, og det hadde fantes litt penger eller muligheter for å få dette ut til pasienter, ville det kun vært bra for de som har vært en kasteball og har vært mye frem og tilbake, og ikke...

E: Nei, det synes jeg er vanskelig å si. Det må nesten prøves ut, altså.

A: Jeg bare tenker på for de, hvor terskelen for tilbudet skulle ligge i så fall.

E: Ja.

A: Vi får de ferdig screenet, men det... er pasienter som sier de har, eller er redd for å bevege seg, de blir gjerne ikke screenet så grundig før sent i prosessen?

E: Nei, jeg er enig i det. Nei, kanskje i første omgang så er det de som er litt plaget da. Ikke liksom enhver som har vondt i ryggen. Men de som... de har hatt smerte en stund, og de som scorer over en viss prosent på Tampa **(referring to the Tampa scale, see background)**, ja. Det gir jo god mening, det, da. Hva kan du få på Tampa maks, husker du det?

A: Nei.

E: Nei, jeg husker ikke det, jeg heller.

A: Da er oppe i førti femti tallene, eller?

E: Ja, her **(referring to the initial inclusion criteria)** får de være med hvis de har mer enn 40, eller 39, da. Den går kanskje til hundre, da, jeg vet ikke.

A: **(inaudible)**

E: Mhm. Nei, det gir jo en viss mening det, altså, at det skal på en måte tilbys pasienter som kanskje har prøvd litt forskjellig, i første omgang, sant. Sånn at man får litt mer kunnskap om det, og så kan man i neste omgang se om er dette en sånn super quick-fix som bør rulles ut i enhver fysioterapiklinikk rundt omkring i Norge, sant. Men da må man liksom ta skrittene og prøve å evaluere litte granne.

A: Ja.

E: Derfor er det jo veldig bra at dere gjør dette her.

A: Ja, håper det fortsetter. **(inaudible)**

E: Ja, vi får jo se da, hva som skjer. Mhm.

A: Jeg forstår at arbeider så tett med sånne pasienter i yngre aldersgrupper?

E: Jo, jeg har også kontakt med pasienter som er yngre, ja. Sånn vanlig voksne. Men ikke så mye, som sagt, når det gjelder rygg da, det er mer sånn ... knær og hofter, først og fremst, jeg ser. Jeg jobber én dag i uken på en sånn poliklinikk.

A: Ja. Da blir det kanskje mer oppfatningsspørsmål da, men ... **(pause, correction)** Ja, eller kanskje, hvilke tiltak og øvelser er det dere har å velge mellom hvis dere får en sånn pasientgruppe i behandling?

E: Ja...

A: Jeg forstår også at det er en del... man går gjerne til verks med kognitiv adferdsterapi **(cognitive behavioural therapy)**, CFT **(cognitive functional therapy)**, og ser litt på psykososiale faktorer også...? **(inaudible)** men sånn konkret, av øvelser, kanskje også adferdsmønstre i det daglige, hva er det dere ser nøyest eller først på?

E: Jeg tror jeg ville begynt med bevegelse i ryggen, ja. Aktiv bevegelse i ryggen. Det tror jeg ville vært første ting jeg så på, og kanskje også der øvelsene ville vært rettet mot ... øvelser der man skal jobbe med aktiv bevegelse i ryggen. Jeg vet at Kjartan **(referring to Kjartan Fersum, one of Sigerseth's thesis advisors, and his approach to CFT)** har en hel sånn algoritme for dette her. Den kan jeg ikke jobbe ut i fra... jeg er ikke så godt kjent med den at jeg kunne brukt det, da.

A: Er det en bred enighet eller standardisert måte å behandle disse pasientene på?

E: Ja, det er noen sånne "best parctice" regler da, men de er ganske generelle. Det er på en måte øvelser, sant. Det er jo noen som mener at det viktigste for disse pasientene er jo ikke at øvelsene skal være så ekstremt spesifikke, men bare at de faktisk gjør noe som helst. Men igjen, her vi jo mulighetene til å gjøre øvelsene ganske spesifikke da. Og det er en god ting.

A: Så det å vektlegge motivasjon, og adferdsendring, og handlingsmulighet, det står høyt på listen?

E: Ja, uten tvil vil det gjøre det, for som du sier, det er ikke så ofte at de har patologiske funn i den forstand at du kan liksom gå inn og så si at den knokkelen eller den mellomvirvelskiven som er årsaken til at du har plager, sant. Vanlige diagnostiske metoder, så finner man ofte ikke så mye da. Så ... igjen glemte jeg hva det var du egentlig spurte om.

A: Jeg og. **(laugh)** **(pause)** Jeg tenkte på da hvilke tiltak som vektlegges høyest av øvelser eller adferdsmønstre, hva dere ser først på.

E: Mhm.

A: Så er det vel kanskje ... det var vel kanskje grundig til verks i samtale for å finne ut om kognitiv adferdsterapi og CFT er veldig, helt nødvendig for å kunne skape endring hos denne pasienten da?

E: Ja. Det er jo kanskje også for de som har gått med det en stund, tenker jeg. Jeg tror man ville jo kanskje angrepet det, altså, hvis du kom på klinikken og så du hadde hatt vondt i ryggen i en uke, så tror jeg jeg hadde begynt med det helt sånn kroppslige; se om du kan bevege deg, ja det her går jo fint, gå hjem og gjør det du har lyst til. Sant. Så har du de som blir sånn superakutt og kroniske, og da må man kanskje gå litt mer spesifikt til verks, begynne å snakke litt om forventninger, tidligere erfaringer, livssituasjon ... ja, tenke litt sånn som denne algoritmen til Kjartan **(Fersum)**, der det ene bevegelsesmønsteret så skal du ha den behandlingen, og det andre bevegelsesmønsteret så skal du ha den behandlingen, sant ... manuell behandling som kiropraktorbehandling kan være aktuelt. Ja. Så det er ulike veier å gå, tenker jeg.

A: Nå bruker Maja også veldig spesifikke effektmål og metoder for å måle de. Er det noen effektmål som dere ofte tillegger hvert kasus som ”best practice”, eller er det per pasient at dere setter sammen ulike som dere følger med på?

E: Det er jo noen sånne her spørreskjema som er mye brukt da. Som dette som heter Rolland-Morris, som jeg tror Maja bruker, tror jeg er i veldig utstrakt bruk i klinisk praksis. Men også en helt vanlig smerteskala fra null til ti tror jeg også vil være veldig aktuelt mange steder.

A: **(pause)** Ja, jeg tror jeg kan hoppe over noen av de punktene. **(pause)** Ja. Kanskje det viktige for min oppgave har vi vært gjennom en god del allerede. Så lurte jeg også på, er det noen helt konkrete øvelser eller aktiviteter, altså alt fra noen øvelser du kommer på her og nå, som er veldig interessant å ha ”spillifisert”, hvis du vil?

E: Ja, da har jeg lyst til å ta utgangspunkt i opplevelsene i spillet her nå da.

A: Ja, for all del.

E: Det som jeg tenkte var veldig bra der, det var jo de å bøye seg fremover. Og sånn jeg forstår på deg også, så var de jo noen av de som dere har inkludert **(trial patients)** som synes det var krevende, ikke uten grunn. Sant. Det er noe som ... når du bøyer deg frem, så aktiverer du musklene for å holde at du ikke skal liksom dette fremover. Så alle sånne ting man kan gjøre, der man får frem den fleksjonsbevegelsen, tenker jeg er en god ting, altså. Og samme med rotasjon, som vi hadde mer av i det siste spillet, HoloDance spillet, der du hele tiden må orientere deg i forskjellige retninger, ikke sant. Så de to bevegelsene der er det jeg ville tenkt var viktig å prøve å få frem.

A: Skulle du bedt en pasient gjøre en øvelse i en klinikk- eller treningssituasjon, hvordan ville den øvelsen sett for å ... eller, hva er en veldig vanlig øvelse for å ”provosere” ryggfleksjon?

E: Det kommer litt an på hvor dårlige de er; du kan på en måte bare si det at nå skal vi jobbe med å bøye ryggen, og så skal du sitte på en stol, og så skal du falle fremover, ikke sant, rolig. Så inspiserer man—hvordan skjer bevegelsen, er det en veldig sånn stiv bevegelse der hele ryggen er med, eller er det sånn at øker gradvis fleksjonen? Hadde vi ikke gjort det, eller hadde det vært en pasient som på en måte mestret det, så kunne man kanskje brukt mer dynamiske ting og mer dagligdagse ting; plukke opp ting, snu deg, legg noe på hyllen, grip ballen som jeg kaster til deg, den type ting. Finne noe som er litt utfordrende da. Og så jobbe seg opp mot toleransegrensen til den enkelte pasient. Og den toleransegrensen kan være avgjort av smerter og stivhet, men det kan også da være frykt for bevegelse, ikke sant.

A: Ok, tror vi har vært gjennom det meste da.

E: Ja. Hvis du kommer på noe mer videre—

A: Skikkelig ergerlig at ... det var jo det vi skulle gjøre, å lage en sånn type ”puzzle/opplevelsesspill” der man skulle bevege seg rundt i miljøer og plukke opp, bruke ting, så det var en lav terskel og ...

E: Ja ja, men det ble en ... vi visste alle at dette kom til å bli krevende.

A: Joda.

E: Så... det første steget nå, jeg synes det buespillet ble **(profanity)** bra jeg, altså.

A: **(author describes the planned level-switch feature for RoBoW Agent where the "base platform" remains the same, but the surrounding environment was interchangeable.) (short exchange, off the record, then pause to pick up from previous question)**

E: Nei, vi snakket om øvelser. Hvilke øvelser jeg ville gjort. Som sagt, jeg ville jo begynt med bevegelser, og ettersom hvordan pasienten tolererer det, få bevegelsene mer og mer inn i dynamiske situasjoner og daglige situasjoner. Bøye seg og vri seg. Det er jo det det er snakk om, egentlig. Det som du faktisk ikke kan gjøre så mye i en sånn VR-situasjon, foreløpig, er at du kan jo ikke ha så mye belastning, ikke sant. Så det ville jo kanskje vært en ting, for eksempel da, hvis jeg hadde en pasient på klinikken, at han skulle snu seg med vekter i hånden eller en kasse med et eller annet i hånden. Så det har vi jo ikke helt muligheten til.

A: Ja. Det har vi jo faktisk **(Qualisys)**, de hadde jo en Unity demo spesifikt **(referring to their Unity SDK)** der de hadde satt markører på et sverd. Så var det to stykker **(people)** som gikk i samme rom med VR-briller, plukke opp to forskjellige sverd og interagere med hverandre. Det var litt kult. **(this question wasn't pursued but is left as a thought on bringing tracked objects into VR through an existing example, which is possible not through HTC Vive trackers etc.)**

E: Ja.

A: Men det var faktisk noe jeg ville ta opp, for at "teknologien VR" er jo ikke bare bedre headset og flere trackere, de får jo haptic suits og disse fingrene som faktisk kan yte noe motstand, og drakter som kan regulere temperatur og gi plutselige impulser av varmt eller kaldt og elektriske... Det er jo ganske...

E: Ja. Mulighetene er store.

A: Ja. Man snakker om PTSD og sånn, de behandlingene som man gjør her i forsvaret i Norge, til og med.

E: De gjør det, ja?

A: De som kan... regulere alt fra temperatur til nøyaktig av taktil stimuli og med haptics. Kontrollere miljøet.

E: Sier du det, ja. Det høres jo litt omfattende ut, men...

A: Det er omfattende, men det er også i forbrukerteknologi, det er det som er spennende.

E: Ja. Du kan kjøpe det, altså, det blir hyllevare, det er det du sier? Ikke hyllevare, men at du kan kjøpe det...

A: Det blir nesten hyllevare, altså, i prisklasse som ikke er sånn forsknings... Det koster ikke skjorten heller. **(slang for relative inexpensiveness)** Og det er det som er det gøye at spillindustrien, de er god til å presse på innovasjon. Når de først tar tak i noe så hives det penger på. **(inaudible, pause)**

A: Men helt spesifikt, jeg vet ikke om vi snakket om det i sted **(during play or earlier interview part)**, men i pil og bue spillet, der var jo det at vi skulle få frem ulike ryggbevegelser, vi skulle ha en progresjon og vanskelighetsgrad. Så tidlig i testingen, stakkars Remy **(Monsen, one of my supervisors)** fikk vond rygg i flere dager fordi han fikk spilt en tidlig versjon på det vanskeligste, der det var to bøtter på hver side og han måtte strekke seg langt ned. Så han var litt gåen etter det. Derfor kom idéen at det var en som kunne bevege seg, først og fremst—

E: Det var velig smart.

A: —sendes opp og ned, da fikk du litt variasjon. Og så disse ”feltene” der pilene dukket opp på forskjellige steder, så du fikk der...

E: Mhm. Veldig smart.

A: Så var det litt kunstnerisk valg av meg underveis men vi valgte å beholde at de fikk disse ”laserpistolene”, eller ”vannpistolene” som jeg sier...

E: Jeg så jo at i det siste levelet **(last wave)** så var det både den bøtten og piler som dukket opp.

A: Ja.

E: Og da tenker jeg det at... **(pause)**

A: Jeg vet ikke om du la merke til at du ble ”beskutt”? **(laugh)**

E: Nei, det gjorde jeg ikke! Ble jeg beskutt?

A: Bra. Det er veldig “subtle” fordi jeg ville at kun de som la merke til det, de skulle få lov å dukke unna. Det kommer noen sånne små, grønne prosjektiler som jeg valgte å ikke gi så mye oppmerksomhet. Av og til...

E: Jeg så at det var noen... Ja, riktig.

A: Så de kommer i retning ”hode-volumet” ditt **(referring to the tracked HMD transform/position)** sånn at av og til må du... **(indicates a dodging movement by motion)** og det hender da at noen som står sidevendt, de må kanskje gjøre sånn. **(indicates a flexion movement to dodge, from a side-stance, such that a forward or backwards flexion is likely encouraged)**

E: Det er jo veldig smart også. De kunne sikkert bli liksom understreket enda mer.

A: Ja. Jeg er litt glad for at noen av pasientene ikke ... **(inaudible, but comment expressed that some patients experiencing some degree of pain at that time of play did not notice or paid attention to the projectiles)**. Det skulle jo vært en vanskelighets-setting da.

E: Mhm.

A: Og så det me de “vannpistolene”, der også var jo tanken at de skulle få en liten pause fra bøy og trekk **(referring to the repeated movements of the archery exercise)**.

E: Ja! Det var...

A: ... pluss at de fikk litt sånn **(indicates the forward reaching motion to reach for the batteries/reload)** for å lade opp igjen, og så holdt de da strak **(indicates holding and aiming the zappers)** og fikk litt spenning der.

E: Ja. Veldig... tror den var veldig fin.

A: Ja, spør helt generelt da, er dette en god belastning for dette problemområdet? Er de rette musklene berørt for..?

E: Ja, det vil jeg definitivt si. Altså, du kan si... hvis målet er at du skal bli sterkere, så er jo ikke denne belastningen nok til at du blir sterkere. Da må du ha en slags overbelastning. Det jeg tenker er hovedgevinsten her, det er jo det at man... ja, egentlig, jeg går litt tilbake på det jeg sier, det at du holder litt sånn i samme posisjonen, det kunne jo... kanskje til og med du skulle hatt mer strøm på pistolene slik at du tvang folk til å holde armene oppe. Det er kanskje et poeng. At du holder den belastningen lenger, rett og slett. Det er faktisk et lite poeng.

A: Om de hadde en stråle i stedet for kulene, at de måtte holde den litt?

E: Nei, det med kulene, det var egentlig litt kult, synes jeg. Det fungerte godt. Jeg er ikke ikke sikker på om det... det blir kanskje litt for lett da, hvis du har en sånn stråle. Da er det ganske lett å sikte.

A: Ja. Da blir poenget i så fall at de må holde den en stund i stedet for at de kan skyte litt her, og litt der, at de må holde, kanskje ”tracke” og? **(trace or track objects)**

E: Sant. Det er jo skulder da, eller skulder og nakke.

A: Ja. Det også var jo en spennende variasjon da, etter det jeg kunne se - nå er ikke jeg fysioterapeut eller helsepersonell – men noen holdt sånn, og noen gikk opp og ned, og det så ut som om noen faktisk, altså bare for å være morsom og peke godt med pistolen, så spennet de virkelig... **(indicating various heights and arms reach that patients would varyingly use to hold and aim the zappers)**

E: Ja. Litt sånn cowboy...

A: Ja. Og den holdt de ganske lenge. Det var jaggu og de som fikk vondt, eller ble sliten. Jeg vet ikke.

E: Ja, det er jo ikke alle som har problemer, eller sikkert mange som ikke har noen problemer med å holde den posisjonen der. Nei, men, jeg synes det fungerte kjempegodt jeg, altså. Det var, ja... Kanskje de her målene skulle kommet enda høyere over de, sant. Så nå treffer du de der, men kanskje du skulle egentlig helt opp der. **(indicating that the flying targets could be at even higher altitudes, such that the patients would need to aim higher, thus increasing tension/load)**

A: Ja. Det hadde vært kult å prøve. Tror jeg må intervjue Lars Peder senere i uken, jeg, og fikse litt på spillet i mellomtiden. **(this was not done, of course)**

E: Ja.

A: Men da, for the record. Tusen, tusen takk!

E: For the record, bare hyggelig.

Recording and interview ends.

C.3 | Domain Expert Interview 2

C.3.1 Premise

Interview session with Physiotherapist and University College Teacher, researcher and master's student, Lars Peder Vatshelle Bovim from the Faculty of Health and Social Sciences, Western Norway University of Applied Sciences.
24.6.2018.
Location: Neutral chosen (small poly-clinical examination room, 2.5x2.5m play area, used in clinical trial).
Goal: Ascertain value of produced research and cross-disciplinary observations used in supporting the thesis' goals. See Chapter 4.
Stimulus: 2 first clinical trial games. Full run of RoBoW Agent. Expert is already partly familiar with all three games, HoloDance was skipped due to time constraints.
Apparatus: Same Oculus Rift setup as used in trial.
Method: Unstructured interview and mixed conversation, playtesting (Author's observation and video recording), GEQ. **Data collection:** Voice audio recording (transcribed, quoted). Video-recording of play session (screenshots provided).
Premise of conversation, as decided beforehand: See Chapter 4..

C.3.2 Transcript

Video transcript

Excerpts from the video recordings made while expert played HoloBall og RoBoW Agent. Parts of this were referenced afterwards in the voice interview, and are therefore given here.

Video 1 (Hball)

3:10
E: Jeg er blitt for vant til Vive-kontrollene. (out of straps) 5:30
E: Vive'n er førti ganger bedre på sånn håndtak, mens denne er mye bedre på hender. Du føler liksom at du holder på å miste den hele tiden. 10:15
A: Ja, hvordan føler du deg? Som fysioterapeut, kan du beskrive treningseffekten av alt dette her?

E: Godt oppvarmet.
A: Akkurat det jeg vil. Supert.
E: Og så var det litt sånn... Det digge der er jo at den blir vanskeligere hvis jeg er bedre. Sånn som når det ble tjuefem prosent raskere, det hadde vel ikke skjedd hvis han hadde slått meg. Det er jo veldig greit at han justerer seg til mitt nivå. At jeg ikke kjeder meg, og at du (gesticulates towards author) får en utfordring.

Video 2 1:25
E: Jeg ynker meg jo allerede fordi jeg må bevege på meg, så det er jo perfekt. Og det har liksom, i hvert fall i denne settingen der det er snakk om rygg-pasienter, så er det ikke så nøye at jeg står og skyter som en tulling, sånn som dette (demonstrates the short-hand bow-firing movement that is discussed in chapter 5 and the voice interview). Det vil jo ha mest på skuldrene å si. Så lenge jeg hvert fall får kommet i gang. (rotates upper body sideways in both directions to demonstrate and motions actively with hands) Og så kan du heller instruere senere om at jeg må gjøre det skikkelig. (demonstrates drawing the bow string far back, such that the bow-gripping arm is extended, and the bowstring-drawing hand is pulled back with high elbow)

2:28
E: Jeg tolket liksom den lyden som at jeg har bommet, men så kom jeg på at det er en trist lyd for det er han som er lei seg.
E: Ja, akkurat den var forvirrende. Hva betyr ”trekk litt raskere i én bevegelse”? (referring to textual instructions in the game UI before the third wave) (explanation given) 5:20
E: Skal du ha et tips? Du har ganske mange sånne ”nå skal du berøre batteriene”, for eksempel. Da er det greit å ha et batteri synlig. 6:30
E: Denne blir jeg stående mye mer i ro på, da. 6:59
E: Hvordan reagerer folk da? Er det glede?
A: Mye forskjellig, altså, men—
E: Er det det noen som har sagt ”dette får jeg ikke til”?
A: Nei, eller altså, så snart de har funnet ut av det lille problemet, så kjører de på. Det er veldig kult.
E: Er det noen som sier at ”dette har jeg for vondt til å gjøre”? Må jeg ta i pilene eller holder det å ta i bøtten? 10:34
E: Kunne det gått an å låst buen til venstre elle høyre hånd, så du på forhånd definerer om du er venstre- eller høyrehendt, og så går det ikke an å ta feil?

Voice Interview transcript

Interview commences after Expert has finished playing the prototype game.

A: Ja. Nå har du vært gjennom to **(VR)** opplevelser. Du spilte easy/medium... nei, bare medium, kanskje... på HoloBall, en god stund, to runder; så spilte du RoBoW Agent, egentlig samme rekkefølge og alt som pasientene fikk. Det første jeg skal be deg gjøre...

Expert fills out GEQ Core- and Post-modules. No relevant voiced remarks recorded during questionnaire. Interview resumes afterwards.

E: Jeg er nok en del strengere fordi jeg har spilt en del før.
A: Ja.
E: Så det er jo bra. Det er jo greit å tenke, for nå har du Bård **(Bogen, other interviewee)** og meg. Greit å skrive litt sånn bakgrunn at jeg driver med utvikling og har mye spillerfaring, mens han har litt mindre.
A: Ja. Det kan vi kanskje ta med en gang. Du er jo kanskje å regne som ekspertbruker på dette her.
E: Ikke ekspert, men...
A: Meget erfaren?
E: Jeg har nok brukt en del timer på det, ja. **(laugh)**
A: Og er daglig involvert i? **(laugh)**
E: I leke-VR. Ja.
A: Og sånn, for the record, hva vil den bakgrunnen si? Hvordan vil du beskrive den selv?
E: Nei, den er litt vel egenlært. Som den ofte **(inaudible)**. Men altså, du vet det, men jeg kan si det. Fysioterapi, og så har jeg jobbet i industri før, så jeg er vant til sånne konkrete millimetermål og alt det styret der. Og så siste halvannet året har jeg blitt interessert i VR, og så driver da med veilede av utvikling av VR gangspill **(walking game in VR)**. Jeg trykker ikke selv, men er veldig mye inne og tester fra helseperspektivet og så gir jeg tilbakemelding på hvordan det kan endres.
A: Ja. Det er bra. Så du er kjent med både helseperspektivet og en del av det tekniske, og på opplevelse—
E: Ja. Spesielt brukeropplevelsen. Det er jo det jeg er mest inne på.
A: Ja. Det er det viktigste vi trenger å få frem nå.
E: Ja, det passet jo bra nå.
A: Good, good. Så. Vi begynner på toppen da. Så brukeropplevelse kan du, og du spiller til vanlig?
E: Ja.
A: Spill? Og **(inaudible)** teknologien som...
E: Ja. Ikke sånn som spiller fem tider for dagen, men...

A: Men gamer godt?

E: Ja. Jeg kan ”trykke”. **(laugh)**

A: **(laugh)** **(pause)** Hvor ofte har du møtt på spillteknologi eller forbrukerteknologi generelt i forskningen, eller utdanningen? Eller som behandler/fysioterapeut.

E: Som fysio?

A: Ja. Eventuelt på forskersiden eller utdanningssiden.

E: Skal vi se, når jeg jobbet så brukte jeg lite teknologi. Altså, det jeg brukte var journalsystemet og slå av og på treningsapparater, omtrent. Mens i jobben her på høgskolen **(HVL)** så er det vel mest teknologi jeg holder på med. Men da er det, altså ... si, 20 prosent av tiden da er på spill i behandling, mens resten er mer annen teknologi for måling av bevegelse og kraft og den biten. Så det er jo mye teknologi som begynner å komme da. Så da er det greit å kunne litt.

A: Ja. Da kan vi egentlig hoppe ned på det, tenkte jeg. Så du møter altså på det i både klinisk praksis, forskning, og jobben her, utdanning?

E: Mye i forskning, litt i utdanning, lite i klinisk praksis der jeg **(var?)**.

A: Ja. Og en ting jeg tar opp for research sin del er hvordan ... hvis du har opplevd det i klinisk praksis, hvordan opplever du at teknolgi finner seg... nye teknologier finner veien til klinisk behandling eller praksis?

E: Ja. Det har jeg lite erfaring på. Men det er klart, utfordringer er jo det—nå tar jeg bare ut i fra tanken på det vi bruker—det som ofte stopper helsepersonell er at det ikke er trykk på en knapp og så er det i gang. Altså, vi er såpass... Det er ikke nødvendigvis teknologien vi er interessert i når vi driver med klinikken. Så vi må ha én knapp vi trykker på, og så må vi ha instillinger som stemmer overens med det vi snakker om, altså bevgelsesfrihet, pasientens fremtoning og han **(pas.)** fremstår sikker eller redd. Og sånne type begreper må ligge inne i programmet. Det kan ikke stå tekniske begrep som vi som helsepersonell ikke klarer å gjenkjennes i da. Så det er ofte det som er ”baugen” med teknologi og. Ja.

A: Mhm.

E: Men det var veldig greit her **(referring to the VR experiences)** for jeg bare satt på meg brillene og så fikk jeg beskjed på normalt språk om hva som kom til å skje. Mens det kan godt være at du drev og trykte og sånn, men det trengte ikke jeg som pasient i denne settingen å bry meg med.

A: Ok, veldig bra. **(pause)** Så du vil si at det er altså en høy terskel for å ta i bruk teknologi som ikke er helt målrettet utviklet mot ...

E: Ja.

A: ... eller som er spesialutviklet mot det området?

E: Ja. Altså du har spesialfeltene, Sunnås **(Norway’s largest hospital specialized in physical medicine and rehabilitation)** og noen klinikker som har en eller annen teknisk interessert person som pusher det gjennom, men på generelt grunnlag tror jeg det er høy terskel for å ta i bruk sånn som dette i klinisk praksis. **(the VR interventions or tech)**

A: Så her snakker vi altså om forbrukerteknologi da, som gjerne selges til ivrige brukere overalt, og som kanskje ikke har den tilpasningen som du etterlyser?

E: Ja. Altså, sånn som jeg nevnte i sted, det passer ikke nøyaktig til... altså, for at jeg som terapeut skal føle at det er noe jeg skal bruke, og ikke noe som pasienten bare kan finne selv fordi han synes det er gøy, så må det være en terapeutisk vinkling på hele programsettet. Selv om ikke pasienten trenger å føle på det.

A: Ja. Veldig bra. Så ja, det er også en ting vi undersøker i prosjektet, kanskje mer i bakgrunnen, er at hvis dette skulle finne vei inn i noe klinisk praksis, at det både kunne hatt en komponent som ble gjort på klinikken men også at det kunne vært en del av pasienten sitt hjemmeopplegg, på trening, og der kanskje forbrukerteknologien har en så lav terskel og så lite teknisk måte å brukes på. Hva tenker du om det? Hvis de kan tatt med seg noe utstyr som ikke er så komplisert som dette **(referring to the Oculus Rift desktop setup in the lab)** med seg hjem?

E: Ja, det er jo drømmen. Og det kan være så komplisert som dette og, bare... Altså, vi har jo masse terapeuter som drar på hjemmebesøk. Og hvis det at du drar på hjemmebesøk og setter opp disse sensorene gjør at du slipper pasienten innom tre ganger da, så har du spart inn tiden, og vel så det. Så sånt utstyret er nå er jo egentlig tipp topp, bare det er billig nok for terapeuten eller brukeren. Så det er jo det som er fremtiden, å få det hjem og la folk holde på. Vi skal jo bli så mange gamle i denne verdenen etter hvert at vi har jo ikke nok behandlere uansett. **(laugh)**

A: Ja. **(laugh)**

E: Det er jo bare sånn det er.

A: Ja. Tenker du da at... eller hvis du tenker som behandler i dag, hvis du gir pasienten et treningsopplegg for behandling av denne typen pasienter **(NSCLBP)**, er det lett å få de til å følge det opplegget i hjemme og klinikk?

E: Nei, det kommer jo veldig an på terapeuten, vil jeg påstå. Ja. Altså, alle pasientene, hvis de først har kommet til behandling, så er de jo motivert for å bli bedre. Da er det terapeuten det står på å klare å finne den knappen som trengs i den gitte personen. Og da er det jo klart at med den pasientgruppen her så er dere jo virkelig inne på noe **(referring to Sigerseth's project/trial)** når dere tar fokuset vekk fra smertene i ryggen. Og litt sånn, hva skal jeg si, lure pasienten til å bevege seg, så heller ta støyten etterpå, men da er du allerede kommet langt i prosessen, for da kan han eller hun heller få snakke om hvordan var det faktisk å bevege seg, i stedet for at jeg som ofte gjør, og må gjør, står og ser om pasienten får beveget seg; men da er det vanskelig for pasienten og ikke tenke på at ok, nå skal jeg få vondt. Mens her kan de heller tenke på at nå må jeg få den poengsummen, nå må jeg treffe den roboten.

A: Det er heldigvis noe vi har opplevd med stor suksess, eller... Ja. **(referring to patients often focusing on the score, robots, competitive elements)**

E: Ja, og det er vel nøkkelen bak dette her.

A: Ja, motivasjonsaspektet **(inaudible)** ikke se bort i fra.

E: Nei. Nå vet vi jo så lite, altså... Dette her kan jo dere bedre enn meg, men alt funker på denne gruppen og ingenting funker. Det er bare sånn, må få gjort et eller annet, så vil det ha en viss effekt. I hvert fall kortsiktig. Og da er det, da sitter du kun igjen med motivasjon. Greit, du må gjøre et eller annet, men du må gjøre et eller annet hele tiden. Så hvis du da til den gruppen som blir fenget av spill, så kan jo dette være løsningen fordi at du med enkelhet kan få stor variasjon. Sånn som du har gjort nå, at av og til så har du bøtten foran deg **(RoBoW Agent)** – du beveger deg ikke så mye, og så av og til er det at han bare beveger mye; men det er ikke låst slik at nå må jeg bevege meg mye for jeg kan ta et steg bort og følge etter. Så du får den variasjonen hele tiden. Og den er jo vanskelig å få til gjennom et treningsopplegg.

A: Ja. Kanskje litt naturlig å ta "segue" inn på dette med den pasientgruppen vi snakker om da. Har du noe klinisk erfaring med å møte denne pasientgruppen?

E: Ja, men veldig lite. Jeg har jo generelt litt kort klinisk erfaring. Men det er jo en... Hvis vi sier at gruppen er personer med bevegelsesfrykt og korsryggsmerter, så er jo det en gruppe alle møter. For de er så mange, i stor og liten grad. Og derfor er det sånn, det dere kommer med her **(VR interv.)** vil på ingen måte hjelpe alle, men det er jo ingenting som ser ut til å kunne hjelpe alle. Så derfor må vi har ting som hjelper den rette personen. Og da må vi ha flere ting å velge mellom. Så jeg ville vært forsiktig med å gått ut og sagt dette hjelper alle. Men du kan heller vinkle det som at dette er en gøy måte der du kan bli bedre på, forutsatt at du synes dette er gøy. **(laugh)**

A: **(laugh)** Ja. Det er jo... Dette er verktøy.

E: Ja, som alt annet. Bare at jeg tror dette kan være dekkende for ganske mange. **(laugh)** **(pause)** Og det er jo litt viktig å være realistisk på. Vi snakker ikke her om noe som hjelper alle, men heller en stor del.

A: Ja. Vi har jo også ganske stramme kriterier **(referring to inclusion criteria)** for hvem som slapp til på akkurat denne studien også da.

E: Ja.

A: Vi **(Sigerseth)** ville jo at de skulle score veldig høyt på bevegelsesfryktskalaen.

E: Mhm.

A: **(redacted an imprecise count by the author on patients that were high on the pain scale but not necessarily Tampa. Has no bearing on further discussions, and no relevant exchange followed.)**

A: Men også for researchen sin del, hvis du har fått inn en pasient faller inn under våre kriterier, med høy bevegelsesfrykt, kanskje en del smerte i det daglige, og prøvd mye, vært "kasteball" **(slang for patients that are referred between several institutions for diagnosis and/or treatment)**, hvilke øvelser eller intervensjonsopplegg ser du for deg at kan være aktuelt?

E: Jeg ser jo for meg dette da. **(both laugh)** Jo, men det er jo det. Altså, har du...

A: Finnes det noe standardisert **(inaudible)** som blir utforsket først fra gjeldende forskning eller gjeldende praksis?

E: Nei... Dette er gruppe som... Nå er ikke jeg ekspert på denne gruppen, må jo få tydeliggjort, men det er jo en gruppe som det nå er veldig mye diskusjon rundt fordi at vi ikke har én gitt ting som fungerer for alle. Men vi har ting, altså vi har intervensjoner som begynner å komme veldig og å sier at det er løsningen, men det er jo egentlig intervensjoner som egentlig bare sier... altså jeg er stor fan av sånt biopsykososialt, det er jo genialt, men, det det sier er at pasienten må få gjøre det som er rett for pasienten, og så må vi være med å finne ut av det. I stedet for at vi faktisk skal komme og si dette funker på deg; gjør det, så er du frisk. Det er ikke det som er poenget. Vi kan... Og da vil det jo ofte ende opp med motivasjon, sånn jeg ser.

A: Så det med psykososiale faktorer og biopsykososialt, det er..?

E: Ja, altså det hjelper ikke at pasienten... altså, pasienten, mange av de vet hva som må bli gjort, men de har kanskje gjort det. Uten at det hjalp. Og da er det vanskelig å få beskjed om å gjøre noe annet—"nei, det er ikke det du skal gjøre, du skal gjøre dette". Allerede da kommer du inn skeivt når du har vært gjennom masse behandlinger der du har antageligvis gått "all in" på noe du har fått beskjed om at skal fungere. Og da er det vanskelig å få en ny sånn beskjed om at "nei, det var helt feil, men dette vil fungere". Da går du allerede inn—det kan være ubevisst—men da går du allerede inn i det med en tanke om at du er skeptisk. Mens her er det ikke behandlingen som er i frem... nå har jo ikke jeg vært inne og sett på når dere har en session her, det er jeg jo lyst til; men sånn jeg ser det her er det ikke behandlingen som er i hovedfokuset. Hovedfokuset er "ta den roboten, skyt den blinken, ha det gøy". **(laugh)** Og det er jo vakkert.

A: Ja. **(laugh)** Det er vel nytten å gradvis pushe komfortsonen uten å ha eksplisitt gitt beskjed om det.

E: Ja.

A: Og så snakke om, den største kraften med dette her når vi designer for VR også så har vi et grunnprinsipp om at "keeping the brain busy" er en god ting.

E: Ja.

A: Distraksjon og sånt er kanskje noe vi ønsker å... Det har kanskje et veldig sterkt fokus i spill som har med bevegelse og utradisjoelle bevegelsesformer å gjøre **(motion games or untraditional locomotion)**, der du kanskje opplever bevegelsessyke eller diskomfort. Så da har vi spesielt lyst til å "keep the brain busy" ved at vi distraherer den fra å prosessere de tingene som kan gi en sansekonflikt...

E: Ja, og det passer jo fint og med... trenger ikke regle om dette, det har dere jo lest, det passer fint med smertefenomenet, det.

A: Ja. Nå har vi stillestående spill da, riktig nok, i at det ikke er mye ufrivillig bevegelse.

E: Nei, altså ikke av deg, men det er alltid noe som skjer i synsfeltet, og veldig mye av impulsene du får inn får du gjennom synet, og lyd. Og så har du "pow pow", gøye lyder som kommer hele tiden, på godt og vondt.

A: Ja. Hvordan opplevde du det når du spilte de spillene? Var det mye sånn sansedistraksjon? Nå er jo du ganske erfaren bruker da.

E: Jada. Men jeg er nå fortsatt... Det er fortsatt når jeg tar på meg VR-briller og begynner å spille, så... Jeg er jo en person som alltid går og grubler på ting, men jeg gjør ikke det når jeg inne på der, da er det leke og ha det gøy. **(laugh)**

A: **(laugh)** Ja, alltid noe å finne ut av.

E: Ja. Nei, det er vanskelig det der med hvor mye stimuli du skal gi, og hva er for mye, og hvor mye er nok...

A: Tror dere har sjans til å være med på utviklingen der og gi...

E: Hva sa du?

A: Der har dere gode sjanser til å gi oss **(developers)** gode retningslinjer å utvikle mot.

E: Ja. Den er tricky. Det er dessverre enkle løsningen, sånn ordmessig, er at du må koble det til den som holder på. Og det gjør dere jo. Altså, det er ikke sånn at du må holde på i 10 min. **(referring to the approximate time each game is played in the trial)**, men nå skal du holde på så og så lenge, og så tar du pause med en gang du føler at du vil det. Det er jo det du må gjør. Og så igjen da finne ut hvorfor man velger å ta en pause hvis det skulle skje.

A: Ganske artig, jeg tror det var ingen av pasientene som sa "uff, nå vil jeg ta pause".

E: Nei. **(laugh)**

A: Det var mer sånn at vi observerte de og spurte om det gikk bra, "vil du en pause?" og så sier de "Hm, ja, ok". **(this question was more generally phrased than intended)**

E: **(laugh)** Ja, men da er det jo... altså, med denne gruppen her så er det jo antageligvis inne på noe sånn at da er det så mye stimuli at de ikke nødvendigvis får med seg den smertestimulien. Og det er jo flott det; dette er jo en gruppe som er blitt undersøkt og vist i den gode gamle patologien at her er det faktisk ingen ting som er gale. Da er det jo nydelig å kunne vise de at du kan holde på, uten å ha vondt.

A: Det skal sies at vi har observert mange som har fått vondt av at—

E: Men mens de holdt på?

A: De sier det, noen har fått vondt mens de holdt på. Men altså, det er jo en av de store tricky greiene med dette her, at det er så mye variasjon? Vi har så lite pasientutvalg, og vi har kort tid. Så.. Men jeg tror ikke jeg kan huske noen som sa **(suddenly)** "nå har jeg vondt, nå må jeg stoppe". **(sudden stop of gameplay due to severe pain)**

E: Nei.

A: Men at noen ble anstrengt, og viste tydelig at de hadde smerte, og anga det på spørreskjemaet de fikk, det var tydelig. På godt vondt.

E: Ja.

A: I de fleste tilfellene var det bra **(unqualified)**, men det var et par pasienter som virkelig var på tuppen av inklusjonskriteriene da, at de hadde mye smerte konstant.

E: Har dere filmet de?

A: Nei, vi forespurte ikke om lov til det fra REK. Det var mer sånn at vi spør, og så har vi skjemaene, og så noterer jeg hvis det er noen spesielle tilbakemeldinger som var veldig interessant.

E: Ja.

A: Så vi kan se på noen av de hvis vi rekker det. **(remarks that the interview time allotted by expert is running out)**

A: Men ja, for eksempel Oculus GO, kjenner du til det? Disse nye Facebook-settene?

E: Jada.

A: Så det er prisklasse to tusen **(NOK, approx., at time of writing)** og kan ha rom-skala opplevelser uten eksterne sensorer da.

E: Har du prøvd de?

A: Nei, jeg har lyst. Vi må jo få tak i de her og, **(inaudible)**. Og hvis de kommer med en sånn lisensieringsmodell eller bruksvilkår som gjør at du kunne sendt noe sånn med hjem til en pasient, og de kunne kjøpt spill eller brukt spill, eller...?

E: Jeg hadde jo sendt det med alle. **(laugh)**

A: Ja, der har du litt samme frihetsbevegelsen uten de **(eksterne)** sensorene, uten ledninger, uten telefon. Sånn type teknologi er det du kan sende med, gjerne også hvis vi klarer å lage det da, at vi har et treningsopplegg som de får programmert inn i opplevelsen med loggføring som du kan ta opp med behandleren... Er det interessant, sånn i behandlingssammenheng?

E: Ja, altså, det er jo... Har du sett på de som holder på i Nordstrand? Virtuell trening på skjerm.

A: Ja, sant.

E: Ja, det er jo akkurat dette konsptet. Men der det da trening, altså spesifikt "gjør den øvelsen, gjør den øvelsen" og så tilbakemelding. Og det er klart, hvis det er målet her, er det bare å slenge sammen noe.

A: Det er jo noe av det interessante, hvis vi kunne hatt noe som tok data fra applikasjonen, registrerte litt bevegelser.

E: Men hva data hadde vært interessant sånt sett da? Det hadde vært noe sånn typisk totalbevegelse, at du har inkludert i programvaren så har du en aktivitetsmåler, som vi buker, eller mange nå bruker, med FunBit og sensorer som man bare har som klokker. Men du krever jo at pasienten er villig til å bli meget overvåket; det tror jeg det er mange som er etter hvert.

A: Ja. Når de trener?

E: Nei, men jeg tenker at det interessante her er jo ikke hvor mye de beveger seg når de trener. Det interessante er jo hvordan de har det når de ikke trener.

A: Så du mener altså sensorer som kunne vært aktiv mer av døgnet?

E: Ja. Altså at du har en aktivitetsmonitor på de. Og det kan være de standard vi bruker, klokker, som du har på deg og som er registret til det samme systemet, som er da sånn at når du tar en treningsøkt, når du tar på deg GO-brillene og slår på programmet, da kommer det en automatisk dataoverføring fra håndleddet til programmet. Og så blir det gjort om til en veldig kort forståelse, si det er antall steg, antall timer våken eller et eller annet sånt, som da, hvis pasient vil det, går det i en e-mail til behandleren. Så når du sitter på kontoret ditt **(therapist)**

og ... torsdag ettermiddag og har litt tid, så kan du gå inn og se på de femten pasientene du har med sånt utstyr hjemme nå, og så kan du se hvordan aktiviteten er. Eventuelt får du en varsel-mail hvis noen har gått ned så og så mye prosent i aktivitet, sånn at du kan ta en telefon og spørre om det er en god grunn til det.

A: Vi hadde en liten teori om at du kunne ha sånn tele-overføring i VR, at du hadde hatt en ekstern sensor som behandler kunne ha hatt, så kunne du en slags ... ikke akkurat Skype, men en VR-samtale eller noe sånt, der det... enten det gjaldt å demonstrere noe, eller tilbakemeldinger, eller en liten kontakt.

E: Men da er du tilbake på, altså da må det være en time **(scheduled session)**.

A: Ja.

E: Og det funker jo, det og. Men knepet sånn utviklingsmessig er vel å finne én greie som skal være liksom—nå når det er en så tidlig fase—dette skal prøves ut i dette prosjektet, men også skrive alt sånn at det kan flettes sammen i én stor greie hvis man vil det. Men den smellen de fleste går på er jo at de skal gå over på alt samtidig. **(possibly referring to "the ambitious author")**

A: Ja. **(both laugh)** Rart nok. **(pause)** Jeg får bare ta kjapt. Det er sånn lavprisklasse da **(consumer)**, mens i klinikk så må vi ha disse Enterprise-settene **(referring to HMDs that allow for commercial use)** og lisensiering, pluss de må kanskje kjøpe dyrere spill. Der er vel kanskje en femten tusen pluss for datamaskinen, ti tusen for en Oculus For Business eller HTC Vive Enterprise. Og så opplevelser. Er det en overkommelig pris for en klinikk?

E: Hm. Jeg tror vi må satse på, i hvert fall nå de nærmeste årene hvis dette skal bli noe, så må vi satse på spesialistklinikker. Litt som Kjartan **(Fersum)** og de har sin greie på klinikken, og så har vi jo noen... ja, nå begynner psykomotorikk å bli stort, men før var det sånn ... de klinikkene i Bergen holdt på med. Og det er jo det som er realistisk her, på kort sikt. Dessverre.

A: Ja. Det er jo også en ting at pasientgruppen vi har sett her, de har jo også vært "kasteballer", de har vært gjennom mange instanser i helsevesenet, de har vært innom spesialist, og de har vært screenet ganske grundig... så terskelen for at de skulle komme i kontakt med dette behandlingstilbudet hvis det kun gis til kinesiofobiske ryggpasienter som er så-og-så dårlig, og som ikke har en patologi som man kan konkret behandle ... hvordan ser du på det i forhold til å ta dette i bruk, hvis det skal så mye til før du havner i rett... holdt på si...

E: Før du kommer til rette personen?

A: Ja.

E: Nei, det er jo det store problemet med helsevesenet, sånn det er bygd opp. Men, på si, har du løsningen på det så får du ikke sitte her, for å si det sånn. **(laugh)**

E: Men jeg tror vi skal være edruelig på kort sikt og si at dette her er noe som kan vise seg å ha god effekt, men vi må se mer på det, og så ... realistisk er det å få noen som er god på det. Jeg tror ikke det er realistisk å tenke at om fem år så har halvparten av klinikerne i Norge VR-headset i behandlingen sin. Selv om det hadde vært moro, det.

A: Ja. Og så er det vel ikke for alle pasientene heller bare for de har vondt i ryggen, så må det jo først undersøkes om de..?

E: Du må vite at det faktisk ikke er noe som kan behandles med ”quick fix”. **(inaudible)** Så ville vi jo gått for det.

A: **(pause)** Må bare se litt på listen min...

E: Lurt det.

A: Vi har vært litt innom det, men... **(time-check, off the record)**

A: Tror du har sagt mye der, **(inaudible)** hvilke tiltak det er bred enighet om for den pasientgruppen, og hvordan opplever du forskning og praksis for den pasientgruppen? Er det ganske sånn...

E: Altså, praksis vil alltid henge langt etter forskning tidsmessig. Sånn er det jo. For det første fordi at vi må få god forskning som bygger opp under det, og så for det andre for at er du i klinisk arbeid så... Den ideelle kliniker har tid til å oppdatere seg, men de fleste har ikke det på daglig basis. Så vi kan sitte med forskning og si at dette er helt magisk, men det må jo være praktisk gjennomførbart.

A: Ja, er det mye eksperimentell behandling inne i akkurat denne pasientgruppen?

E: Her skal jeg heller ikke si for mye, for her kan jo ikke jeg alt, men det ville overraske meg om det ikke er det. **(laugh)** Når det er så lite konsensus på hva som faktisk skal gjøres av behandling. Så jeg tipper det... Åh, de er nok gjennom mye rart. Det hadde jeg og vært. Altså, har du vondt så er du villig til å prøve det meste. Så klart.

A: Ja. **(pause)** Ok, jeg tror vi kan ta litt... Da er det bare siste, som jeg tror vi ”segue”’et litt forbi. Men, du har spilt HoloBall, du har spilt Agent, og så er du kjent med HoloDance og lignende spill?

E: Ja.

A: Hvordan oppleves denne typen øvelser du har blitt utsatt for som behandler? Og som aktuelt?

E: Det er jo litt som jeg snakket om mens jeg holdt på da. **(remarks given while playing)** Altså, her oppfordres du til å gjøre mye bevegelser av rygg uten at du får noe beskjed om å bevege ryggen din. Og det er jo helt nydelig. Tilbake til motivasjon. Og det er jo bevegelser som ... holdt på si ... stemmer, uten at vi vet hva løsningen er. Men vi vet i hvert fall at det er fint å bevege seg variert. Og det er jo viktigere **(inaudible)** du får, spesielt i den der første, HoloBall, fordi at... Altså, jeg kan jo spille bordtennis, men det er helt tilfeldig hvor den ballen havner når du hadde på stor ”range” **(horizontal/vertical setting)**. **(laugh)** Så du vil jo alltid få en ulik passering. Og så samme med din **(RoBoW Agent)** at... Holdt på si, bøtten beveger seg. Men den kunne godt ha beveget seg mer.

A: Ja. Det er sant, det.

E: Ja. Altså ikke bare sidelengs men og fram og tilbake, opp og ned. Men det har dere sikkert lekt med. Det hadde faktisk vært gøy hvis –

A: Men sånn, opp og ned, tenker du spesielt at det skal være sånn dynamisk at du ikke setter det bare som én vanskelighet, men..?

E: Ja. Men det hadde vært sykt gøy å... når vi får headset uten ledning, så må jo den begynne å bevege seg bak deg og.

A: Det hadde vært kult.

E: Mhm. **(laugh)**

A: Uten de trådene også da. **(referring to the wires that were used in the lab to keep the HMD cables behind the player and above the floor, see section on aparatus)**

A: Ja. Men også bare noen av grunntankene når vi designet var jo det at du ville ha en høy posisjon å skyte fra, sånn at du av og til fikk litt bøy eller fremoverlening **(forward leaning)**, implisitt. Det ikke alltid skjedd så mye, men de fleste sikter litt nedover, og noen strekker seg også hvis de akkurat skal ...

E: Ja, for å komme over rekkverket.

A: Ja.

E: Stemmer.

A: Og så at hovedbelstningen akkurat for ryggbevegelsen var det å trekke opp en pil i forskjellige stillinger så de fikk litt variasjon.

E: Ja, og der er det klart at for meg som ikke har vondt i ryggen, så tenker jeg den kunne vært mye lavere. Men det er nettopp derfor du trenger den funksjonen på å kunne justere det.

A: Ja. Og det har blitt en ”build”-variasjon...

E: Jo, men at du som behandler kan sitte og justere avhengig av responsen. På si, jeg beveger på armene **(gesticulation)**, men du må jo ha på skjermen, så klart. **(both laugh)**

A: Men her altså er det ikke noe særlig interessant med bue-bevegelsen, selv om de får rotert, så er det mer sånn for treningseffekt men ikke konkret belastning av korsryggen du tenker da? Er det innafor?

E: Ja, men jeg synes jo det fortsatt er et problem med at du kan stå og gjøre hele skyte-bevegelsen foran deg uten noe som helst rotasjon i ryggen. Men jeg vet ikke hvordan du får gjort noe med det.

A: Nei, vi kan altså... vi kan skalere opp buen og avstandene sånn at for hver pasient kan du bli på en måte tvunget, for å skyte mer effektivt, å trekke langt bak. **(forced to draw bow-string further)** Og det blir mer sånn... vi observerte jo at en del ”jukset”, eller... og for noen måtte det være greit, for de var...

E: Ja, ja! Og men det er nettopp det som er utfordringen hvis du skal gjøre dette hjemme. Altså, for å gidde å holde på med det spillet så må du kunne stramme buen sånn at du kan skyte på blinkene. Men noen er såpass gode at de jo godt kunne fått en del rotasjon i øvre del av rygg, og da må du ha ganske heftig spenn for at du er nødt til å få frem den, mens noen vil jo da hvis du har det spennet, ikke få noen som helst god opplevelse fordi de aldri vil gjøre det ... vil få muligheten til å skyte den pilen.

A: Ja. Så det kan jo også kanskje være dagsformen.

E: Ja. Så akkurat den rotasjonen er vanskelig.

A: Vi tenkte jo litt å lage det som en kalibrerings-greie, at ”trekk buen så langt du er komfortabel med i dag”, og så blir innstilligen satt til det.

E: Ja. Det er ikke dumt.

A: Og at det også kan gjelde trekk-bevegelsen og.

E: Da må du ha justering etter en fem-seks-syv minutter da når du har begynt å bevege deg.

A: **(inaduible, time-check)** Ja, kanskje pacingen **(pace of the gameplay)**, når... disse syv rundene **(waves in RoBoW Agent)** er så å si det vi har brukt på alle... Det var litt sånn etter tempoet, at du begynner rolig med blinker som de kan ta i eget tempo, så går det litt raskere, og så får du disse her på bakken som de fleste opplevde som litt vanskeligere å treffe, og da måtte—

E: Ja, da får du jobbet mer.

A: Ja. Og så ble de ivrig etter å få til like mange treff i den tidsrammen som...

E: Ja. Er det de samme syv sekvensene de går gjennom hver gang? **(waves)**

A: Hm, ja. Vi har egentlig bare variert på vanskelighetsgraden på bøtten og dette her ... **(this is not entirely accurate, some sequences were varied due to pain, some were interrupted due to crashes/bugs etc., and a few experimental adjustments of challenge suitable to patients. But largely, the sequences were kept consistent.)**

E: Hva synes de mot slutten? De er inne ti ganger? Synes de fortsatt det er gøy?

A: Ja, de fleste – tror alle synes det var gøy på slutten også **(this actually varied, see discussion)**, at de ble motivert for poengsummen, å treffe flere per runde, sånn at... Det var sånn vi hadde tenkt å variere veldig mye på selv, å sette det opp på forhånd, men det vi opplevde var jo at de fleste fant måter å gjøre det mer spennende på, mer bevegelse og mer fart og spenning, selv.

E: Vi er jo, holdt på si ... vi er jo enkelt lagd. Vi trenger jo bare respons på det vi gjør. Og poengsum, så lenge du sammenligner med deg selv, vil jo alltid fungere.

A: Ja. Og så kom vi jo med et par ting, ”dette kan du gjøre for at det skal bli mer engasjerende”, ”har du prøvd det?”, sant? Gi litt sånn kanskje uvitenskapelige instrukser, men at det var også viktig for å engasjere de. Så siden vi ikke rakk å lage et spill som ikke var selvforklarende på alle måter...

E: Nei, nei. Men det du tenker ut fra dette er hva kan gjøres videre for å få det enda bedre? Jeg er alltid der.

A: Ja. Som forsøk også, sant, var det jo interessant for da fikk du automatisk tilbakemeldinger. Og da er det greit å ha litt pasientkontakt uten å bryte innlevelsen helt, men at du kan spørre og si ting underveis.

E: Det er den mest effektive måten å gjøre det på.

A: Også, ja... En av grunnene til å vi tok de ”zapperne” med, pistolene, det var jo at det var veldig kult og sånt, men og så for at de skulle få en pause fra hvis det ble tungt... Når vi spilte, med Remy for eksempel, veilederen min, han ble jo dårlig i flere dager... Sant, og så merket vi det selv at å trekke langt ned i bøtten i ti hele minutter, samme hvordan det ble delt opp i, så var det slitsomt. Og da fikk du disse her rolige batteriene også **(referring to the reloading motion)**, men ... det var mange som faktisk strakk seg ganske bra og raskt, og allikevel fikk rygg-bøy.

E: Jo, jo. For at du er jo helt inne i det. Og det er jo fordi det er laget sånn spennende farger og at det skjer noe hele tiden, så blir du veldig oppslukt. Det er jo en stor forskjell på VR-briller og skjerm.

A: Ja. Men når du spilte så sto du ganske nært batteriene og fikk ikke like mye bøy?

E: Ja, men det er jo fordi jeg har spilt mye. Og det er jo det som er litt sånn ... hva da med de som har spilt mye fra før?

A: Ja, sant.

E: Men jeg tror jo at med det opplegget du har laget der, her, så får du jo med de og, fordi at ... hvis du tar bøtten veldig langt fremme, så vil jeg ta en steg frem. Men hvis du bare setter opp et lite bord, at bøtten står litt lengre borte på et bord, så vil jo jeg fordi jeg har spilt dette her, så vil jo jeg være villig til å leve meg inn det og unngå å krasje i bordet. **(laugh)** Så det er jo bare å lene seg frem.

Interview is concluded at this time.

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