Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

Anders Bråten Støen
Magnus Lie Fridheim

VRehab

Designing for VR-based serious games in neurorehabilitation

Master's thesis in Industrial Design Engineering
Supervisor: Ole Andreas Alsos
Co-supervisor: Emanuel Lorenz
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“Reality exists in the human mind,
and nowhere else.”
– George Orwell, 1984

Preface

This Master's thesis is written at the Department of Design in collaboration with the Department of Computer Science at the Norwegian University of Science and Technology, spring of 2021.

When we discovered this task in a list of suggested subjects, we were immediately intrigued. At a glance, we saw an opportunity to play around with games in virtual space while making a great product for a very specific purpose. This may well have been what we set out to do, but the original intention somewhat fades at the finish line. What this thesis hopes to present is not only a game concept for a specific purpose, but a way of getting there as well.

This thesis did not go exactly as planned. There were many road bumps and setbacks along the way, leading to unfavorable changes to the set schedule. A constant thorn in our side was the constant uncertainty of Covid-19 regulations and guidelines, impacting our ability to meet and interact with the stakeholders and users. We would like to see some sort of vengeance on part of the thesis subject matter in that respe. It deserves to be discovered, discussed, and demonstrated in person with the people that will benefit from the exciting work being done.

We would like to thank our supervisors, Emanuel Lorenz and Ole Andreas Alsos, for all the advice, patience, encouragement, the noes, yeses, do's, and don'ts.

Thank you to Umble for letting us occupy their facilities at Digs, and our girlfriends for the patience they have shown us.

We also want to thank all the participating experts and therapists. Listening to our laymen questions for hours on end must have been a test of patience, one which was passed with flying colors.

Finally, a special thanks to the ones who chose to give us their time and their stories about life after an acquired brain injury. We were – and are – humbled by your brilliant candor and ruthless optimism. Without you, this process would not be any good.

NTNU
Fakultet for arkitektur og design
Institutt for design

Master's Thesis for Magnus L. Fridheim and Anders B. Støen

Neurorehabilitation using VR-based serious games
Nevrorehabilitering med VR og nyttige spill

Every year, millions of people of all age groups suffer from traumatic brain injuries. Such injuries can severely impact physical, cognitive, social, and emotional abilities. However, our brains have the ability to repair and restore some of these abilities. An intensive and multidisciplinary rehabilitation program is vital to the recovery process. Treatment programs can be strenuous and demanding not only for patients and their relatives, but also for the healthcare system and society. Emerging technology such as virtual reality (VR) has the potential to challenge the way rehabilitation is carried out, and could mitigate costs linked with treatment of traumatic brain injuries.

Serious games could serve as a tool for rehabilitation after a traumatic brain injury and be incorporated into existing treatment. This thesis will explore potential uses and solutions for VR-based serious games in such treatment, focusing on the rehabilitation of lower or upper limb motor function abilities for patients in their home environment. The resulting insights and designs can contribute to further development in the broader scope of neurorehabilitation.

Proposed work includes:

- Understanding the affected patients, clinicians and family, and the context of use
- Idea generation with patients, clinicians and family
- Building prototypes in collaboration with the Department of Computer Science
- Testing out the prototypes on patients with brain injuries

This project is executed in accordance with "Retningslinjer for masteroppgave I Industriell design".

Supervisor: Ole Andreas Alsos (ID)
Additional supervisor: Emanuel Alexander Lorenz (IDI)

Starting date: January 8th 2021
Due date: June 6th 2021

Trondheim, NTNU, January 8th 2021

Ole Andreas Alsos
Course supervisor

Ole Andreas Alsos
Head of Department

The Master's thesis contract.

Sammendrag

Bakgrunn

Ervervet hjerneskadet (EH) er begrepet for enhver skade på hjernen etter fødsel. EV er vanlig og en av de største årsakene til død og uførhet i verden. Disse skadene kan påvirke både fysiske og kognitive evner. Hjernen har en evne til å reparere seg selv og gjenopprette noen av disse evnene gjennom rehabilitering. Ny teknologi, som virtuell virkelighet (VR) har potensial til å endre måten rehabilitering foregår på, og med riktig bruk kan det senke kostnader og bedre kvaliteten på behandling.

Formål

Dette prosjektet har som formål å undersøke hvordan VR-baserte seriøse spill kan brukes for rehabilitering av funksjoner i underekstremitetene i en hjemmesituasjon, og hvordan dette kan inkorporeres i dagens rehabiliteringssystem. Dette vil gjøres med tankesett og metoder fra menneskesentrert design (HCD), som søker å finne sluttbrukernes behov og krav assosiert med rehabilitering.

Prosess

Prosjektet er et eksplorerende designstudie. Først ble en litteraturgjennomgang om temaet gjennomført. Deretter ble innsikt samlet gjennom intervju med fysioterapeuter, ergoterapeuter og personer med ervervet hjerneskade. Denne innsikten ble analysert for å formulere målene og snevre inn omfanget av prosjektet. Ved gjennomføring av workshoper ble ideer for konsept generert. Til slutt ble en prototype bygget og et rammeverk for designprosessen utviklet.

Resultat

Prosjektet legger frem et nytt rammeverk for hurtig design av spill for rehabilitering, som består av fem konkrete faser og involverer flere interessenter. Ett spillkonsept blir også lagt fram og illustrerer hvordan rammeverket kan brukes i praksis.

Abstract

Background

Acquired brain injury (ABI) is the term for any injury to the brain sustained after birth. ABIs are common and a leading cause of death and disability worldwide. These injuries can severely impact physical and cognitive abilities. However, our brains have the ability to repair and restore some of these abilities through rehabilitation. Emerging technology such as virtual reality (VR) has the potential to change the way rehabilitation is carried out, and with the right application it could reduce costs and improve the quality of treatment.

Objective

The thesis will investigate how VR-based serious games can play a part in home rehabilitation for lower limb function, and how this can be incorporated into the rehabilitation ecosystem. This is done using human-centered design (HCD) mindsets and methods, aiming to uncover the target user's needs and requirements associated with rehabilitation.

Process

The thesis is an explorative design study. First, a literature review was conducted to gather data about the subject. Then, insights were gathered through interviews with physiotherapists, occupational therapists, and people with sustained ABIs. The insights were then analysed to reframe and narrow the project scope. From this, along with two workshops, ideas for concepts were generated. Lastly, a prototype was built and a framework detailing the process developed.

Results

The thesis proposes a new framework template for rapidly designing games for rehabilitation, which consists of five concrete stages involving several stakeholders. A game concept is also presented and illustrates how the framework can be used.

Contents

Some terms

Term	Description
ABI	Acquired brain injury refers to any type of brain damage that happens after birth. Causes of ABI include disease, blows to the head, alcohol and drug use, or oxygen deprivation.
TBI	Traumatic brain injury (TBI) is sudden damage to the brain caused by a blow or jolt to the head. Common causes include car or motorcycle crashes, falls, sports injuries, and assaults. Injuries can range from mild concussions to severe permanent brain damage.
XR	Extended Reality includes Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR).
VE	Both immersive (HMDs) and nonimmersive (flatscreen, projection) virtual worlds.
HMD	Head-mounted display. Headsets, like VR goggles, that displays a VE.
BBS	Berg Balance Scale. The test takes 15–20 minutes and comprises a set of 14 simple balance related tasks, ranging from standing up from a sitting position, to standing on one foot.
BI or BS	Barthel ADL index or Barthel scale. An ordinal scale used to measure performance in activities of daily living (ADL). Each performance item is rated on this scale with a given number of points assigned to each level or ranking.
FAC	Functional Ambulation Categories. A functional walking test that evaluates ambulation ability. This 6-point scale assesses ambulation status by determining how much human support the patient requires when walking, regardless of whether or not they use a personal assistive device.
SMART	A framework for setting goals with patients.

Introduction

Acquired brain injuries (ABI) are a huge global health problem. Generally split into two categories, traumatic (TBI) and non-traumatic brain injury, it ranks high amongst causes of global deaths (2nd) ("Leading causes of death and disability," n.d.) and disability from traumatic insult (1st) (Dewan et al., 2018). Needless to say, lots of resources go into treatment and rehabilitation of people who have suffered an ABI. While hospital and rehabilitation facilities make up the most intense period of training and recovery, serious cases of ABI can have a profound and prolonged impact on one's physical, cognitive, social, and emotional abilities for years, if not life. However, recovery can also be a prolonged process, with incremental change continuing far outside the walls of health care facilities.

The teams that follow up people with sustained ABIs through their initial phase of recovery consist of many specialized workers. This thesis will focus mainly on two groups from the carer side: physiotherapists and occupational therapists. Especially the practices of physiotherapists in neurorehabilitative treatment will be central.

Serious games are redefining the way we learn. With an explosion in development and abandonment of its buzzword status, the phenomenon is conquering new turf: education, attitude change, skill training, and healthcare make up a short segment of a long list. The last element, by the way of gamification, has been subject of many serious game projects in industry and research. Clinical rehabilitation at its core is about improving physical and cognitive function through training and treatment. This has shown to make it well suited for adoption in this new field.

Virtual reality (VR) is a denomination of extended reality (XR), a group of novel technologies that seeks to immerse users in fully or partially virtual environments (VE). VR is the most immersive of these technologies. Using head mounted displays (HMDs), users can step into virtual worlds and interact with it through handheld controllers or motion capture cameras. It adds a new dimension to gaming, removing the need for monitors and keyboards, instead using the body in space as the input. As the thesis will show, VR has been explored in the context of rehabilitation for a long time, but is still not widespread in practice.

In design, empathy and understanding are often thought of as the foundation upon which good products and services are built. The thesis will apply design methodology in the described fields – neurorehabilitation, serious gaming, and virtual reality – to find out how value

can be created for people with ABIs and the systems they interact with. The study details a thorough insight phase where interviews with therapists and people with sustained ABIs were conducted. These insights were analysed and turned into design requirements. Building on these, multiple rounds of ideation led to finished concepts, and eventually a VR game prototype. The process that was followed was reworked as a deliverable, becoming a framework template for future game development.

Objectives

This thesis will explore how VR-based serious games could serve as a tool for rehabilitation and be incorporated into the current treatment ecosystem. The work will focus on the rehabilitation of lower limb motor function abilities for patients in their home environment. The resulting insights and designs can be used to further develop solutions in the broader scope of rehabilitation.

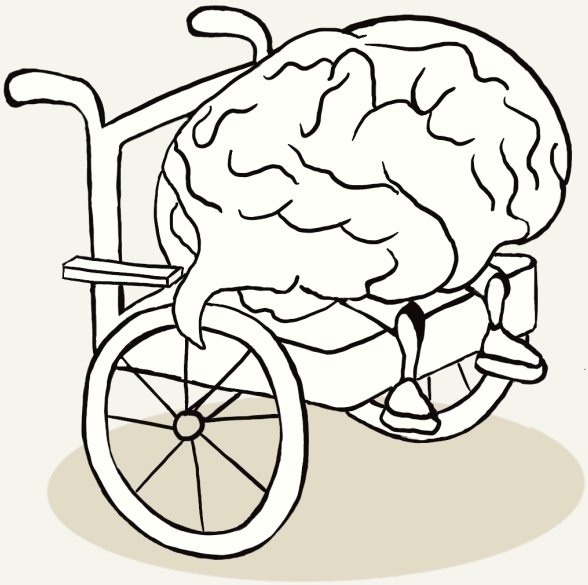
The research question is vague to give leeway for any possible solution. Although the channel detailed in the task description is set to be VR-based serious games, the thesis uses an exploratory study design to remain open to interpretations. The objective is still to abide by the intended channel, but also entertain other avenues and possibilities as the project runs its course, fully exploiting the “how” in the formulation.

Background

Understanding the research topic requires basic familiarity with a couple of terms and concepts. These will now be introduced. The study design and methodology will also be explained in broad strokes.

Aquired brain injury

Acquired brain injury (ABI) is a collective term for any type of injury to the brain after birth except from hereditary, congenital, or degenerative causes (Teasell et al., 2007). Stroke and traumatic brain injury (TBI) are neurological pathologies that fall in under this umbrella, and are two of the major causes of affecting the central nervous system (Eng et al, 2002). Although they differ in their aetiology and patient population, stroke and TBI shares similarities with regards to treatment and neurologic disorders. The injuries may impact physical, cognitive, social and emotional abilities – reducing the quality of life for patients. However, the brain has the ability to recover itself, and restore some of the previous functionality (Castor & El Massioui, 2018). This calls for an intensive rehabilitation program, involving multidisciplinary neurologic units, in order to facilitate the recovery. The disorders originating from brain injuries vary to a large degree, resulting in the demand for individual follow-up, and a patient-centered approach ("Physiotherapy Management of Traumatic Brain Injury," n.d.).



Games for rehabilitation

Amongst the most concerning barriers in neurologic rehabilitation is patient nonadherence. Rehabilitation tends to be an intensive and expensive process over a long period of time. Also, the progression of the recovery is often incremental. Research suggests that video games could have a positive effect on cognitive and motor skill learning, and that game elements lead to increased motivation and engagement (Lohse et al., 2013).

Serious Games has the purpose of adding some form of utilitarian value to games. There are several domains for these types of games, but for the purpose of this thesis we will look into the area concerning health benefits, known as exergames (Bartolomé et al., 2011). In the extension of exergames, the main area of interest is games used in neurologic rehabilitation.

Picture of CAREN (Computer Assisted Rehabilitation Environment) in use. The system is one of the more advanced ways to use VR or games for rehabilitation.
Photo: Motek

Extended reality

Emerging technologies such as virtual reality (VR), augmented reality (AR) and mixed reality (MR) have the potential to challenge the way rehabilitation is carried out. These technologies, collectively referred to as extended reality (XR) (Figure 1) are increasingly being endorsed by different industries, healthcare among them, as they become more user-friendly, affordable, pervasive and ubiquitous (Mathew & Pillai, 2020). Amongst the Norwegian institutions placing faith in the technology and innovation around VR is Sunnaas Rehabilitation Hospital. They have established a VR lab where they include both commercial and specialized games in the rehabilitation of patients. Motivation is a key aspect of prolonged rehabilitation, and they experience that doing exercises in a fun VR setting makes the patients increase the duration and frequency of their training. Sunnaas believes that the synergy between conventional treatment, technology and innovation is the answer for the future of rehabilitation ("Innovasjonsprosjekt VR-lab," n.d.).

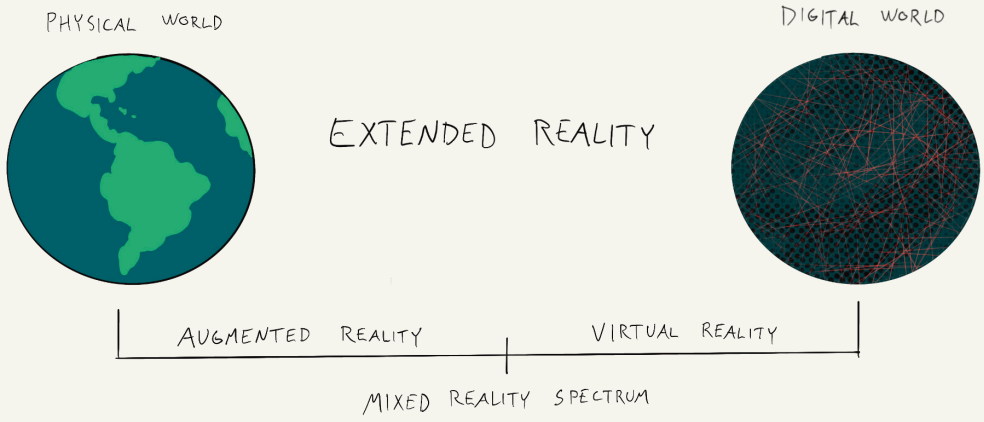


Figure 1: The extended reality specter.

Method

The project is a design study. We used a framework and methods consistent with the human-centered design (HCD) approach (Figure 2). This approach uses user-centered research to understand needs and requirements to create better products and services. The HCD process is commonly described and carried out using the Double Diamond framework (Figure 3). It illustrates the diverging and converging nature of the different phases (The International Organization for Standardization [ISO], 2019).

Typically in HCD processes, insight work and discovery – analysis of subject matter, interviews, observation and similar methods – is conducted in a diverging manner. The data is processed to let designers make decisions and reframe problems, which in turn leads to idea generation, prototyping and user testing. The approach emphasizes the user and leverages the insights from early stages to reframe complex problems and tackle real needs and wants (IDEO, 2015).

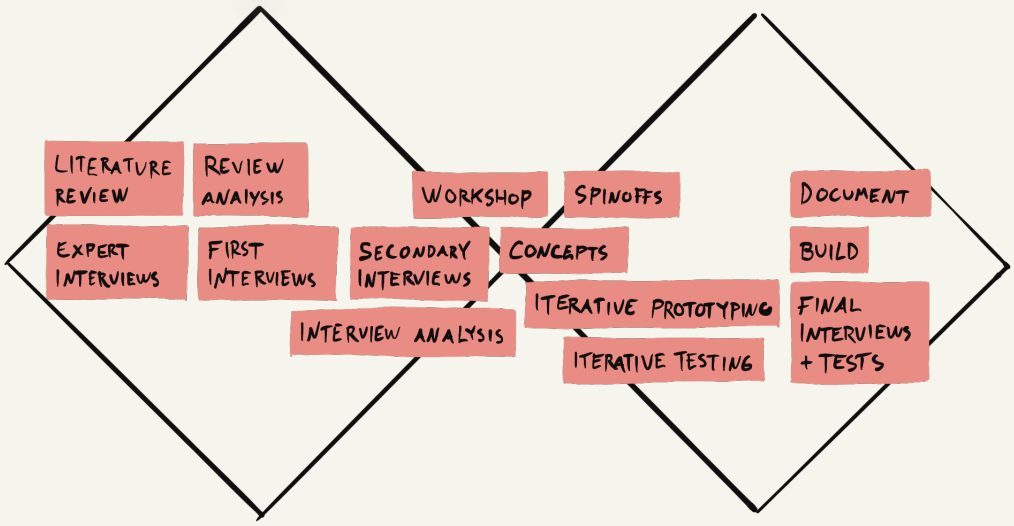


Figure 2: The project plan.

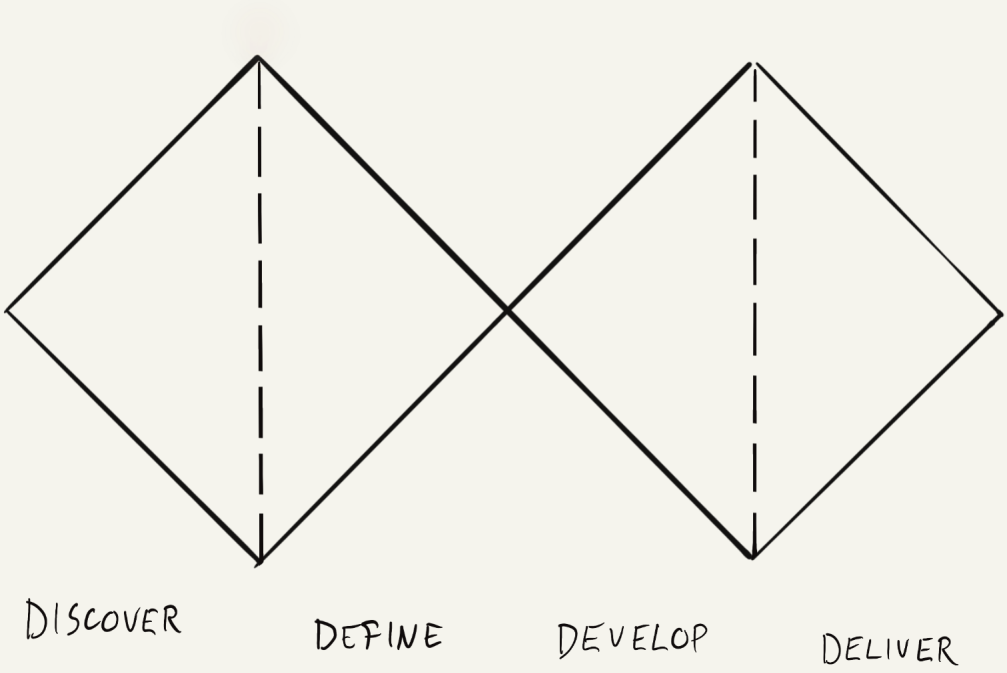


Figure 3: The Double Diamond framework

Insights

Literature review

Material and methods

An explorative literature review (Adams et al., 2007) was conducted to investigate what existed in terms of research in key fields. The approach was wide in scope and was used to identify gaps and debates to generate research questions. We consider this form of review suitable for design projects given its relative leniency towards a dynamic scope and motive. We chose to include all XR denominations in the literature review to avoid ruling out pertinent research.

There is extensive literature on several themes and domains that touches on our subject matter. Authors have approached XR gaming and exercises for rehabilitation coming from fields of medicine, physiotherapy, and human-computer interaction (HCI). We wanted to extract qualitative and quantitative information on both practical and theoretical applications to identify missing points and gaps in academia, and lay the cornerstone of our own insight phase.

In addition to articles suggested by our co-supervisor and in early interviews, we conducted multiple rounds of searches in scientific databases using a range of keywords. The papers retrieved through the searches gave us an idea of which authors to look into more thoroughly (Figure 4).

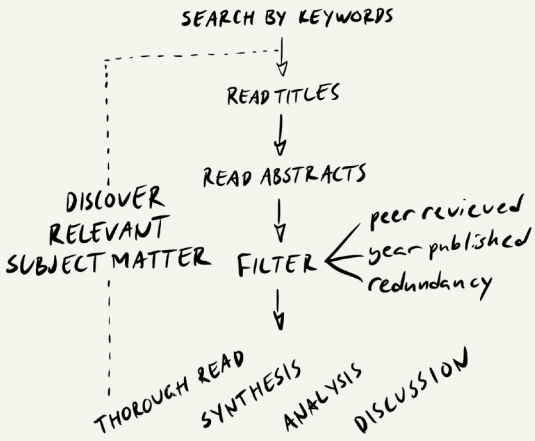


Figure 4: A flow map of the explorative design review.

Search logistics

The databases searched were PubMed, Elsevier, ResearchGate and Google Scholar.

To capture research related to extended reality and neurorehabilitation the following search logic was applied: extended reality (all denominations) AND (* brain injury OR stroke) AND rehabilitat*. The logic for research related to exergaming in rehabilitation used the following keywords: (exergam* AND/OR * reality AND/OR serious gam*) AND rehabilitation. As the scope narrowed to focus on lower limb motor function, the previous search was supplemented with: lower limb AND/OR (lower limb OR balance OR posture OR gait). In addition to this, searches were combined with keywords specifying the setting for rehabilitation: home AND (rehabilitat* OR train* OR exergam* OR * reality.

The initial exclusion criteria were peer-reviewed, english articles published after 2005 (except articles on general rehabilitation). Articles were selected scanning titles and abstracts, establishing a selection of ~50 articles. Furthermore, the abstracts were read more thoroughly, removing redundant scoping and systematic reviews, of which only a few were included. The final selection, after the secondary filtering, consisted of 25 articles.

The scope and depth of the material poses a challenge in filtering out redundancies and less relevant literature. For example, many articles compare the efficacy of VR in rehabilitation in different clinics, but offer little insights into how users interact and react to the systems and interfaces. There is also a host of scoping reviews documenting the literature itself. This could be used in mapping approaches in research activity or to identify knowledge gaps.

Themes and debates

Efficacy

Central to the literature is the question of the efficacy of exergame programs and XR/VE-enhanced rehabilitation. In general, the consensus is that exergames have complementary qualities that benefit rehabilitation, either in tandem with conventional therapy, or to an extent, stand-alone therapy for some part of the treatment (Barcala et al., 2013; Broeren et al., 2008; Cho et al., 2012; Choi et al., 2014; Darekar et al., 2015; Jordan & King, 2011; Larson et al., 2011; Levac & Miller, 2013; Levac et al., 2019; Lohse et al., 2013; Lucca et al., 2010; Maggio et al., 2019; Morone et al., 2014; Sekhavat & Namani, 2018; Song & Park, 2015; Thornton et al., 2005). In the context of the entire rehabilitation pathway, no evidence can be found that exergaming has been tried as an alternative to conventional therapy, likely due to its experimental nature and lack of precedence, implying that human expertise and interaction still is irreplaceable.

The studies are inconsistent whether exergames or XR therapy is superior to conventional therapy. Although improvement is evident in many studies, the statistical significance against the baseline is insufficient, and studies almost universally call for further research on the matter. However, going by the quantitative results alone, both XR/VE and exergame rehabilitation enhancement show great promise in terms of efficacy and is validated by several systematic reviews and trials, with test scoring (Berg Balance Scale (Berg et al., 1992), Barthel Index (Mahoney & Barthel, 1965), and Functional Ambulation Categories (Holden et al., 1984) performance) and executive skill transfer being favorable (Barcala et al., 2013; Broeren et al., 2008; Cho et al., 2012; Choi et al., 2014; Darekar et al., 2015; Jordan & King, 2011; Levac et al., 2019; Lucca et al., 2010; Maggio et al., 2019; Morone et al., 2014; Sekhavat & Namani, 2018; Song & Park, 2015).

Motivation

Motivation, a major driver and challenge in carrying out successful rehabilitation (Egglestone et al., 2009; Choi et al., 2014; Lange et al., 2012; Lohse et al., 2013; Nijenhuis et al., 2015), is measured and gauged throughout the research, appearing as a key element on the psychological side. It is considered integral to the progress of patients undergoing rehabilitation and the sustained effect of maintenance training (Choi et al., 2014). Often an introductory claim, motivation is used as a background dependency for many of the papers. As exergames have extensively been used in similar treatment, there are strong cases to be made for the motivational factor of this

as a tool (Nijenhuis et al., 2015). The case for XR/VE has less empirical backing. It relies more on the inherently motivational aspects of gaming in and of itself (Lohse et al., 2013). Increased motivation following VR interventions have, however, been shown (Llorens et al., 2015).

Difficulties with technology and equipment have been observed in several studies. Study participants, both patients and therapists, experienced issues with the XR/VE and exergame systems (Broeren et al., 2008; Larson et al., 2011; Levac & Miller, 2013). Linking this with game design, outcomes like aggravation, resignation, failure to complete tasks, and in the worst case, adverse physical and psychological effects could be associated with these barriers (Larson et al., 2011). Individually, these issues may only be minor road bumps, but combined may render alternative treatment unsatisfactory and demotivating. Ignoring motivational instruments with regards to specific user groups and capabilities could also be unfavorable. In games, individual users are motivated by different mechanics and aspects, and to some extent, this can be generalized. For example, elders and youths have been shown to display different responses to motivation factors in exergames (Subramanian et al., 2019).

Ownership

A common theme in the research was that the XR/VE and exergame treatment was supervised. Physiotherapists were present during the training protocols, usually facilitating actively, and at the very least as a safety precaution. As neurorehabilitation is subject to highly variable pathologies, game parameters should ideally be adjusted for the patient according to their capabilities and needs. Naturally, most trials underwent thorough screening to be able to produce comparative and significant findings with homogenous user groups. Rehabilitation clinics and their users do not have this liberty. The expertise of physiotherapists and occupational therapists in administering treatment is still viewed as a necessity for XR/VE and exergame treatment (Levac & Miller, 2013; O'Neil et al., 2018; Pirovano, 2016; Weber et al., 2020).

Technology

The availability, relatively low cost, and usability of commercially available EV and XR systems (Wii console, Oculus HMD, and similar systems) make them popular in measuring exergaming efficacy. These systems are commonly used in many rehabilitation clinics today (O'Neil et al., 2018).

Gaps

Several knowledge gaps were identified in the selected articles and within the searched domains. The gist of the findings was the unequivocal notion that XR/EV and exergame approaches are likely to be beneficial and has great potential for further development, but that further studies are needed to validate the efficacy, and construct protocols and methods for the administration of treatment.

Parameters

A recurring theme is a lack of individualized game parameters suited to therapy needs. Most games in the studies allowed for changing variables like speed or difficulty, but lacked fine-tuning of game parameters (Levac & Miller, 2013; O'Neil et al., 2018). With neurotherapy being so diverse, this shortcoming could be amplified by the need for highly frequent game parameter adjustment. ABI patients experience varying pathologies, in addition to varying degrees and pace of rehabilitation. Constant monitoring would be necessary if high-frequency adjustments are needed. With time resources already strained at institutions and in home visitation, this need would be difficult to cater to. Real-time feedback loops and automated parameter adjustment is a possible solution to this problem. This would require that monitoring sensors satisfy requirements set by the underlying adjustment parameters. Many of the papers suggested that commercial solutions (Wii and Kinect) provide a good blend of low cost and decent fidelity, but remain unsure of the capacity for further development without hardware and software evolution.

Motivation

Efficacy of treatment is the primary metric in the literature selection, with perhaps motivation as a second. This generalizes the complex composition of motivation, which is not inherently bound to any numeric scale. Motivation can be measured as an output range, as shown in the literature. Input is needed to generate these ranges, and methodologies differ in how motivation is measured. Surveys of study participants are used to generate quantitative indications (Nijenhuis et al., 2015), other studies codify themes and statements from interview sessions or focus groups, or otherwise deconstructed the term to gain a qualitative perspective (Lohse et al., 2013). Design theory tends to adhere to qualitative methodology, but will often use a combination. Our findings suggest it is such a combination of methods that can be beneficial to the research field.

Home adoption

Adoption of XR/VE and exergames for rehabilitation in the home setting is explored as hypothetical in many cases. Because the studies require strict control

of variables and execution, tests can become difficult to translate into real-world usage. Aspects of outpatient and at-home treatments have been studied, and in particular, the feasibility of VR coupled with telemedicine with some success (Lucca et al., 2010). In trials with elderly participants playing balancing exergames at home with supervising nurses, improvement on the Berg Balance Scale was greater than in the control group (Karahan et al., 2015). While the results from participants adhering to training regimens prescribed in trials and treatment are well documented, those who fall off the studies are rarely a point of interest and fall neatly into the not-applicable bin, a category needed to ensure data consistency. In contrast, these cases are applicable in a design study. In some ways, they are a necessity to capture the range of experiences within a population. Home rehabilitation also raises the question of how users will interact with the systems in isolation. An analysis of peripheral factors of exergaming and XR/VE systems – setup, onboarding, safety, ease-of-use, time management, etc. – must be conducted to validate the actual feasibility outside controlled environments.

Discussion

The efficacy of XR-based games in ABI rehabilitation leaves little room for speculation: The promise of self-administered, high-intensity training that increases adherence to training in the home could be a reality if implemented well. However, the identified gaps illustrate the relative infancy of this resource as a real agent of change. The individual components – exergames, XR hardware, and the use of these in rehabilitation settings – often follow the parameters set by existing solutions and practices, and are not based on thorough, user-centered processes, resulting in rigid systems. The widespread use of commercial games do provide engaging activities and have been shown to increase motivation, but lack essential features for use in clinical settings.

The findings suggest that motivation differs from person to person, but offers little evidence of underlying reasons for this. Nevertheless, the most important takeaway is in the observation and confirmation that exergames outperform conventional therapy in motivation metrics. Gamification of training increases enjoyment with game mechanics and rewards. These considerations have to be central to any design process in this field.

Interpretations of the literature review concluded in a set of design implications (Figure 5) that would have to be considered moving on. These detail absolute necessities as well as gaps in the field today.

Shortcomings

The literature review did not cover material dealing exclusively with physical HMD equipment. In future research, system liabilities and dependencies must have a place in the bigger user experience picture. Furthermore, participant characteristics differed in many of the studies, with an overrepresentation of elders in particular. Additionally, there is little literature dealing with ABI or TBI exclusively, leaving the review exposed to a bias towards stroke patients.

Geographically, North-America, Europe, and East-Asia were the hotspots for publications in the selection. Several variables in the discussion are demographically and geographically dependent. Rehabilitation, treatment, use of technology, and even actual reporting of ABIs differs between locations and demographics (Dewan et al., 2018). This, however, makes a case for design as a tool for innovation, as it highlights the need for ethnographic investigation of the user group it serves.

The system and application have to be safe.

Parameters have to be adjustable with a high fidelity by trained personnel, the user itself, a responsive algorithm, or preferably all of them.

Adjustments must be quick and unproblematic so they don't lead to errors or wasted resources.

The application must be as easy, or easier, to use as commercially available solutions. This applies equally to primary users (patient), secondary users (therapists and caregivers), and potentially other users (social circle and relatives).

Sensor standards and requirements have to meet the fidelity that lets therapists identify good and bad movements.

The game mechanics must engage the user and incite motivation beyond what standard training does.

The user must like playing the game to ensure adherence.

Social factors, both in and outside the game, should be considered in development and implementation.

The user should feel that they have ownership of their own experience.

The hardware used has to be comfortable and non-disruptive.

Figure 5: Design implications from the literature review.

Competitor analysis

An analysis of competitors is a good way to gauge the market and spot strengths and weaknesses in similar solutions. Combined with thorough literature research, it can reveal opportunities and missing links in the service that are delivered today (Levy, 2015). It is also a good prompt to eventually ask ourselves if the result delivers innovation and originality. From a designers perspective it can also be a way to evaluate the heuristics of the solutions delivered today, and look for shortcomings in usability.

Our goal of conducting a competitor analysis was to get acquainted with the specter of XR rehabilitation delivered today, and look for gaps between what is delivered and the needs of the users, thereby making informed design decisions in regards to home rehabilitation with the focus on lower extremity.

Five XR systems for rehabilitation were analysed based on the predetermined criterias (Figure 8). A pivotal limitation was not having the opportunity to access the different platforms to test the games. Parts of the analysis was therefore based on the available data and videos of patients using the systems, making it more assumption based than empirical.

Target users

All of the solutions focus on the recovery from neurologic limitations, and all are meant for stroke patients. Neuro Rehab VR ("Neuro Rehab VR," n.d.) is the only one that includes TBI as part of the user group. Although the other solutions do not mention TBI explicitly, many of the activities performed would likely cover a wider scope of neurologic pathology.

All of the solutions target upper extremity exercises, with Immersive Rehab ("Immersive Rehab," n.d.) and Neuro Rehab VR including lower extremity as well. The only two systems primarily intended in a home setting are Cognivive ("Cognivive," n.d.) and Rewellio ("Rewellio," n.d.). None of these two focus on exercises for the lower body. Rewellio differs from the others with their intent of self administration of the exercises. Another differentiation is that Rewellio wants to supplement the physical therapy rather than replacing it. The idea is to use the system for simple repetitive training at home between therapy sessions, making more out of the valuable time with the therapists.

Technology stack

The most significant difference regarding the services is whether they provide a combination of software and hardware, or just software (Figure 6a). Three of

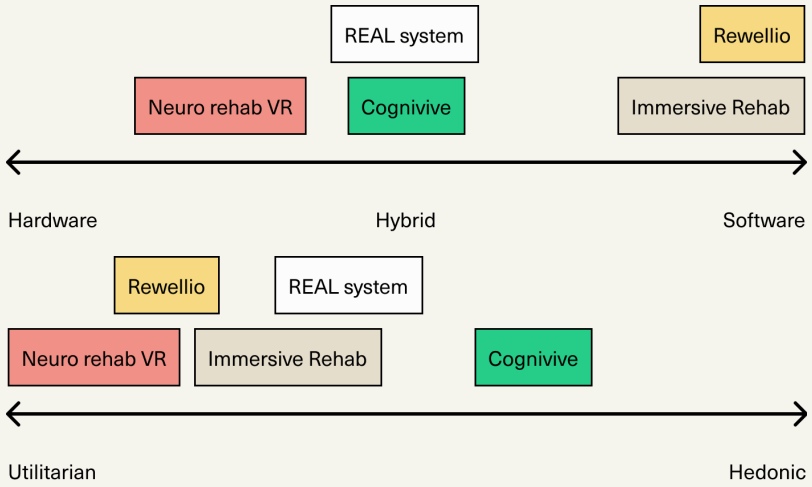


Figure 6a (top) and 6b (bottom): Different ways og mapping games by characteristics.

the services provide the combination: Cognivive, Neuro Rehab VR and REAL System ("REAL System," n.d.). Delivering "the whole package" could have several upsides to it, like providing a seamless onboarding and a connected experience, but risks being left behind by the evolution of commercially available, and more affordable XR systems. Another concern is the narrow scope of possibilities for the users if the system restricts them to only one service. The other two systems, Immersive Rehab and Rewellio, base their value in having a software compilable with affordable XR systems, making them robust for new alternatives in the technology. The problems these providers may encounter is that the users may require assistance in setting up and using the commercial system.

Hedonic vs utilitarian

Common for all the systems is that they are often based on the performance of a single task. The inputs are focused on a specific movement or exercise, and often translated to a task performed in a natural environment, e.g. putting a green box on the green table, or picking groceries from a store shelf. There are also examples of avatars that guide users through exercises. Sort of like a virtual therapist. Although these games make the user perform exercises accurately, there are limits to how many trips to the store people want to make in a day.

One of the systems, Cognivive, seems to shift focus towards a more fun and exploratory concept where the users can walk around in a resort by the sea. Thereby giving the user freedom to experience more than just doing exercises (Figure 6b).

The perceived environment of the systems are in general out of date when it comes to game graphics. They are either pixelated or based on a polygon mesh with a relatively small number of polygons, commonly known as Low Poly. This is not necessarily a bad thing, but could influence the enjoyment of the game when the gameplay mimics a natural environment or situation. Although VR games in general do not have the same detailed graphics as other consoles, these systems still lag behind similar commercial games. Another observation is that several of the systems have a childish look and feel, regardless that the main user group are adults.

The systems are in different stages of what they deliver, and how they deliver it. Some have integrated a variety of games in their platform and have an ecosystem of hardware systems surrounding it. While others are in an earlier phase having developed a couple of different games to use with commercial VR systems. All of them seem to have the medical perspective in focus instead of the gaming experience, making them less desirable than casual games found in the market.

There are only two systems intended for home use, and none of these focus on lower extremity. They are also quite different from each other, where one replicates a therapist through an avatar, while the other shifts focus towards intriguing experiences. The feasibility pitfall of the different platforms might be that most of them are designed around a dependency of medical supervision, and not suitable for a home environment.

It is difficult to determine whether or not the systems deliver on all aspects of the three lenses of innovation (IDEO, 2015). The thesis aims to achieve desirability, viability, and feasibility in its result (Figure 7), giving it the best chance to succeed in implementation and use.

Price

None of the systems state the price at their website, making it hard to take that into consideration. A concern is that the lack of price accessibility makes the threshold high for possible users to evaluate if the system is suitable for them.

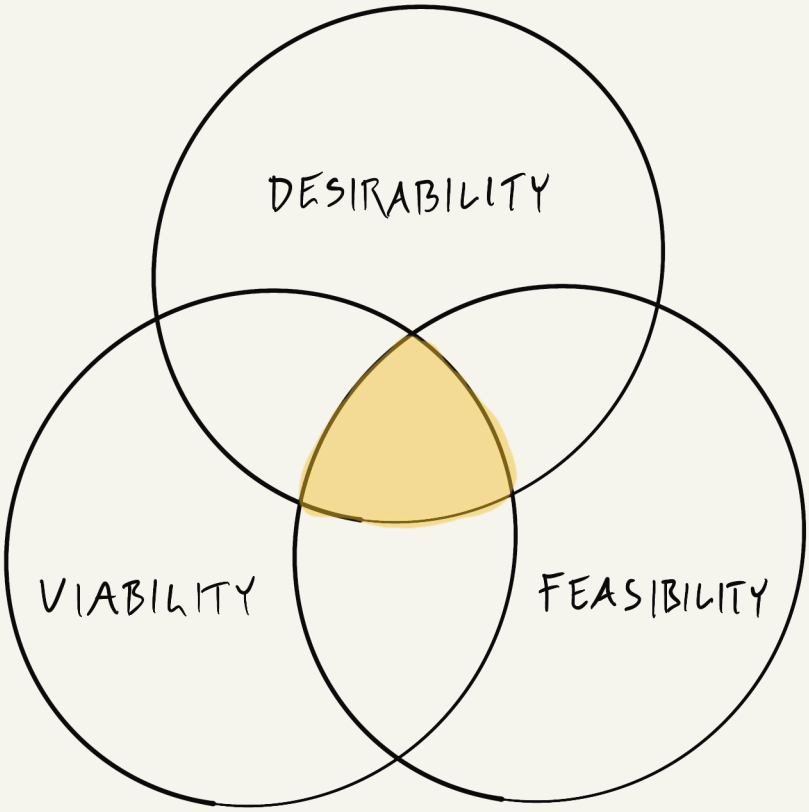


Figure 7: The Three Lenses of Innovation.

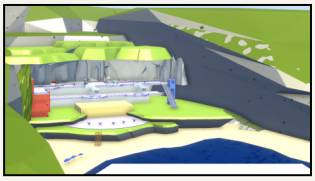
	Immersive Rehab	Cognivive
		
Target users	Stroke patients with upper limb or balance issues.	Stroke patients with upper limb issues in their home (with supervision)
Desirability	Development phase. The simplicity narrows the problem it solves (now).	Focus on exploration and fun. Could help inactive patients do more training.
Feasability	Involve patients in their development. Could uncover good solutions.	Their game design focus might give them a lead in patient engagement.
Viability	Too early to say, and not clear if it's intended for home use.	For home use, HTC as partner might hinder more affordable options.
Price	?	?

Figure 8: A competitor analysis matrix for the VR rehabilitation game market.

Neuro rehab VR	Rewellio	REAL system
		
Stroke and TBI patients with upper and lower limb issues at institution.	Stroke patients with upper limb issues at home.	Stroke patients with upper limb issues at institution.
The focus of the tasks might not be that engaging in length.	Clear value proposition: getting the most out of the valuable therapy time.	Large sets of different games, but in a very childish environment.
Seems to have prioritized the interaction with medical hardware.	Well planned patient/ therapist/game-interaction.	Big set of games, with a lot of features. Requires a lot of supervision.
Not for home use. Designed for access to medical equipment.	Helps both patients and therapists, creating two sources of income.	Too complex and feature creep for an easy transition to home.
?	?	?

Commercial games

Consumer grade commercial games were not included in the competitor analysis. However, games for popular consoles, Wii Fit and Kinect Sports in particular, are widespread in the literature. As such they are alternatives to specialized games. On the other hand, they've not afforded the streamlined approach to therapeutic exercise that their counterpart offers in their value proposition. Furthermore, they do not have to comply with safety standards that clinicians would require. Therapists can apply their expertise and select games for these consoles that fulfil exercise requirements, but this takes time and effort. A project by Norsk forening for Slagrammede and Sunnaas Sykehus set out to classify which existing games could be used to train different body parts and published it in a web portal ("Om prosjektet," n.d.). This shows the extra layer of resource use required to make the knowledge available. At the same time it illustrates the will to integrate gaming in treatment.

Playing on the Nintendo Wii console with an input balance board.
Photo: Business Wire

Interviews

"Converse like a talkshow host, think like a writer, understand subtext like a psychiatrist and have a ear like a musician" — Lawrence Grobel

The main body of insight in this project revolves around interviews with therapists and patients. We proposed three rounds with different approaches for our interviews: an initial round of exploratory interviews for building understanding and empathy, a secondary round to integrate users into the design ideation phase, and a final round to accompany the user testing. We chose four to six participants as a guideline for each user group in each round. This number is not arbitrary. It applies in cases of user testing and heuristic evaluators (Nielsen & Landauer, 1993), but transitive properties could argue the case for interviews as well, especially since user testing would be expected carried out with the same participants. The assumption is that the sweet spot of effort and return is in this range. It'll also lend us the time to iterate and analyze data in between rounds.

A semi-structured form was used for most of the interviews. Interview vs kept the conversation in line with the key objectives for each round. The structured aspect made sure the findings were adequately comparable. The unstructured aspect was important to capture the plethora

of experience and sentiment the users possess. The transcripts were used as raw material for processing through analysis (larger to smaller pieces) and synthesis (smaller to larger pieces) (Portigal, 2013).

Going into the project, there was uncertainty about how ABI patients would respond and react to the interview setting. Cognitive capacity and capability differs from patient to patient and could change significantly in a short timespan. To counter this we imposed an upper time limit of 30 minutes in accordance with advice from therapists. A brief summary of interview themes and subjects were sent to patients in preparation, expanding on information from the outreach leaflet.

Two groups were targeted for recruitment: therapists and people with sustained ABI. The therapists were recruited via rehabilitation centers, listed as external collaborators. Patients were recruited from the same facilities, with help coming from care personnel in reaching out and screening potential participants. One patient reached out after an open post on Facebook (Appendix Y). An introduction to the aim and nature of the study was sent to the participants before recruitment (Appendix U-X).

Three female and two male therapists were interviewed. Two are occupational therapists and three are physiotherapists. They had an average experience of 18 years (SD: 8,4) working in their fields.

The people we interviewed with sustained ABIs were all male, and the average time passed since injury was 14 months (SD: 3,9). They were all in their 50s or 60s.

All participants taking part in the study were located in Norway.

Because of NSD and REK compliance requirements, we were more cautious of spinoff questions and digressions (Appendix I-J and K-M). All the interviews were conducted and recorded in Microsoft Teams. The recordings were transferred to a secure server and transcribed into text for further processing using NVivo.

The interviews are the crux of the project. They shaped the direction at all times. In the end – since the end goal valued a solid concept higher than a polished game – user orientation and inspiration set the bar for the process and results.

Preliminary

Physiotherapist

At the outset of the project, we quickly realized we were out of our depths on domain knowledge. As designers, the first instinct was to speak with experts about rehabilitation and exergames. First, we had a chat with a physiotherapist and researcher with vast experience in ABI rehabilitation. He was the first therapist we spoke with, and would be the primary source of much of the information for the project.

He explained how therapist teams work with ABI patients in the different phases of post-trauma rehabilitation and treatment. As he described, the effects and outcomes in this treatment are highly diverse, and the clinical pathway has to be constantly tailored to the people involved. We were introduced to the patient-therapist relation and how it is centered around user needs and goals, something that would become a recurring theme. He explained the metrics used to evaluate progress and how physiotherapists utilize their skill sets to craft roadmaps for patients – a practice characterized by a blend of qualitative and quantitative measurements – as well as the ways they communicate and co-develop it.

He also pointed out that exercise is not necessarily exercise. While patients are encouraged and pushed to cultivate and regain their pre-trauma interests and activities, intensity and frequency play a large part in ensuring progress. The transfer of knowledge and habits between life at a clinic and at home is also a challenge, but underlines the importance of the essential factor in rehabilitation in general: self-sufficiency.

Expert 1

We had a chat with an expert in exergames. Her background was also as a physiotherapist. Now she is contributing to research studying the potential of exergames, particularly with elderly users, and how consumer-grade solutions could make treatment more viable and available. Having explored a lot of existing solutions on the exergames market in trials, she knew the upsides and caveats of using household consoles and games in the sphere of welfare technology.

She reiterated the diversity in clinical pathways and described a competency gap between demographic segments stemming from technology familiarity. The motivation factor also differs, and pre-trauma habits tend to transfer to post-trauma rehabilitation. She also stressed the importance of cognitive condition when working with ABI patients, raising the issue of capacity and perceptiveness when designing for them. Her stance was clear on one point: a part of the rehabilitation has to happen at home, and if VR-based

serious games are to enter this space, ease-of-use and safety is paramount.

Expert 2

We also spoke with another expert, a PhD candidate also looking into exergames and how to make them more available for people at home. She shared many of the physiotherapist's and the other expert's sentiments, and had experience with how game mechanics could play into these. The fine line between casual and serious gaming is a challenge for video games in rehabilitation. If tasks are carried out erroneously or not as intended by the therapist, a strong feedback loop is required to make the treatment beneficial. In the worst case, game mechanics and performance can directly counteract productive recovery by rewarding participants for taking the shortest path to victory, taking shortcuts, and not doing exercises properly. Until now, a therapist-in-the-loop has been the go-to solution, but machine learning has provided an opportunity to leverage visual data for creating dynamic, real-time feedback loops, although this, in her opinion, would be like shooting birds with cannons. Either way, the transfer and display of feedback to the patient must be addressed to counter adverse effects and promote real improvement.

She had a couple of interesting anecdotes regarding motivation in exergames. One was the adoption of a "gambler's mindset", and the excitement of spontaneous reward systems. To keep the patient engaged over longer periods of time – often a challenge, and key to sustaining progress in rehabilitation – one could design nuggets of surprises and achievements. To take it further, these elements could remain in the game situation to serve as tools for further progress, giving the patient a sense of purpose and incentive for productive play. To wrap up, she advised us to touch ground with therapists and understand their needs as well. Their days are crammed and setting up high-tech and complex systems, when they have their immediate skill-set available in a flash, is not a priority. Again, ease-of-use is not a patient-side problem, but a universal one.

The preliminary interviews introduced us to a plethora of concepts and practices. We summarized them in takeaways from interview cues and secondary analysis to establish baselines and spur early hypotheses.

Therapists

First round

Approach and methods

The first round of therapist interviews concluded with the testimony from three physiotherapists and two occupational therapists. All were asked questions from the relevant interview guide (Appendix AC) and finished on time.

The objective for the first round was to establish a foundational understanding of how therapists work with patients with ABIs. Form and frequency of feedback and follow-up, goal setting, and communication were the focus of our probes. We were also curious of the challenges therapists encounter from handling logistical and technological aspects of their work. Lastly, the therapists spoke of their experiences and thoughts on VR and exergames, and if they were familiar with the concepts and practices related to them.

The output of these interviews were dependent on the therapists sharing genuine opinions and experiences. Uncovering real issues and sentiments is central to the HCD process (IDEO, 2015), and has plenty of pitfalls. Inherent bias and subjective experiences color individual perceptions, but triangulation through a critical mass of interviews seeks to mediate variations while keeping interesting cues from each interview. By letting the interviewees speak in paragraphs, not sentences (Portigal, 2013), they were challenged to exhaust answers to the fullest extent and reflect.

Like the preliminary interviews, after having transcribed the recordings, the long form answers were summarized into short form notes, capturing the essence of dialogue. From this, takeaways and cues were extracted from the notes. Upon finishing the interview round, similar takeaways and cues were grouped into categories to spark further lines of questions for the next round.

- Motivation
- Interactions
- Home
- Logistics
- Measurements
- Methods
- Challenges
- Technology

These themes were identified as topics of interest during the interviews, and should be investigated further when shaping potential solutions.

Interaction

Patient interaction is a complex matter, made yet more challenging in ABI cases. As therapists must engage patients continually through their clinical pathway, the interactions change and the therapists have to adapt. This applies for interactions like the initial setting and subsequent adjustment of personal goals, giving feedback on general progression and specific exercises, and navigating tradeoffs between intensity and capacity within the clinic and during in-home rehabilitation.

Relevant quotes are juxtaposed to the right of the insights.

Early phases of rehabilitation involve getting significant groundwork to establish a toolbox for collaboration between the patient and caregivers. The first hurdle is often communication. ABI patients may suffer from sustained or temporary aphasia, a condition where expression and understanding of language is difficult or impossible.

T2: The most challenging part is when the [person] either lacks language [...] or doesn't understand what you mean, that they don't have the ability to take in information like we normally do. Then there's the challenge of instructing exercises, or doing everyday activities. So it's hard if you don't know if they understand.

Early phases of rehabilitation involve getting significant groundwork to establish a toolbox for collaboration between the patient and caregivers. The first hurdle is often communication. ABI patients may suffer from sustained or temporary aphasia, a condition where expression and understanding of language is difficult or impossible.

Adding to the difficulty of communicating basic, day-to-day activities with patients, aphasia impacts realistic goal setting and self-perception.

T3: For some it can be difficult to create adequate goals for rehabilitation. It should be their own, but we often help them get going with making realistic goals. [...] They're often too ambitious. For example, one person had a brain injury almost a year ago. [They] still have no active standing functionality, and [they've] rather regressed. [The] goal to get up and walk isn't realistic, but it's what [they] want.

The patient's support team involves speech therapists to cross this gap. With the occupational therapist and physiotherapist they form the nucleus of early phase rehabilitation.

Goals and motivation

Goal setting is an essential part of rehabilitation. It lets the patient and their caregivers align to a goal that can be leveraged as motivation and practice. Parallel and complementary to this mental and interactive activity, there is often also a rediscovering of, and sometimes coming to terms with, physical abilities and capacity. Here, if a mutual understanding isn't present, it will be difficult for physiotherapists to work with motor functions. Like with goal setting, therapists have to engage the patient in creating this understanding.

Several therapists emphasized the value of tailoring rehabilitation programs and exercises to the patient's interests. Past hobbies and recreational habits make ideal milestone targets. There was also a sentiment that patients with physically active pre-injury lifestyles tended to incorporate it into rehabilitation to the benefit of accelerated progress. This sentiment extends to increased motivation and ultimately a productive home rehabilitation.

Looking at motivation in the broader sense, the therapists recognized it as important for all aspects of rehabilitation. An interesting input led to the hypothesis that progression and motivation perhaps could be described as a proportional relationship, having a direct effect on each other over time. The impression was that a demotivated individual is likely to experience insignificant progress, and a lack of progress could be equally detrimental to motivation. This puts more

T0: The patient sets their goals, shaping the exercises, then feedback is given on the execution of those. How does it deviate from normal movement? We make the patient aware of this. It could be gait, symmetry, how to land on the foot. You often ask "how do you observe yourself doing it?"

T2: It's [...] how they view themselves. [...] I use my own body to tell them what they're doing, where there's a need for corrections and how to do it right. We use mirrors where they can see themselves executing exercises if they're fine with it. That is, if you have a slight deviance [...] that they aren't aware of, a mirror can be very useful to see how they use their body."

T4: It can be challenging because everyone doesn't see the need for further rehabilitation. [...] It's important to identify activities they enjoy [...] We look for activities [in their area] or interests that can translate to home activities.

T2: [...] if they show progress here you have to underline the importance of continuing training to make lasting improvement. And you have to find activities they enjoy. Many become passive [when they go home] [...] Often, if they have a hate relationship [to exercises], it won't get done. [...] it comes naturally for the ones that were active before. A lot of stroke patients we get are passive and may have health problems prior, have little familiarity with training and exercise, and suddenly have to start when they've fallen ill.

pressure on the patient to be more disciplined and follow up treatment more closely.

In interplay with the motivational barriers derived from a lack of realistic goals or historically passive routines, a negative feedback loop can occur. As mentioned, therapists work intensively with patients to avoid this pitfall. Progress is not necessarily predictable, however realistic or well designed the planned treatment is. Circling back to the preliminary interviews, game mechanics and rewards could supplement or substitute real, physiologic improvement to push the user when progress plateaus or declines, ensuring further adherence to continue or maintain effective levels of activity.

The facility-home transition

Transitioning to home rehabilitation signifies a break with the bulk of therapist interactions. After the early phase of inpatient rehabilitation, people must tackle a change in routines and dependency when leaving an institution. Offerings in this phase – which is more or less indefinite – differ from place to place. Different facilities also provide the patients with different resources after discharge. Relatives and social circles also come into play and in many cases become a source of care, filling the void left by healthcare services. As opposed to professional care, these sources have to make do with what they think is helpful for the patient.

Equipping the ones around homebound patients with the tools and resources to provide secondary care and support can be critical for the continued progress in rehabilitation, especially if the contact is frequent or constant. Watching someone close to you struggle with menial tasks can be difficult, but the pushing of boundaries is important to develop skills and capacity for independent functionality. Independent functionality encompasses a broad spectrum of requirements. While all ABI patients do not have the potential of reaching total independent functionality, many do, and their clinical pathway is often shaped by this goal.

T2: If you have next of kin involved, having practiced something [at an institution] without anyone helping to manage on your own, they have to be in on that. The family has to be in on it.

T1: I have an impression that users that are assisted in their home get too much help at times, for example losing patience when the user is dressing, depriving them of the chance to actually try it.

Balancing the workload between training and everyday activities is meticulously observed at inpatient rehabilitation facilities. The patients are followed up on their goals with daily exercise programs and administered workloads. Transitioning to home is not an abandonment of this framework. The impression was that all the institutions represented in the interviews work together with patients to make plans and schedules for everyday life after discharge. Many patients are also set up with follow-up from ambulant therapy teams in their municipalities, who can observe developments routinely. Ultimately, patients that are transferred to unassisted living situations are left to follow up their own development from day to day. From that point, the weigh-offs of workloads are in their own hands.

T2: The ones who follow up the best do exercises at home and take more responsibility, in comparison with those who go to a physio once or twice a week and think they've "finished" training. [...] Just taking the stairs and getting dressed can be exhausting, you get tired of it, so how much training they manage differs.

T4: We don't usually send people home with no follow-up. Most are discharged to another institution with follow-up. One of the greater challenges is capacity, cognitive and physical, that they don't have the energy they used to. We focus on the economics of energy and the structuring of the day-to-day.

Progress – methods and metrics

Therapists use a combination of methods and metrics in their work with patients. The Berg Balance Scale is perhaps the most common way to measure lower limb functionality, gauging capability through a series of balance-based activities (Berg et al., 1992). Progress can be communicated through improvements to the baseline and paints a clear picture. The physiotherapists value such metrics as they outline indisputable changes in either direction of progress.

Established tests and frameworks are used for quantitative evaluation of patients, but are also frequently used in patient-therapist dialogue to spark discussions about baselines and progress. Challenging the patient's self-perception is vital to their understanding of their condition and motivation in goal-setting meetings and physical sessions. Physiotherapists and occupational therapists explained their methods as separate, but similar in this sense: confronting the patient and promoting introspection. Together with the quantitative metrics, physiotherapists use other artefacts like mirrors and bathroom scales. It becomes a way of translating more intangible skills of observation between physiotherapist

and patient. Occupational therapists make use of trial and error in everyday activities to achieve the same effect.

Technology

This interview round scoped rough sentiments towards technology. Talking with therapists about this leaves a scattered impression. Generally speaking, they all have some sort of experience using technological tools and aids, anything else being impossible in the rapidly digitised healthcare sector. That being said, attitudes and competence lay on completely different ends of the spectrum among the interviewed individuals. Age, facility, and exposure were clear cut variables for use of technology in day to day therapeutic work. Older therapists have practiced established methods for longer, and may be more comfortable using them. Also, practicing at an institution where technology is often used seems linked with confidence and operational skills. Themes like preferences and requirements, thresholds for use, and the application of casual games in a therapeutic way were all discussed in the discourse on technology.

Exergames had been tried at all the represented institutions, and most of the therapists were familiar with the Wii platform. One institution is also being the leading proponent of exergames and VR in rehabilitation nationally. VR stood out as a highly novel technology, with regular use occurring only at the mentioned pioneer, with others having knowledge of it through other venues like trade conferences or fairs. Using games in treatment was more familiar, and occupied a space between

T0: Take a stroke patient: sitting to standing after the injury. They put all the weight on the good foot and little on the bad. This is a typical pattern. I put a bathroom scale under their feet and measure the pressure between their feet. "Try to get to 30 from 20." The feedback is direct. I let the patient guess and that can be fun, maybe even take away their vision. They often get a good feel doing this. The patient often gets into a pattern where they don't use both their feet, so we do this regularly, like every two weeks.

T4: We have a standardized testing set we use to measure the general effect of rehabilitation. It's different how physios and occupational therapists measure upper and lower limbs. [...] We also have some tests that measure everyday activity and participatory things: structures observation of the patients without necessarily including forms, but methodical use of activity. If the patient is in the kitchen doing a task I'll think about how I would do it and what the norm is. Then I compare the patient's execution with the norm.

therapy and recreation. Because activity undoubtedly is a facet of rehabilitation, casual games are not only tools to incorporate general motion into the patients' life, but can also be pinpointed and tailored to more specific uses, say, training balance. Considering the enjoyability component of gaming in this regard, commercial games potentially have an edge over therapy-first games.

The uncertainty when initiating a sequence is just as prevalent with the therapists themselves. Corroborating findings from the literature review, losing resources during clinical rehabilitation strongly repels novel technology exploration. Setup and use simply have to be smooth and fast. A term that occurred more than once in our talks was the concept of the "one-button" solution, something that was prophesied in our preliminary interviews. Many of the therapists were uncomfortable with the thought of having to spend time and effort onboarding past the point of pushing a singular button. One therapist who had extensive experience using serious games in his practice fully agreed, adding the importance of seamless setup in the home environment.

T4: The first thing to look after is if it's fun, if I want to play it again. Then I use that experience in treatment. Which movements are required to play? Is it something our patients need? Specialized games need to stand out from commercial games in a good way, also how easy it is to initiate. Patients with reduced cognitive function can find it difficult to start a game if there is too much to press and choose from at the outset.

It can be asserted from the interviews that the threshold for using technology in practice is high. The weigh-off in terms of time used leans towards efficiency and familiarity. If the tool is tried and tested, while having an uncomplicated setup, the bar is lowered and the probability of adoption is higher. There seems to be little difference in perceived value of technology between physiotherapists and occupational therapists, suggesting that both groups can identify productive use settings.

T1: I have to be comfortable with using [digital aides]. I try them myself first if there's something that can be used. And it has to be simple, preferably plugging in and pushing a button and everything is set.

T2: It's a time thing. If there's a lot of installation and hassle you put it off and do what you're used to, so it has to be very simple to use.

Second round

After the first round of interviews the findings were analyzed and a new interview guide (Appendix AD-AE) was developed. In-depth questions were derived from themes from the first round with the motive of expanding on topics aligning with the research question. An ideation prompt was also included.

Setting goals
Boundaries
Game ideas

These themes were elaborated in the second interview round.

Setting goals

In the first interview, goal-setting was discussed as an interaction between carer and patient. Going further and looking at the outcome of these interactions, a lot of thought and effort goes into the goals themselves. The goals of the patient form the nucleus for active treatment at facilities.

Moderation of expectations and establishing realistic goals are the checks and balances of recovery. Failing to impose these means the patient is bound for disappointments and setbacks. With this in mind, goals must be ambitious and challenging. Most would like to train within their comfort zone, This rarely leads to lasting progress, but sooner an illusion of it in the early phases of rehabilitation.

Common practice is to take big, challenging goals and break them down into chunks. The smaller sub-goals have a shorter lifespan and should realistically be possible to achieve within weeks. One analogy for this was a LEGO building set, where the finished structure is complex and multi-faceted. The sub-goals – individual LEGO blocks – are compartmentalized versions of the final goal, giving therapists the opportunity to use their skill sets on specific exercises and functions needed to achieve it. This way of thinking gives the rehabilitation team and the patient both short- and long-term timeframes points of reference.

Therapists use frameworks and best-practice methods to make goals feasible and understandable for everyone involved in the rehabilitation process. Several therapists mentioned such a framework. Borrowing a page from the management theory playbook, SMART goals have become a staple of neurorehabilitation (Bovend'Eerdt et al., 2009). The acronym stands for Specific, Measurable, Achievable, Realistic, and Time-related. It is easy

T0: When they're with us [...] they get a coordinator; could be a physio OT, nurse, or a social worker. They have the responsibility of setting goals. Then it's about setting goals the patient feels are important here and now, but that can change over time. In the beginning they often want to walk. When we talk about realistic goals – some patients can be very unrealistic – we see damage so great that this goal is highly unlikely to achieve. It's important to not discourage and demotivate them, but leave it as a general goal that's hard to reach, but at the same time having sub-goals that are realistic within 2 weeks.

T1: Sometimes you've got to try the goal to feel that this can't actually be done. One person wanted to swim in a pool. When one side of your body is not cooperating that's not realistic. No matter how much that with your injury and so on, they wouldn't hear us out. So, we actually tried it. It became apparent that it wouldn't work out. It's about that reality check and how you do it. If it's through talks and small trials that's good, but sometimes you've got to take those big steps like the pool. It's also about the type of injury, thinking about understanding.

to see why therapists would adopt this framework, as it effectively addresses most of the criterias they look for when discussing what makes a good goal.

Focusing on interests and making them part of the goals also helps. Therapists will work with patients to explore if they can take back hobbies or activities they did before, and that tends to be where ABI patients want to go. Even if pre-injury levels of execution are unrealistic or impossible, alternative adaptations can be used as main goals. The second interview round reiterated the importance of interests and working with them through the entirety of the clinical pathway, and this comes through when setting goals.

Pushing boundaries

Having the ability and will to challenge the current situation in rehabilitation is the only way to achieve progress. This was a recurring theme in the literature review and the first interview round. It also plays into the timeframes in the post-injury pathology of ABIs and the neuroplastic properties our brain shows in these situations. Progress is easier to reach and notice closer to the injury epicentre, and at some point patients will plateau. In the second interview round, new insights were added through conversation about safety, capacity, tools, and translation to the home environment.

Safety is a big concern for many people with sustained ABI and people working with them. Coordination difficulties can make simple actions perilous. The governing principle for dealing with safety concerns is supervision. Until a patient is able to perform activities independently without significant risk of harm, a supervisor is needed. This provides a sense of safety for everyone involved, but can also be restricting. The typical comparison is learning to ride a bike or swim: You

T4: We work with something called SMART goals. It'll be more motivating to see that in this and that time you'll be able to be attentive to an activity for 20 minutes. When we have a new goal meeting where we see that the patient is able to be attentive for 20 minutes, more of them think it's motivating to work on such a specific goal. That is, some patients think so; it does take a certain amount of cognitive capacity to actually reflect on how the goal is shaped and what makes it motivational. For someone who doesn't have that insight or meta-cognition it's more challenging to see small goals as more motivational than big goals. It depends.

will never truly master either if not left to your own devices at some point. That point, however, where the parent lets go of the bike seat or takes off the floaties, often coincides with transfer from the rehabilitation facility. The problem was raised more than once.

When we talk about pushing boundaries, or training towards them, we talk about challenging physical and physiological limits. When working with patients, therapists are very aware of the patient's condition. They need to find a balance between too easy and too difficult, and facilitate rest when the workload is too high. We see that dosage applies to all aspects of the patient's life: exercise, chores, rest, and recreation. Pushing boundaries continues well into normal life, and the patient needs to take sole responsibility somewhere down the road. With the added element of support in the home, showing restraint with regards to interference in difficult situations is necessary.

Game ideas

In the second round, the therapists were asked if they could envision a VR-based game to serve as a tool for lower limb rehabilitation, and what that would look like. They were put in the shoes of the game designer, which led to a valuable, but not unexpected insight. More often than not they stuck to the same solution: an immersive open air environment with basic mobility as the main input. Given the openness of the question and commonality of walking outside as a rehabilitation goal, this type of proposal was the obvious answer.

T3: It's a challenge, being safe while challenging yourself. We have a patient with great balance difficulties, but cognitively healthy. They're going home in a week. We've recommended linking up with a physio at a facility and keep pushing themselves so they can be safe. They want to walk home, walk in their garden, but I think you can't truly push yourself in the same way if noone is there to help a little. We can't follow up a lot on the effect of independent exercise. We're responsible for guiding them, but depend on their support to contact us. There isn't always a need – we'd like to know more.

T2: If they're cognitively functioning it's pretty alright. We're about independence in practice from day 1, so we try to not over-supervise them and tell them to do this and that in regards to dosage, so they know how to handle responsibility when going home.

T4: We're very cautious when we send our patients home. For a while they're to do less than they feel they can, to get to know another situation. The stimulus changes, everyday life sets in. We work with physical and mobile schedules before they go home, setting aside time for rest. We distribute chores, "must, could, should", over a week, among their fixed appointments. The structuring is essential when they go home.

T2: Maybe if you could create a goal, let's say an uneven terrain to a cabin. To get there you must walk 200 meters a trail and then… uneven like ascending some rocky stairs, the last part perhaps, then over a bridge and maybe there's no bridge at all so you have to get across in some other way. Then up the stairs to the cabin. [...] You could make it realistic in relation to the goal they have, maybe their goal is to go to their cabin.

T0: Ideally it would be a stimulating environment for the patient, something they can enjoy regardless. If the patient likes skiing it could be a game with skiing. Both cross-country and downhill, performing those things in a motivating environment or a virtual world. Often games have simple graphics and are not very motivating, especially games for rehabilitation. You don't get the fancy environments like in commercial games. So I would like a gaming environment adapted to the patient so they can explore in a safe way. With regards to balance it's not so easy if you have a very stimulative environment with VR goggles and it can result in falling. It would be interesting to hear what patients say about it, what they want. If it's balance, there's walking over hurdles, walking a tightrope over a canyon and so on. There's infinite possibilities. But the safety aspect is different compared to healthy people, and that can be challenging in games.

T3: The first thing that comes up is challenging their gait, doing things while walking. Like watching out for hurdles, looking to the side, that type of activity. I think that could work very well. Training attention, reaction, balance. It would be fun if you could create a reality on a treadmill where you include other elements that just walking.

T4: Some open world game. Preferably on an omni mill so they can walk around freely. Going up and down a hill, going task to task, navigating, with obstacles along the way. A fun game in an exciting world where they perform tasks.

This tendency among the therapists confirmed that a one-to-one translation between environments and activities is a likely outcome when they are put on the spot, and proved rather unproductive in terms of game design ideation. However, some new additions – simultaneous movements and cognitive challenges, explorative freedom, and goal incorporation – were discussed.

Summary and takeaways

Through the course of the interviews, a few fundamental values emerged at the core of the therapist-patient relationship (Appendix AJ-AK). How communication orbits around long-term goals, pushing boundaries in and out of the home, the therapeutic toolbox and its limits, and the conservative approach to new technology were some of the themes that went beyond the research question.

Themes that were swept through quickly highlighted dark areas that were not as prominent as anticipated. Sentiments on post-discharge phases – in-home treatment and long-term rehabilitation – garnered astonishingly little in terms of new insights, except protocols and practices leading up to this event, displaying a clear disconnect. However, this is partly by design because of mandated handovers of responsibility between clinical facilities and municipalities. These connections, at this time a symbol of uncertainty and discontinuity, could be explored and rephrased as a potential resource.

The complexities of aphasia and similar afflictions were well known from the outset. The therapists corroborated these and colored them with stories from their trade. These stories showed the need for a human touch in daily interactions, especially in the early stages. Engaging with patients to help them co-create and gain ownership of their goals and push their boundaries is central to the relationship and the process. Developing a common understanding and mapping out a lingua franca with therapists not only improves communication, but helps the patient understand their own situation and get familiar with their capabilities.

Furthermore, as the patient starts to progress and make sense of their condition, communication can resolve

and untangle the aspect of motivation. Motivation seems to not only be the driving factor for progress in rehabilitation, but comes across as something intangible and impervious. The therapists had many opinions on how motivation fluctuates and how it is influenced. Returning to hobbies and interests, achieving minor and major milestones, and resuming life as it was were some of the usual suspects. This would be a leading question going into patient interviews: Is there a discrepancy between what therapists believe motivates patients and what the patients themselves believe?

Lastly, the lacking adoption of technology, and the allocated resources to do so, reflected an age-old idiom in most occupations and industries: If it ain't broke, don't fix it. Of course, this is a truth with modifications. All the therapists were certainly open to new technology in their practice, and most had used it, but not as a substitute for ordinary training. Games in particular were regarded as useful for recreation and encouraging activity. Still, therapists, and especially physiotherapists, tend to stick to tried and tested methods – what they have learnt in school or after decades of interacting with patients. Some were more willing to try it than others, one even specialized in using it in treatment, and the overall threshold appeared very surmountable.

Patients

Approach and methods

The procedure of interviewing therapists and patients progressively can resemble a courtroom chronology. Therapists make claims and share experiences from their practice before patients step to the stand and divulge their story, sometimes contradicting the therapists. Of course, these proceedings are not adversarial and do not result in any sort of verdict, but the analogy stands. Interviewing patients would let us capture two sides of the system.

Interview guides (Appendix AF-AG) were developed going with the same semi-structured layout. The timeframe was 30 minutes. From a semantic standpoint the questions targeted an individual, descriptive experience as opposed to normative recitals from a system stakeholder. This approach went along with a preconceived motive to obtain more emotional responses to challenge perceptions from the therapist interviews. At the same time the questions sought to uncover experiences with logistical and systemic factors.

The method for these interviews was the same as for the others. They were recorded, transcribed, and summarized in short form notes. An analysis was conducted using affinity mapping, leading to the following themes. Two of the interviews were conducted according to the interview guide chronology, and one had to accommodate the participant's capabilities.

- Progression and followup
- Logistics
- Technology
- Pain points
- Training
- Motivators

The identified themes for this group emerged, to a larger extent than the others, from sentiment clusters, stemming from emotional responses and digressions.

Logistics

All the interview subjects had suffered ABIs some time in the last two years. With this experience they began their journeys through a series of stages and institutions, resulting in different perspectives and outcomes.

All the patients said the first phase was difficult for many reasons. The injury itself is devastating – temporary loss of multiple fundamental functions like vision, movement on one or both sides, speech, and other cognitive processes were sustained. All participants had reflections about the initial stage of their clinical pathway. They shared sentiments that this stage was defined by chaos and ambiguity on several levels. First, the embodied experience of a function loss following a trauma, and second, the uncertainty of not knowing what lay ahead in terms of everyday life. Two participants said they were confused by the system they found themselves in. However, their condition and environment stabilized within a few weeks. A difficult aspect of this period was coming to terms with the injury and its effects. One participant remembered having to be helped with everything, like taking a shower or walking properly. They were unsure if they would ever be able to do these activities without help again. Another said one of his hands felt like nothing more than a lump of meat and not being able to do anything with it. Another was distressed by a loss of language and the ability to express himself. The participants stayed in hospital rehabilitation units roughly between three and six weeks.

P3: My hand was like a lump of meat, I couldn't move or anything. After an operation I was at the hospital a few days before I was sent for exercise at another hospital. Jeg was lifted from bed to bath, always in a wheelchair. That was all there was. [...] I was there for 2 months, I think, at their rehab facility, but then they were closing down for holidays and they said "you're going to a nursing home to continue," but my partner said "No, he's not going to a nursing home. Either he's going home to continue training, or he's going to a specialized training facility."

After being discharged from hospitals, the participants went to different rehabilitation facilities. The patients had a great deal of responsibility for choosing these. One noted that this transition essentially felt like being left to his own devices. Another said their partner proactively defied recommendations and opted for a specialized rehabilitation institute instead of a nursing home, and that this was decisive for his progress and eventual return to normal life. One participant said he had heard through the news of a prominent figure that had stayed at a facility nearby, and chose to follow suit, stating that this stay was

a very positive experience. Altogether, the participants felt that they had been largely responsible for their own paths after the initial phase.

All the participants partook in subsequent rehabilitation facility visits after staying at home for a while. These stays resembled the format many of the therapists detailed in their interviews: between a few weeks and up to over a month with daily exercise led by therapists. These stays came across as having been productive and motivating, not only for further progress, but also in anticipation, as something to look forward to. All the participants identified these stays as the times they noticed the most progress.

Progression and followup

The consensus among the therapists and in the academic field, shown in the literature review, is that progress is more noticeable in the early phases of rehabilitation. Returns from exercise diminishes over time. A participant recalled that this was communicated early: you are going to experience the most progress in the first 10-12 weeks. Because the participants all were well into their rehabilitation they had started plateauing and had dealt with it. Two of them mentioned that they had come to terms with their condition more or less as it is. Nevertheless, they were all optimistic that improvements still could be made, and had varying degrees of ambition in that regard. When asked if they had a training regime they could follow, only one said yes. Another said he trusted his physiotherapist with administering the right training when going to the clinic. The participant with no training program whatsoever had started looking for alternative ways of exercise, exploring solutions like VR gaming. He felt that any further progress was left up to him to pursue.

The balancing of active time and resting time is closely monitored by therapists at facilities, and it was mentioned that the latter is equally important as the former. With the newly gained independence that follows discharge

from a rehabilitation institute or hospital, patients can quickly end up being inactive, but the opposite can also happen. Becoming overconfident and zealous with regards to abilities and capacity can result in resignation or having an accident. All the participants had had episodes where they encountered this. Two said they had suffered from burnout, and one also had an accident when trying a complicated movement. This stood in stark contrast to the participant who had no training regimen at all. Having lost his driver's license and with no plan to follow, he ended up in periodical social isolation and physical inactivity, struggling to find suitable activities to continue his rehabilitation. Unlike the two other interviewees he did not mention any significant follow up from the municipality, except some phone calls now and then. The others said that they were visited regularly by ambulant assistant teams consisting of physiotherapists, occupational therapists, and nurses. In their cases, these visits were characterized as useful and provided a feeling of genuine care.

P3: [...] after I got home I managed to administer my day-to-day a bit myself, with exercises from a municipal ambulant team that I told what I wanted to do. They were great and I gotta do what I wanted. I also did all the other stuff, call it chores, and that's training as well, doing the laundry and the dishes, all those things.

At the point of the interviews, the participants were at different stages of their rehabilitation, not necessarily dictated by time since injury, but circumstantial factors and accumulated mental and physical recovery. One participant was training actively, but was still struggling from the lasting effects of his injury. Another had made a nearly perfect recovery, but still had some things to work on, and was going to a physiotherapist every week. The last participant still had problems with getting back to where he was before the injury, and did not know how and if he could get there.

Mental effects and development

Several pain points were addressed during the interviews. Physical difficulties have visible manifestations through the rehabilitation process, and can be identified fairly quickly. Emotional difficulties are harder to identify and to speak about. The participants experienced different physical and cognitive damage after their injuries, and had different reactions to them.

One participant mentioned that the loss of autonomy and independence are burdens that appear early and span far into recovery. While the physical aspects are clear – loss of mobility and ability to perform simple, everyday tasks – cognitive aspects are just as prevalent. The loss of autonomy can be distressing, and feelings like embarrassment could set in. At the same time, emotions can be more unstable and compulsive, making it impossible to keep feelings penned down. The participant said his experiences had an extensive impact, leading him to the conclusion that complete openness was the best way to cope. Hiding the cognitive and emotional strain was much more exhaustive than disclosing it, and would ultimately be futile anyways. Opening up also gave him the opportunity to get help and turn vulnerability into a resource.

P1: I need to talk to someone because I'm still struggling with this mentally. I've been admitted for it, but I'm completely open about it. I've sat in front of [people] and cried openly, so I can handle it, anything really.

Tackling the emotional ramifications requires great resiliency, something all the participants showed signs of having developed. Another patient thought he had been more selfish during his rehabilitation journey. This was his way of focusing on his short and long term goals, and might have stemmed from a mindset he developed before his injury as a top athlete. This was his way of channelling his personal resources towards productive activities.

P3: I've been so focused on myself, that this would turn out well. I'm so much better now than a year ago. My [family] was sure I wouldn't get through it and afraid I possibly wouldn't make it out alive. There were many complications with the [injury] and the [logistics] and so on. I have to be honest with you, I think selfishness has helped me push through it and move forward.

Another participant found consolation and motivation in his surroundings. He noticed a change of character at one of the rehabilitation institutions where he opened up to his peers and became an instigator. Before the injury, he stated, he thought of himself as a loner. Getting out of his past environment and being confronted with his recovery process made him reach out and become a resource for the other people at the facility. For instance, he made sure that everyone could join trips and walks outside regardless of physical condition.

P2: I have a drive, I'm thinking about maybe starting with public speaking and things like that, and I got a lot of encouragement from carers and co-patients at the rehab facilities. We had an out day where I brought the ones in wheelchairs. "Let's go somewhere everyone can." They lit up when they got to come along.

Motivators

The participants were asked to reflect on what motivates them when training and in general. What stood out was that most motivational factors were relational. Family, friends, and health personnel were all mentioned as motivating factors. The participants valued partners, children, parents highly and found that they had a strong effect on their progress. While the participants felt that they had to take responsibility to get to a point where they could be well enough for their surroundings, their surroundings also took responsibility to help them get there. Personal relations were linked with many milestones and minor victories – going fishing with a child, playing videogames with friends, or driving a parent to get vaccinated. These interactions left deep impressions on the participants and served two purposes: remembering the importance of progression and seeing what further progression may yield.

A return to normal life, or something close to pre-injury routines was mentioned, but was not as prominent as expected. The impression was that pre-injury life in itself was not a goal and that coming to terms with the long term effects of their condition could take a different trajectory. However, failing to regain basic means and functions that were taken for granted before the injury, can be demotivating. One example of this is a driver's license. One participant had gotten it back, and two had not. If this equates to reduced mobility, and there are no relatives there to assist, recreational activities can be difficult or impossible to resume, stunting progress and decreasing motivation.

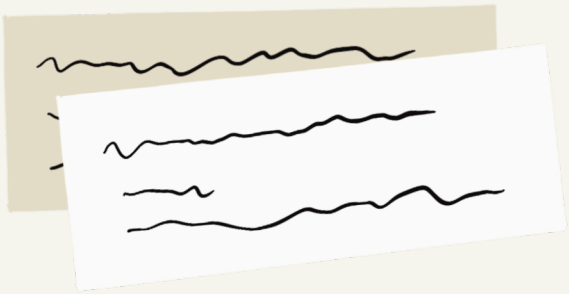
Interests and hobbies also came out as strong motivational elements. The mentioned fishing on a local lake exemplified this. This also underlined the importance of actually having interests and hobbies to come back to, although developing new ones certainly was possible. Strong recreational preferences make excellent motivators and can be used in the goal setting stage, as the therapists noted. A breadth in interests gives therapists more to

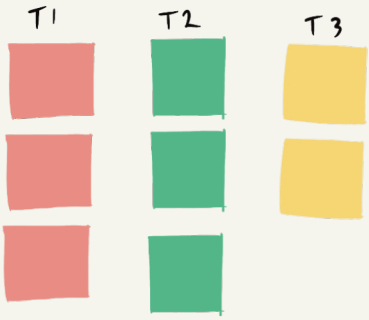
work with and fills the time with progressive activities to complement more intense physical exercise.

Technology

None of the participants had been offered digital tools in their treatment in any meaningful way. Two of the participants were completely unfamiliar with VR games and exergames beyond anecdotal, indirect encounters, like seeing kids use it in a casual setting. One participant had been recommended VR gaming by friends of his child. He purchased an Oculus Quest, tried a couple of games, and found it extremely interesting. In the interview he gave plenty of opinions about how he used VR gaming therapeutically and what worked for him. The other participants were excited for the possibility of incorporating VR and exergames in their treatment, and imagined they would have taken the opportunity if they had been offered it before.

When asked if they had any ideas as to what they thought these tools could be used for in terms of exercise for rehabilitation, they illustrated a broad spectre of complexity: one suggested combining it with a treadmill for running in different environments, another wanted to combine it with music in some way, and one suggested a virtual climb up Mount Kilimanjaro.

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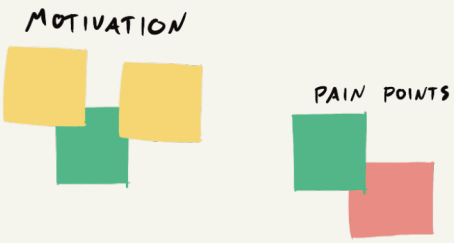

MOTIVATION
PAIN POINTS

Summary and takeaways

The patient interviews confirmed many of the impressions we had after talking to therapists, but contained significant discrepancies as well. Most striking was how little of a patient's total recovery journey one health care worker or facility oversees. The rehabilitation process is, in many cases, years and years of radical and incremental changes, defined by personal milestones and concessions that are difficult to plan for. All the people we interviewed were far along in their recovery, having recovered from nearly every visible affliction sustained from their trauma. Still, some of them had arrangements with their communities to receive practical aid regularly, showing that the aggregated time frame covered by health services is vast. The one person who lacked such an arrangement was disadvantaged by this, and would likely benefit from additional humans in the loop. That does not mean we can say that independence is not paramount. It does not apply to every person with an ABI, but indicates that the public support system inevitably fails in some cases, and that it can be avoided.

The paths the interviewees took logistically, from hospital to facilities to home, told a story of unpredictable logistical practices. The discord between wishes, recommendations, and decisions was confusing and disorienting. Although the experiences at rehabilitation facilities were described as enjoyable and productive, any intention of predictability was lost on the patients, weakening their sense of agency and not making them feel. The greatest achievements in terms of logistics were results of independent decisions. Together with the mental strain ABI and recovery can inflict, volatility arising from being in this system could counteract rehabilitation.

Identifying motivators in patient interviews was not as easy as it would seem. Asking someone quickly what motivates them is a guarantee for an uninspired answer. Off the top of one's head a thing or two can easily be spat out. But listening to testimony regarding completely other things can also lead to interpretations of what motivates a person. What one chooses to trust is a necessary choice, but the superficial answer is often linked with the interpretation. Either way, the accuracy of these assumptions is only important for how productive the solutions they turn into prove to be. When the patients told us activities they were motivated to resume – fishing, biking, going out for a coffee – the context almost always hinted to other motivators: family, friends, the great outdoors, physical mastery and positive exertion.

As far as experiences with technology in treatment went, the whole spectrum was captured, from a participant having actively used VR gaming in training, to another booting up his computer for the first time after the injury to speak with us. In the limited age segment covered, encounters with technology in treatment and pre-injury life were sparse. But the willingness to learn and experiment was undisputable. The biggest challenge, then, is the introduction of the technology, rather than the use. Paired with the strict resource use in health care, a significant hurdle is put in the way of adoption. Designing with and for therapists and patients can be the answer to the challenge.

Synthesis of insights

The synthesis of insights is formulated essentially as two consecutive discussions: how the moving parts of the system are interlocked and behave, and what the nature of the design work should be to meet identified requirements.

We used stakeholder and stakeholder and ecosystem mapping, personas, user journeys, and other tools to organize data and assumptions. The objective of this was to challenge our research question, effectively turning the scope into a frame and concluding the convergent “define” phase.

Interviews were only part of the synthesis. We also obtained data from other written and recorded stories (“Broken: Living with a Brain Injury,” 2016; “Survivor Stories,” n.d.). These provided greater diversity and perspectives from other demographic groups and geographic areas.

Ecosystem

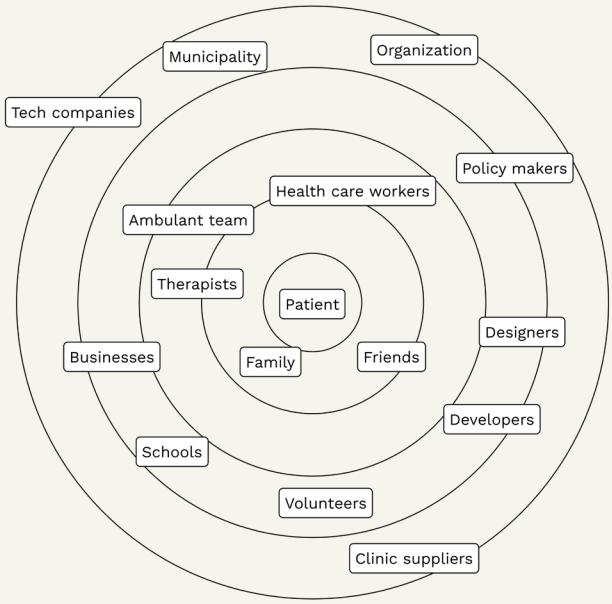


Figure 9: A stakeholder map for the rehabilitation ecosystem.

Stakeholders

The stakeholder map (Figure 9) identifies and gives an impression of who participates in the system. The interactions gravitate towards the center, but have touchpoints and intermediaries in the outer layers. In the current system, we claim that interactions are clustered and concentrated in smaller areas, and that this is where meaningful relationships reside. The outer layers are largely disconnected and their resources isolated. The relationships can differ between local subsystems like municipalities and regions. Because of this, defining the ecosystem as something consistent and uniform is an act of hubris. Acknowledging the wickedness is key to finding the right approach when working with it.

Figure 10a: Persona for “Nina.”

Personas

The personas (Figure 10) are developed primarily to contextualise user journeys, and the gist of the overall breadth of cases can easily be observed from these. For the design brief they illustrate that although problem statements can be made to solve problems in smaller pockets of the afflicted population, sweeping scopes will have too much complexity if not managed and subtasks prioritized.

Name Frode Age 57 Place of recidence Røros

Life situation

Suffered a stroke nine months ago. Was a carpenter and hasn't been able to come back. Avid rock fan and was a heavy rock drummer for most of his youth. Smoked and drank a lot, but kicked the habit some years ago. Been for seven months.

Clinical history

Had an ischemic stroke and sustained partial paralysis of his left side. Regained almost all motoric functions, but progression has flattened out. Still is slow to react and is inactive.

Pains

Lacks motivation to continue training. Sees little value when progress is slow, and is regressing because of inactivity. Thinks exercise is very, very boring. Lost his drivers licence, so relies on sister and kids driving him places.

Gains

Always open to try new things. Has great relationships with his family and tries to meet them as often as possible.

Jobs to be done

- Training sharpness in movement and cognition.
- Become more active and improve lifestyle.

Goal

Get back to some sort of work, hopefully as a carpenter. Want's his licence back so he can move around more freely.

Use of technology

Has used digital/electrical tools in his trade. Owns a computer, only for reading news and communicating with family. Seen his kids use VR.

Support network

Mother and sister both live nearby. Single, but two children from earlier marriage. Two grandkids. Not many others to speak of.

Figure 10b: Persona for “Frode.”

User journey and pain points

Journey mapping is a method used to envision the experiences of a person over time. Usually the situations are based on how users encounter a product or service, as well as what they do before and after the interaction. It is a way to get insight on both existing services and potential, new solutions.

The method has various angles of approach, depending on what type of information is interesting for the process. However, it is always divided into a set of steps or stages, and common ingredients in these steps are description of the main actors' interactions, thoughts and feelings, and which stakeholders are involved.

Another concern to take into consideration is the scope of the user journey. Occasionally the researcher wants to get an overview of the end-to-end experience, and other times it is relevant to zoom in on a narrow timeframe to visualize the interactions in greater detail.

The user journey (Figure 11) was partly founded in personas composed of insights. With personas, journey maps can be contextualized in a realistic situation, building empathy through stories rather than asserting it. The visualization was also based on the interviews and literature review. It is not the story of a specific person, but rather a compound experience of the personas, different stories and likely situations. Although our preliminary focus concerned the home setting, it was paramount for us to understand the whole journey from the patient's perspective and what is required to return home.

The journey map was divided into the most common stages of a person suffering from ABI, from the occurrence of the injury to their return home. Included in every stage were the state of the patient, the goal, thoughts and feelings, stakeholders, recovery curve and duration. It is worth mentioning that all stories concerning a neurologic disease are different, and the situations can vary a lot.

Patient journey

When an injury occurs the first stage is receiving medical treatment at the hospital as soon as possible. At the emergency hospital the patient is stabilized, and severity of the damage is evaluated by a neurosurgical team. The state of the patient differs depending on the severity of the brain damage. It ranges from mild headache to coma. People may experience slurred speech, short-term memory issues or paralysis in legs or arms. They may find themselves confused about their situation. The patient then undergoes surgery if necessary. After the surgery the patient is monitored until considered stable, and the

risk of a secondary injury is low (“Severe Traumatic Brain Injury,” n.d).

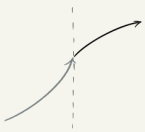
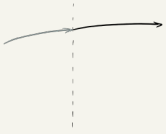
At this stage the recovery of essential functions starts. If the situation is still acute and the patient is placed in the neurorehabilitation department of the hospital. The patient may feel a lack of understanding of the situation, and be discouraged by the lack of ability to move around. Here they start an intensive rehabilitation program: a crucial part of the recovery and where the effect of training is most visible. The team continuously follows up on which measures must be taken. When the state of the patient is no longer acute they are either sent home or to a rehabilitation institution.

At the institution they continue the training of strength and coordination, social abilities and other functions depending on the situation of the individual. The goal is always to become more self-sufficient. After experiencing the result of intensive training the patient may feel hopeful and ready to proceed with rehabilitation. A case coordinator is assigned to the patient and helps out with setting goals and measuring progress. The recovery progress at this stage is still steep, but becomes more and more incremental. When finally considered self-sufficient enough, the patient is ready to return home, either to manage themself or to be followed up by community care providers.

Returning home can be a volatile transition. The patient may be happy to finally be on their own, and motivated in regards to continuing training. Some have family and friends to rely on. Then the reality kicks in. Daily tasks they used to do without further thought is now a struggle. They become tired faster than before, and may still experience strength and coordination issues, amongst other grievances. The balance between training and resting is difficult, and by now the recovery process has become much slower (Figure 12). Staying motivated becomes harder and harder, and the road to emotional distress is short. Some are helped by the municipality, or at local clinics, but others feel left behind, sometimes because their health situation does not mandate professional care.

Stages	Occurrence of injury	Emergency hospital
State of patient What is the main symptoms of the patient?	Minimally conscious Slurred speech	Breathing problems
Goals What needs to happen to move forward?	Get to hospital Preventing further injury	Stabilize & evaluate patient Surgery & recovery
Pain points What struggles do the patient suffer?	Traumatic experience	Uncertainty Loss of independency
Patient thoughts What is the patient thinking?		Shaky short term memory
Patient feeling What is the patient feeling?		Confused Afraid Agitated
Stakeholders What people are involved?	Relatives	Neurosurgical team Doctors Nurses
Recovery How is the progress of the recovery?		
Duration How long does it take?	Seconds and minutes	Days

Figure 11: From left to right, the user journey for a person with sustained ABI.

Rehabilitation hospital	Rehabilitation institution	Home
Muscle weakness, spasm and pain	Mental behavioral and state Strength and coordination	Strenght and coordination Fatigue
Strength and coorditation of essential functions	Physical and social abilities Become self sufficient	Everyday tasks Stay activated Balance training and rest
Dependency Acceptancy Body incapacity	Dependency Acceptancy Not the expected progress	Feeling isolated Struggles emotionally
Lack of self-awareness (understanding the severity of the situation)	Ready for more training after feeling the progress	“Normal” things hard to do Missing the help they have become used to
Discouraged	Hopeful Impatient	Happy, but afraid Motivated, at first
Case coordinator Nurses Therapists Doctors	Case coordinator Therapists	Relatives Friends Community care providers
		
Weeks	Months	Years

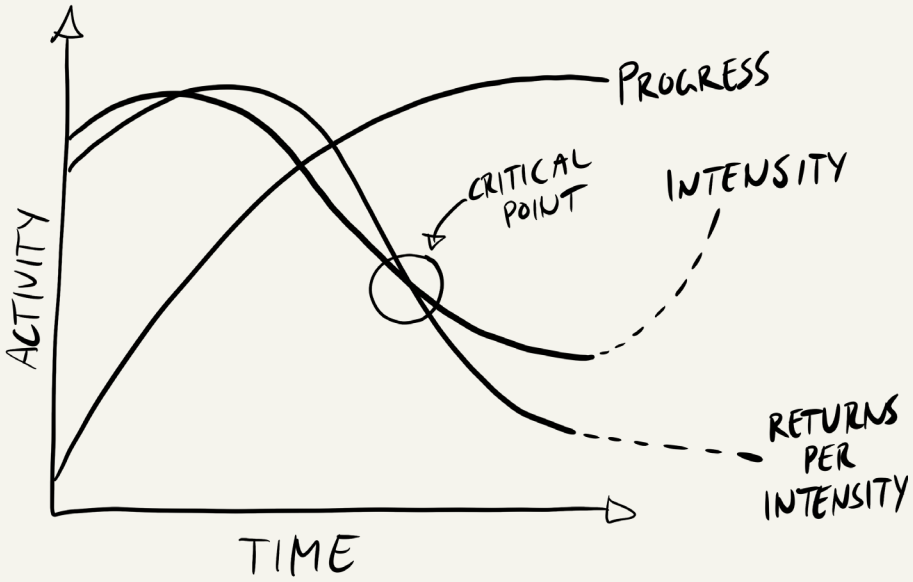


Figure 12: A graph of return experienced in progress as a function of time. The critical point often happens when the patient goes home.

Environmental transitions and characteristics

A recurring theme in the insights is the fluctuation of required training input to reach a certain amount of progress (Figure 13). This relationship is difficult to quantify. It is also essential when discussing long-term health effects of ABI and transitions in living and care situations. The correlation of intensity and the returns of training undergoes changes that are hard to control and predict, but commonalities are present from patient to patient. Easing the transitions and providing the knowledge and tools to pick up good routines and understand the need for continued effort would positively influence the user journey.

	Hospital	Inpatient	Outpatient	Home
Time strain	Low	High	Medium	Low
Intensity	Low	High	Medium	Low
Specialization	High	High	High	Low
Monitoring	High	High	High	Low
Returns	High	High	Medium	Low
Effort required	Low	Medium	Medium	High

Figure 13: Different required efforts and factors in different settings.

Figure 14: An overview of things that are easy and hard to change in rehabilitation environments.

Easy and difficult change

There are elements in the ecosystem that are fundamentally easy to change. These elements are often highly tangible, unobtrusive, and uncontroversial. More obtrusive elements like attitudes or routine workflows are difficult to change (Figure 14). However, including the family more in inpatient settings is something that does require logistical work, but generally seems to be welcomed by carers and patients both. While it can be obtrusive, the benefits are uncontroversial. Time resources are also perceived to be affected by technology; the confidence when using it is low, either because conventional methods are more efficient or there is a lack of skills and proficiency. A design solution process has to consider whether or not it can and will be used, and how it can be incorporated into current practice without much resistance.

Problem framing

Vision

A provisional spec of traits details rough findings from the insights (Figure 5, p. 25). These were noted directly, derived from other testimony, or interpreted as relevant. The features show the initial prioritizations for a VR-based serious game aimed at ABI patients. The characteristics are what should be reasonable to expect from a minimum viable product.

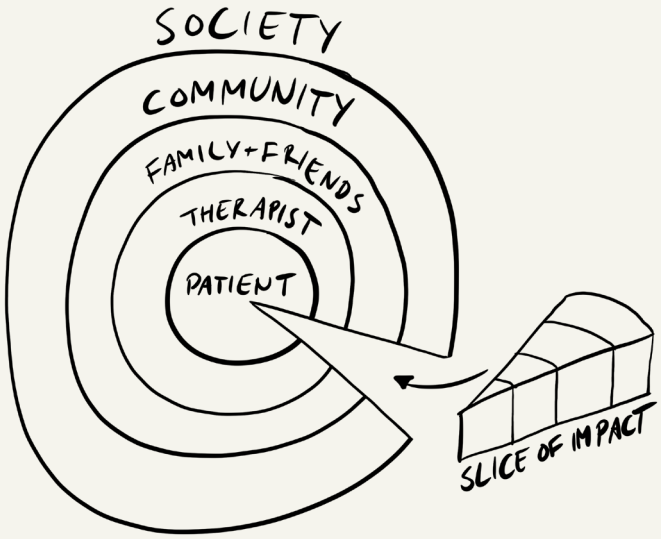


Figure 15: How can a game design solution engage across stakeholders?

Spheres of influence

Subtracting from the complexity of stakeholder interactions was desired to find points of reference for the game itself as well as the system around it. This expanded the scope from the product level to the system level. This made sense because the insights imply a plethora of touch- and pain-points that can form meaningful bonds (Figure 15). By looking at the project as something more than a game design endeavor, more aspects of the patient experience can be improved.

Positioning

Preemptively looking at the solution in light of competitors (or similar products) further narrowed the scope. Seeing what was available on the market was also interesting when comparing it with what therapists had experience with. Games actually being used for ABI rehabilitation, at least in Norway, tend to be less specialized, often landing in the landscape of commercial games played together with therapists. Ease-of-use and enjoyability is a high priority for many of the popular commercial games, both in XR and exergame spaces. Taking cues from specialized and commercial games is a direction that is already prominent. The Wii platform, for instance, has many games that can be used for rehabilitation training. The goal must be to encourage creativity in a space that could leverage the advantages of VR and design approaches with the best aspects of specialized and commercial games. The differential (Figure 16) illustrates the landscape that this goal targets.

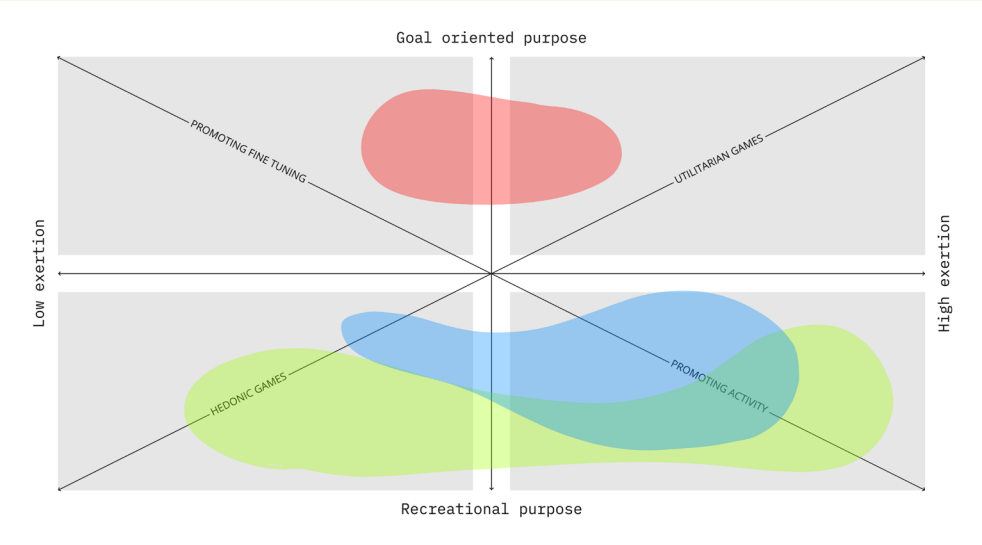


Figure 16: A differential displaying characteristics of games. The red zone is games for rehabilitation. The green zone is consumer grade games. A solution shoulld fall into the blue zone.

Adjustments of scope

Some alterations were made to the scope before transitioning to ideation.

The scope was expanded from TBI patients to ABI patients. The rationale for this was partly due to the struggle of recruiting fitting candidates for interviews. Especially younger people with TBI were difficult to get in touch with. We did not want to design exclusively for a group we had not spoken with. Because the pathologies of ABI patients tend to be similar, we found it relatively unproblematic to make this decision considering the circumstances.

Although MR and AR was included in the literature review, it was decided to focus fully on VR development. AR and MR is more common in some industries for applications like manufacturing and inspection. We did not have easy access to AR and MR hardware, and no experience developing for it. Therefore, VR was chosen as the prioritized technology.

Methodology

The literature review indicated that the research on specialized games for rehabilitation is riddled with normative impositions. Guidelines and requirements weigh heavily on the development process, and rightly so – specialized games should fulfill rehabilitation goals at the level of conventional therapy. Design as a practice is an entirely different endeavor compared to the strict frameworks and methods of clinical and scientific research. It skews more towards social studies, is exploratory in nature, and research questions are continually redefined. It renders replicability nearly impossible but can produce a replicable process that potentially can be replicated by other agents. We wanted to explore how the process itself could be developed as a product, and how this would compare to established guidelines and requirements.

Ideation

Going into an divergent design phase meant opting for methods to generate a large number of ideas. The value of formal brainstorming for this purpose is debated. While some denounce the practice as an idea-generating tool (Gray et al., 2005), others claim that well-conducted sessions can produce good concepts (Fullerton, 2014). We chose an adapted method, combining formal group sessions and individual spin-offs sketching to exploit the benefits of both structured and unstructured forms of ideation.

The insights were temporarily put aside while ideating. The “anything goes” mentality required to achieve an appropriate quantity of possible concepts was difficult to merge with requirements from the synthesis. The solution was to constrain ideation using guidelines from research and let ideas crystalize around them. While this distanced the design process from the research question, it felt necessary to abandon the predetermined vision to create novel propositions.

Workshop

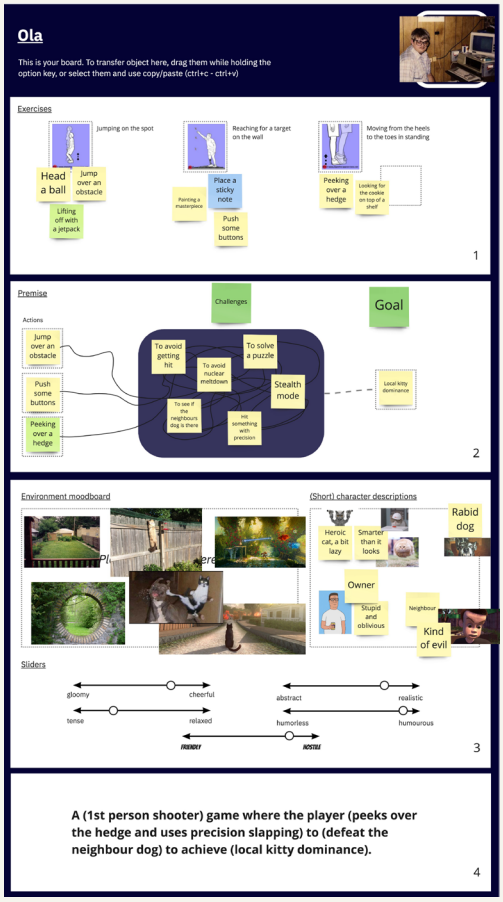


Figure 17: An example player card from the workshops.

Background

We kicked off the ideation phase with two ideation workshops. The objective was twofold: we wanted to gather game concepts for further development or spin-offs, while also testing a game design development framework adapted from an academic paper. The workshops were conducted digitally due to Covid-19 restrictions. Miro, a digital collaboration tool, was selected as optimal for virtual collaboration and ideation, and Microsoft Teams for communications.

Background

The workshop proceedings and flow (Figure 19) followed logical steps of creating game concepts based on incremental developments of different elements: defining movements, relating them to challenges, defining an environment, and finally stitching together elements from previous steps to formulate a game premise. The steps were an adaptation of a proposed method for designing effective and safe therapeutic exergames (Figure 18, Pirovano et al., 2016). In theory and practice, this method does not account for any VR elements. Although this was explained in the workshop introduction, having VR as a constraint or explicit consideration was not desirable – the translation of basic therapeutic exercises to concrete game concepts would more likely provide multiple avenues to explore. The final stage of the method described

in the paper was also omitted from the workshop. The purpose of this stage is to introduce control mechanisms to encourage correction of erroneous exercise execution, for example, a feedback loop prompting the player to adjust their centre of gravity if they lean too far left. We regarded this as requiring some sort of relevant competence in movement elicitation, either through experience as a therapist or with a real-time feedback algorithm developed with this purpose. Therefore, it could be confusing for the workshop participants. Finding analogies between therapeutic exercise and game action was the most important takeaway from the design method.

Participants

The participants were drafted from two groups: research staff in related fields, and students at the university. Notably, patients and therapists were left out as possible participants. For one, both of these groups would have been difficult to gather for a two-hour long session. Patients had shown not only to be difficult to recruit but could also cause trouble if their capacity was not taken into account. Therapists were excluded because of possible dilution of the key objectives. A potential hazard was that their experience and preconceived notions of what therapeutic games should be would lead to a bias towards realistic, unimaginative game concepts. Research staff in relevant fields could be prone to the same issue but are more distanced from the everyday interaction with ABI treatment. Students, on the other hand, were appealing because they lacked this exact experience. They were also relatively easy to recruit.

Proceedings

Two digital workshops were carried out with a total of nine participants. Both workshops went a little past the scheduled time. In general, the exercises were understandable, had a logical flow, and there were few interruptions. The action shifted between an instructional deck and a set of “player” cards (Figure 17), representing work areas where participants had individual tasks and could collaborate on each other’s ideas. Elevator pitches, or short presentations, took place between the majority of exercises to keep participants engaged in each other’s projects. The participants used dot voting to choose one game premise to develop further, filling in their opinions on a range of game traits on a collaboration card. The voting appealed to a competitive aspect, prompting the participants to “sell” their game in a persuasive way.

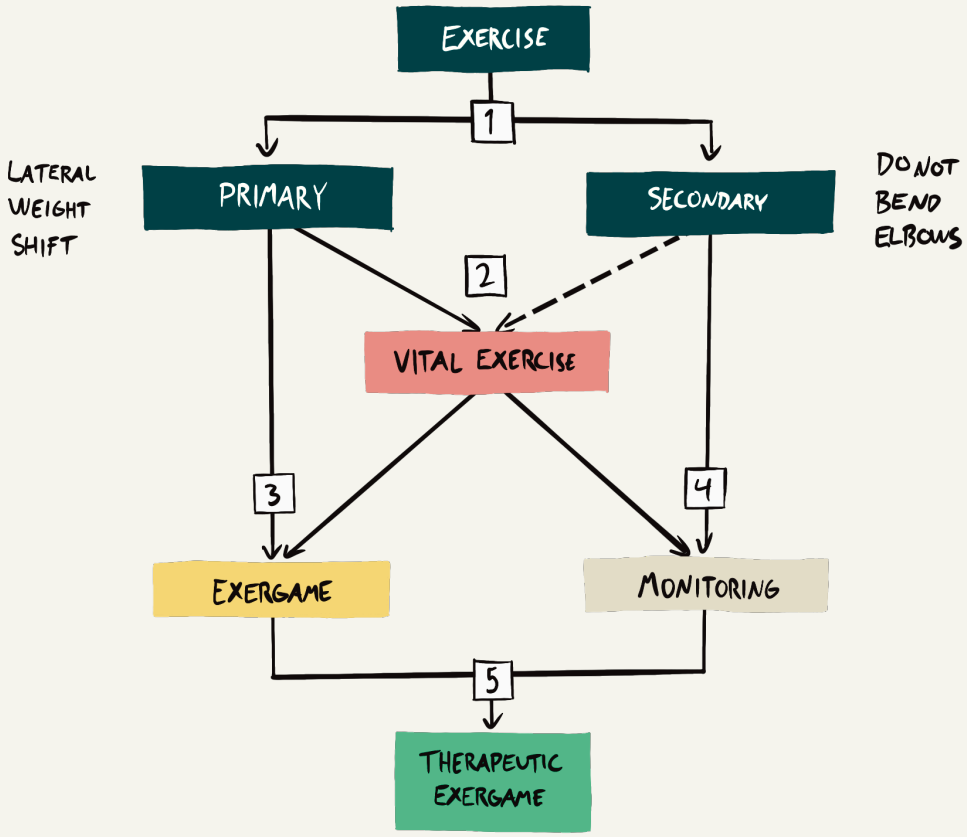


Figure 18: A methodology for the design of effective and safe therapeutic games (Pirovano et al., 2016).

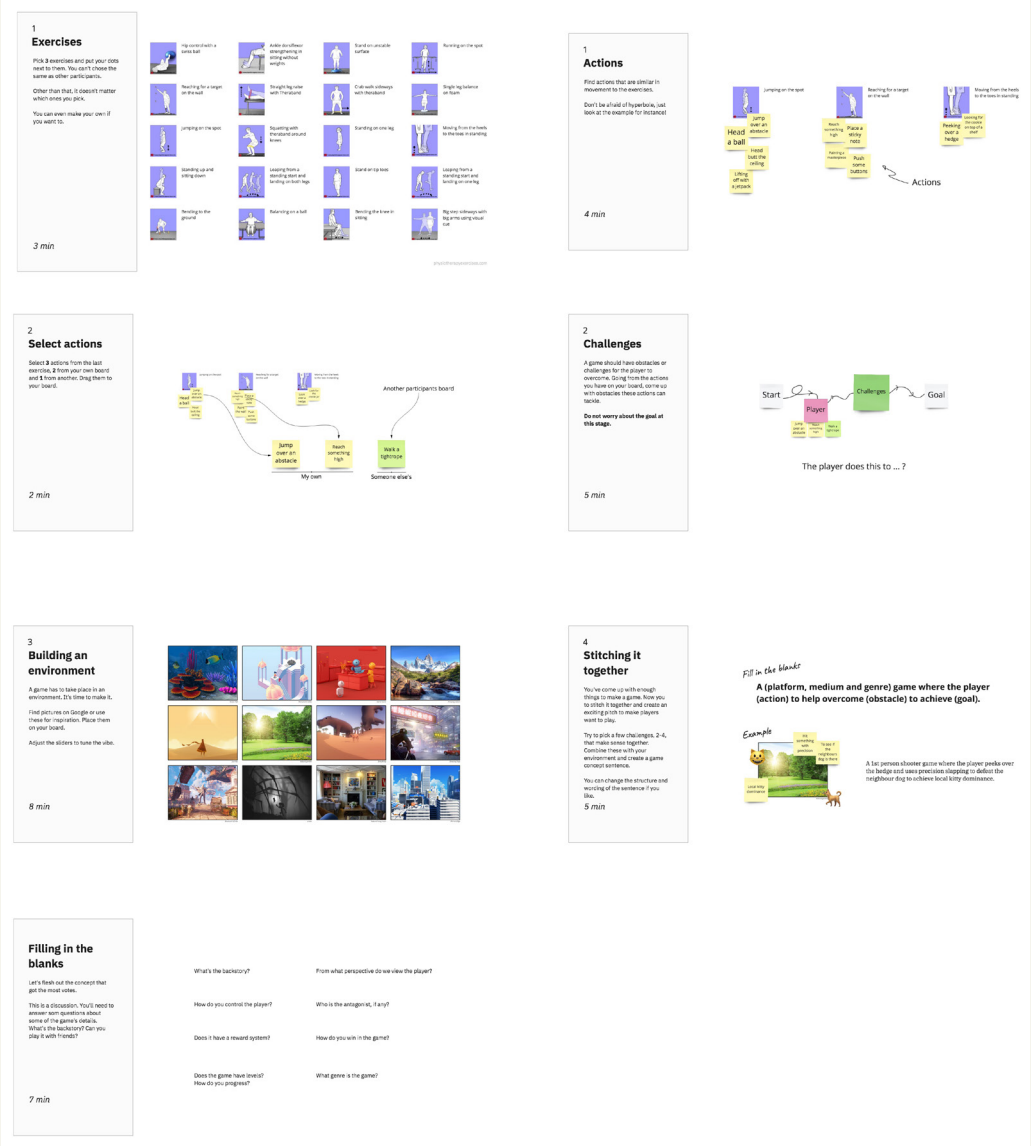
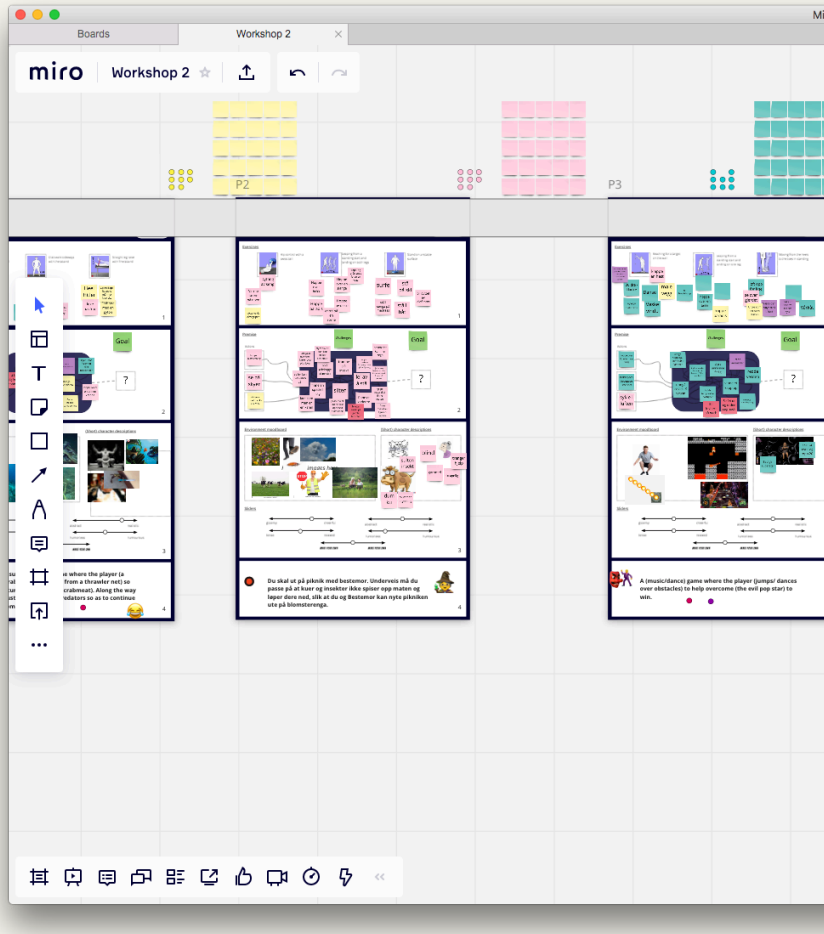


Figure 19: From left to right and downwards, the different activities the workshop containted.



Outcomes

The workshop yielded insights on the provisional game design framework and gave us several concepts to work with (Figure 20). The three-stage flow of selecting exercises, adapting them to in-game movement, and ultimately placing them in a virtual environment proved to be successful in developing ideas rapidly. This success led us to believe that this framework could be expanded and refined, possibly providing a tool for rapid, domain-specific ideation.

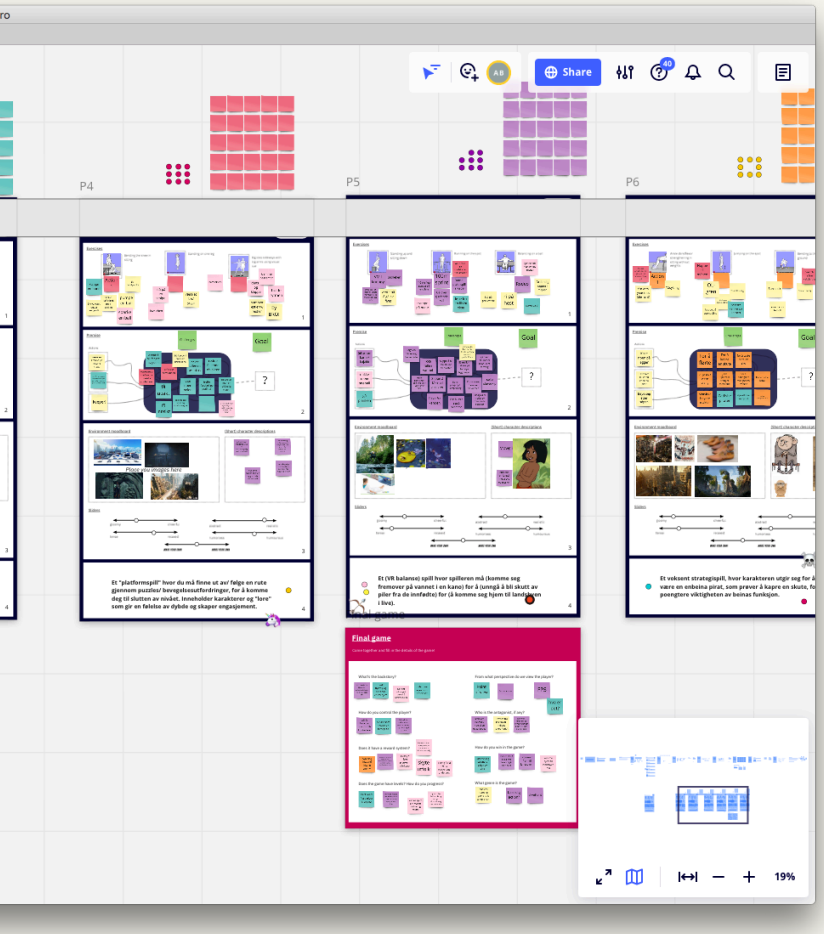


Figure 20: A screenshot from one of the ideation workshops.

Analysis

A caveat of the format was a lack of collaboration between the participants. The collaborative exercises were lauded as engaging and productive in the feedback, but should have been more prominent. The cut-off for the final game also came late, cramming the collaborative process of deciding on game mechanics into a very short session. An in-person workshop could have made collaboration easier. However, the value of focused, solitary ideation was apparent in the quality of each game premise, with lots of variety in the final results.

The final game concepts were generally quite disconnected from the exercises they had been developed from. Because none of the participants had a background in physiotherapy, the regard for therapeutic value was mostly lost in the increasing abstraction between stages. This was both positive and negative. The disconnect certainly separates the concepts from established therapeutic games. In the interviews, the therapists imagined realistic games with emphasis on correct execution. The workshop concepts were more abstract and wild, and made more sense for enjoyable gaming. This is not to say that a disregard for the correct execution of specific exercises is correct or better in any way. We know through the literature study that such games have a proven track record of increased efficacy and motivation. Many therapists mentioned the possibility of regressive execution – that patients, if left unchecked, will develop counterproductive movement patterns. The framework around the workshop concepts would have to incorporate such checks. This was also the omitted step of the original design method the workshops were based on: the analysis and subsequent feedback on the correctness of motion (Pirovano et al., 2016).

Two game concepts – the ones with the most votes – were selected to carry on working with.

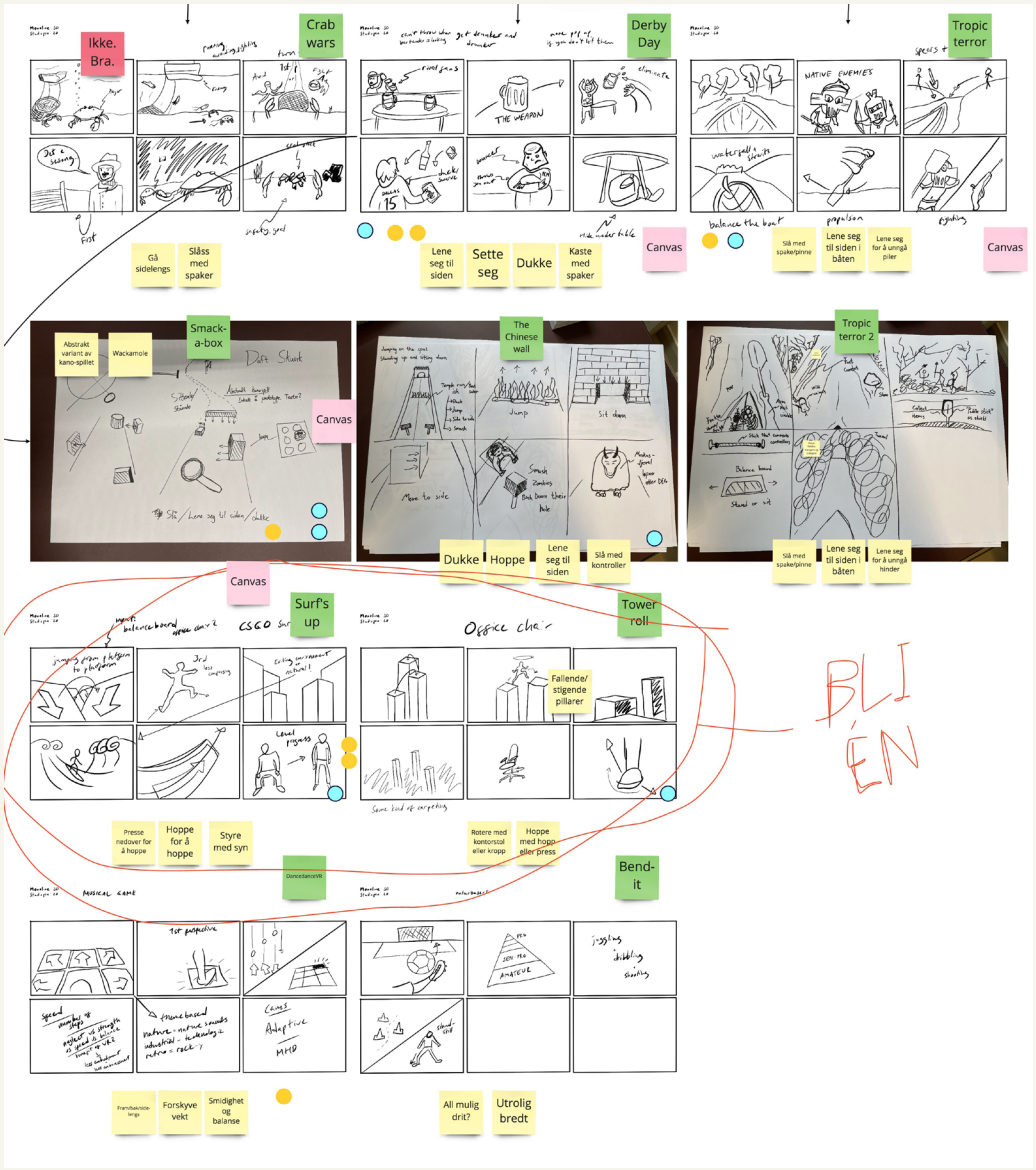


Figure 21: Result of a quick sketching session. It is not pretty, but it does the job.

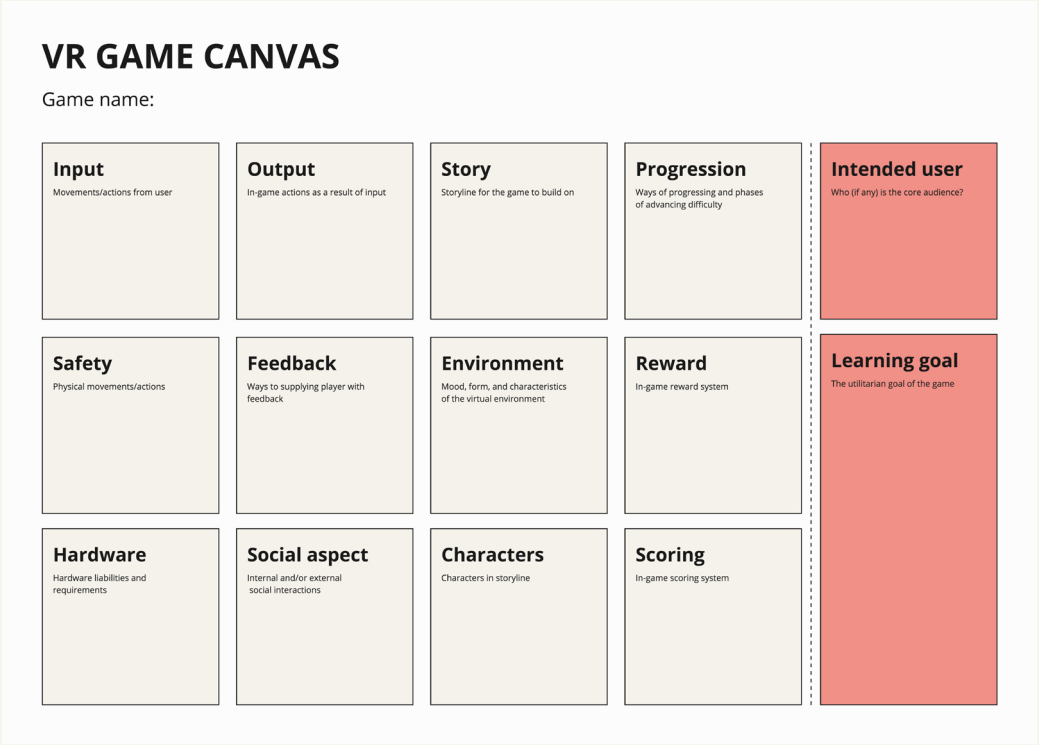


Figure 22: The VR game canvas.

Concept development

We went through another phase of ideation to exhaust possibilities of spin-offs and additional ideas to complement the workshop concepts. Multiple quick sketching sessions produced 10 rough draft storyboards (Figure 21). Some of these were combined to eliminate overlap and redundancy. During a final dot voting session, all but four draft concepts were discarded (Figure 23). The purpose of this filtering was the expected timeframe for prototyping and perceived therapeutic value.

A game canvas (Figure 22) was created as an ad hoc mapping tool to keep track of concept characteristics. The canvas took inspiration from related, accessible examples (Appendix BN). Segments from these were filtered and grouped to create a synthesis suited to our needs. Since we found no examples of templates handling VR elements, this required creating fields to detail novel inputs and outputs controlling player actions with VR hardware. Other fields were added as needed on discovery of necessary requirements for low and high fidelity prototyping. Ultimately, a “serious” element was added, specifying learning goals and intended users.

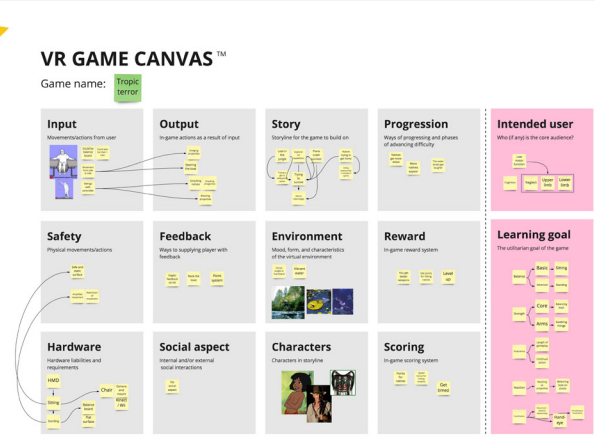
Concepts

From four completed game canvases, two went on to be detailed with storyboarding, moodboards and movement elicitation illustrations.

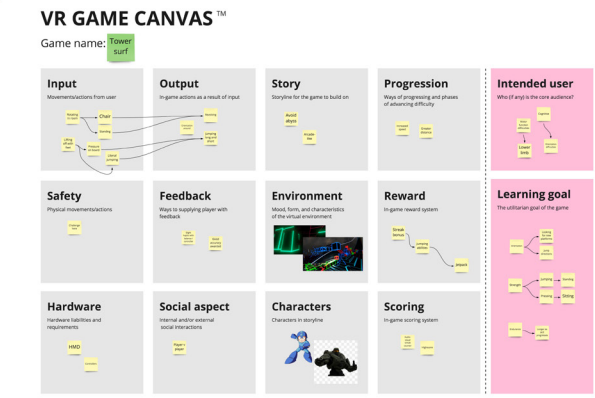
Concept 1: Derby Day

Concept 2: Smack-a-Box

Figure 23: Completed game canvases with concepts.

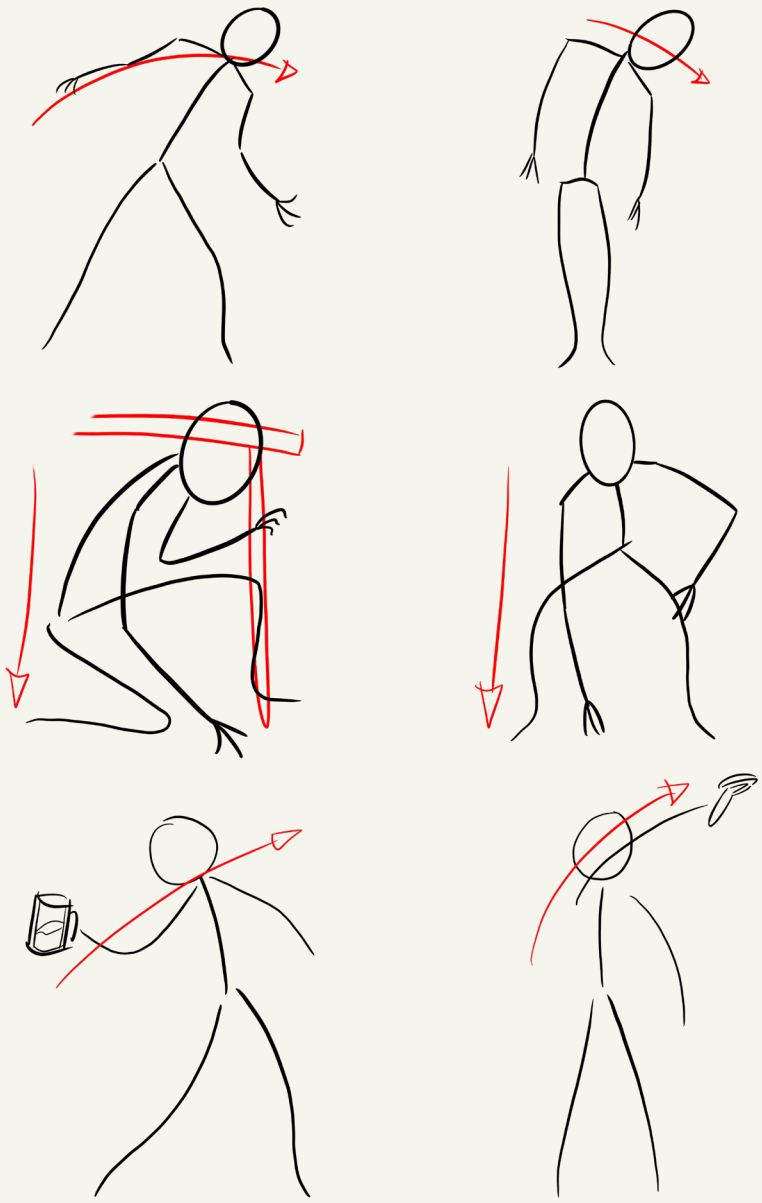


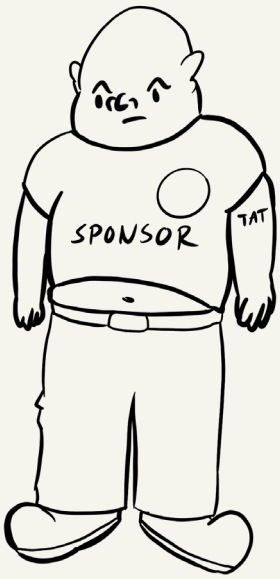
Concept 3: Tropic Terror

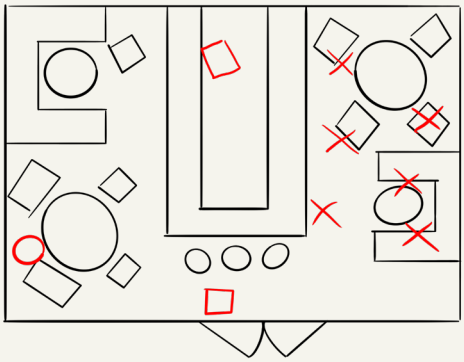


Concept 2: Tower Surf

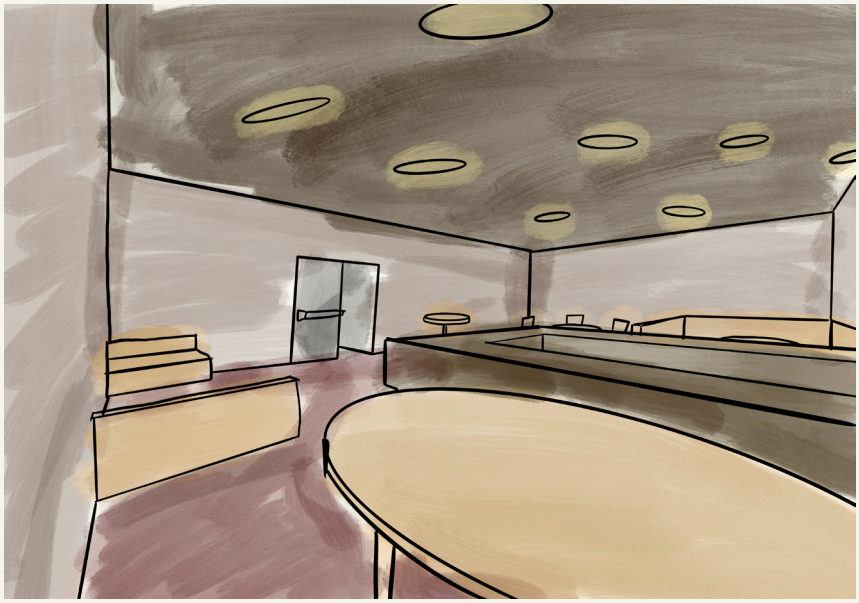
Sketches

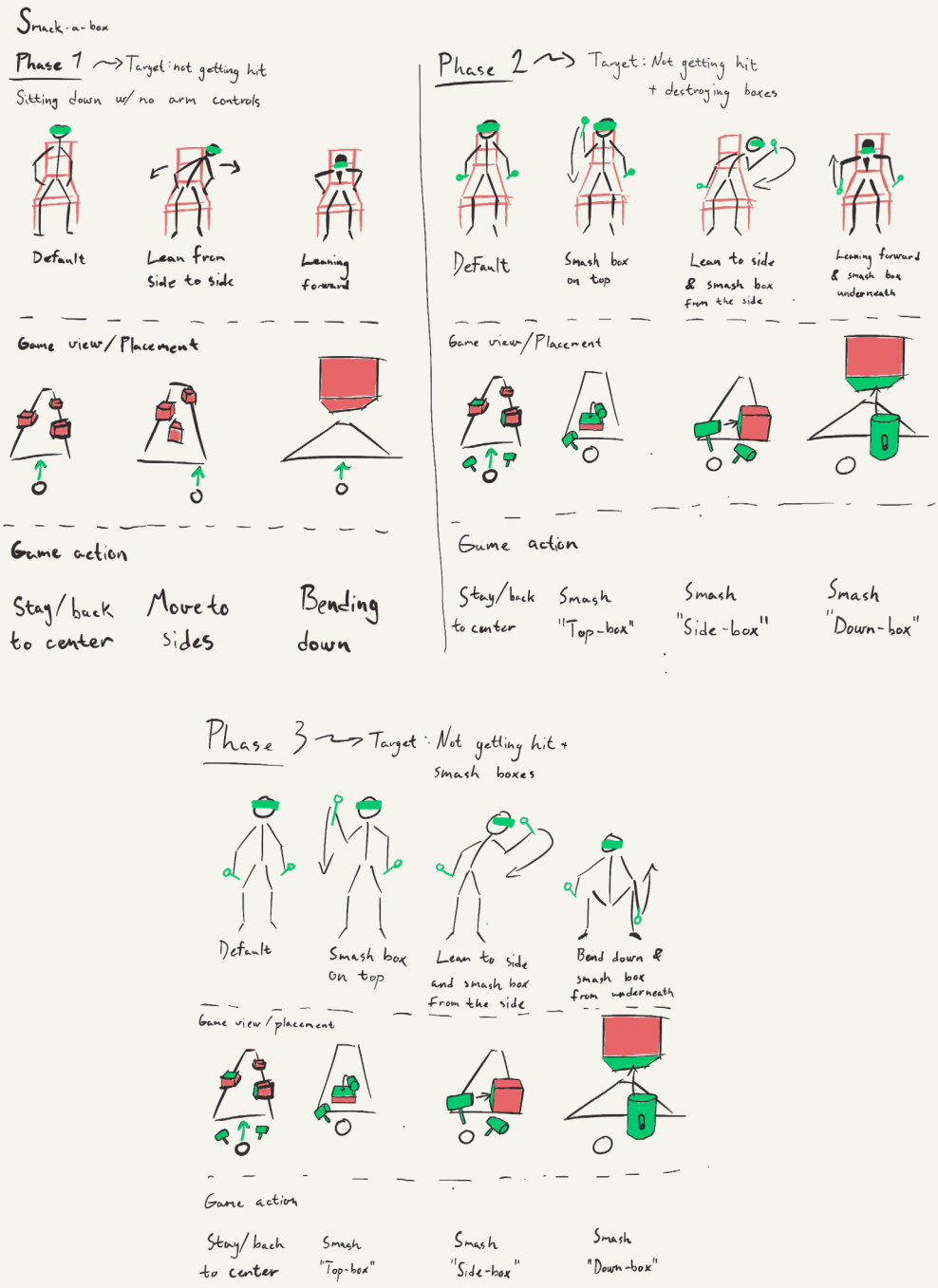


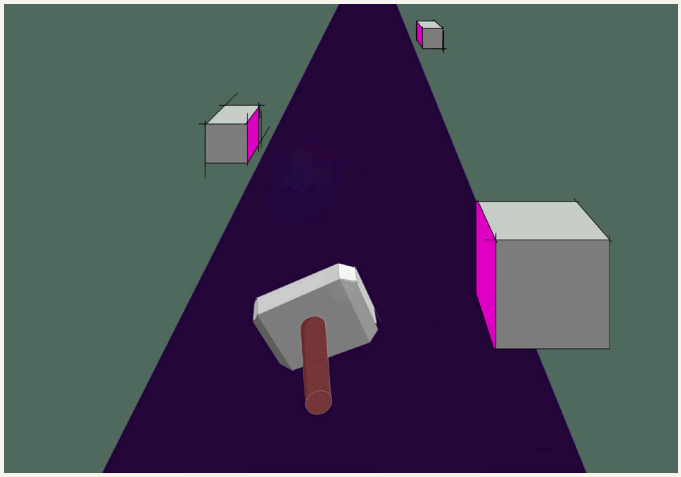


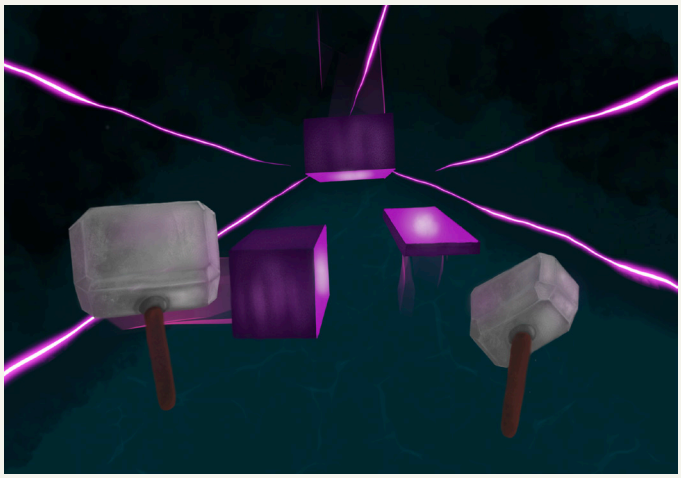


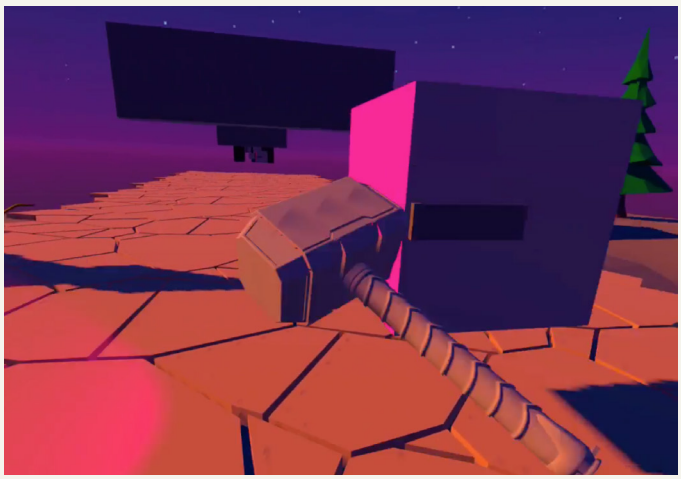
Concept and movement elicitation illustrations from a sketching session for the Derby Day game.




Smack-a-box
Phase 1 → Target: not getting hit
Sitting down w/ no arm controls
Default
Lean from side to side
Leaning forward
Game view/Placement
Game action
Stay/back to center
Move to sides
Bending down
Phase 2 → Target: Not getting hit + destroying boxes
Default
Smash box on top
Lean to side & smash box from the side
Leaning forward & smash box underneath
Game view/Placement
Game action
Stay/back to center
Smash "Top-box"
Smash "Side-box"
Smash "Down-box"
Phase 3 → Target: Not getting hit + smash boxes
Default
Smash box on top
Lean to side and smash box from the side
Bend down & smash box from underneath
Game view/placement
Game action
Stay/back to center
Smash "Top-box"
Smash "Side-box"
Smash "Down-box"







Concept and movement elicitation illustrations from a sketching session for the Smack-a-Box (now Daft Skunk) game.

Build

Game development

Prototyping is vital to any iterative design process – cutting losses and validating ideas early allows the designer to stake out a path using as few resources as possible (primarily time and money) while continuously building communicative tools to keep stakeholders in the loop (Sharp et al., 2019). In game design, build-and-test loops are an incremental process aimed at adding and refining game elements sequentially (Fullerton, 2014), starting with basic game mechanics, supplementing with artistic components, and so on (Figure 24).

Because the working hypotheses implicated aiming for an exercise-to-game pipeline of a few days, the phase would also serve as a test run to establish a benchmark for rapid game prototyping as a cog in a larger framework. Due to the proliferation of fast prototyping and development tools, the lines between low- and high fidelity prototypes are blurring. Digital solutions are knocking on the door, potentially rendering sketching by hand obsolete in the near future. The transition from sketch to development without any low-fidelity prototype in between should serve as a litmus test for the paradigm shift as manifested in our process.

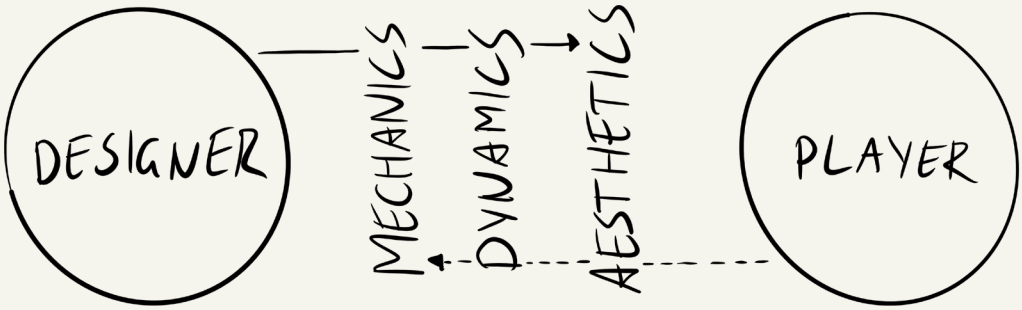


Figure 24: The MDA model for game design is a common way to define the iterative process.

One concept was selected for development. The rationale for this was the prospect of achieving a testable game quickly, which was more realistic building an environment with less necessary assets. A block-based, abstract game could simply be built in less time and would be easier to test at an early stage. The objective of this prototype was to investigate the fulfilment of movement elicitation requirements, the enjoyability of the concept, and the feasibility of short spurt VR game development as a design method. For this process, we got together with a developer who could assist with the build.

The game was a one-day-build in Unity 3D. We used Unity's XR SDK framework with freely available assets, music, and sound effects. Although HTC Vive was considered as the HMD of choice early on, an Oculus Quest 2 was used for prototyping. It is more lightweight, uncomplicated to operate, and cheaper. The prototype was finished in three hours.

Takeaways

One therapist and one patient were introduced to the game concept and prototype. They were asked to give first impressions of the prototype and were shown immersive and real-world footage from gameplay. From earlier interviews, we knew the selected individuals were ahead of their peers in their knowledge of VR and would be able to provide much more succinct feedback regarding envisioned use. This would also help us identify obvious flaws and dearly needed supplements. An elaboration on the surrounding framework – an additional system design component to create new games – of the game was discussed.

On seeing the prototype in use, the therapist and patient remarked its striking similarity to a popular commercial alternative, Beat Saber (Figure 25). Although this issue had been raised before the introduction of fresh eyes, it was interesting to see an immediate recognition of key game mechanics being recognized. The remark brought on further notions of what the commercial game might be missing.

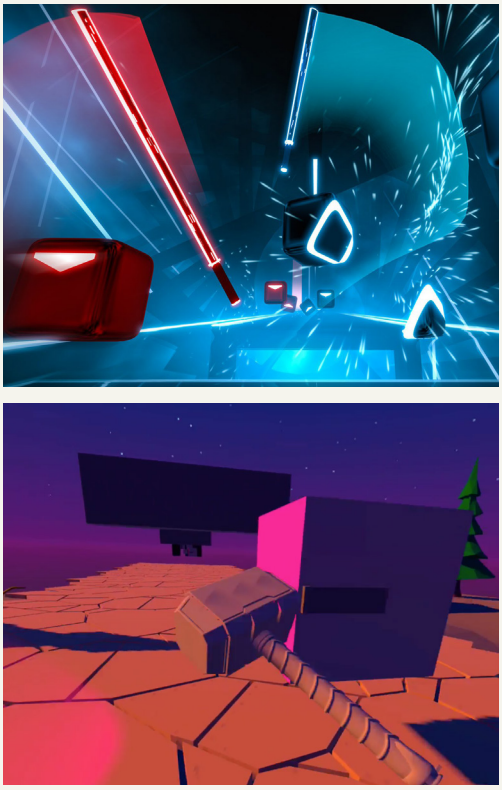


Figure 25: Beat Saber (top) and the prototype (bottom).

In-game feedback

Feedback is essential to enable players to interact with the game and have fun doing it. It adds understanding and meaning to the experience (Suter et al., 2018). Establishing feedback mechanisms and loops through visual, audio, or haptic output lets the player reevaluate states and conditions, furthermore giving them the incentive to act and adapt. In unsupervised, goal-oriented exergames where precise movement elicitation matters, the success of the game itself can rest on the feedback loop it is built on.

The prototype displayed basic elements of feedback, but they were difficult to convey through a video conversation. The patient thought the introduction of haptic and visual feedback to a greater extent would benefit the overall playability. He also missed more feedback for success and failure that is evident in Beat Saber and other games he had tried. In both games he felt better visual and haptic feedback could be implemented. Improving these aspects would be the next logical steps in the design process.

Introducing a reward system was also desirable. This was strongly indicated in the preliminary interviews, where experiences with elders and exergames showed that rewards were effective as encouragement, and to an extent, regardless of how arbitrary they were in the gameplay. The therapist agreed with this. A good reward system can support self-evaluation and work with progression systems to create a holistic feeling of advancement. In the case of our prototype, a couple of solutions had been discussed, like streak bonuses and new levels and environments.

The experience of reward, however, is triggered by the release of dopamine. Our brain gets used to an elevated level of dopamine and needs more and more over time to achieve the same feeling of satisfaction (Wickens et al., 2003). The outcome of this is that timely, clear and meaningful feedback proves essential for the understanding and interaction of the game but rewards can be somewhat limited in the long run.

Instructions

Instructions on how to play a game should be clear and unambiguous. In therapist interviews and during the presentation of the prototype, there was a consensus that a game for rehabilitation should have a thorough onboarding with examples of movement elicitation for patients to follow. Such an element works towards encouraging correct movements and reducing possible confusion. A realistic representation of the player themselves would replicate the mindset physiotherapists have where they show the patients concrete examples instead of simply telling them how. Still, it must be engaging to go through – if it takes too long to play or results in a loss of concentration, the motivational aspect can be compromised. An informative and user-friendly onboarding was highlighted by both patient and therapist as a goal to increase the value of the game.

Results

Game development framework

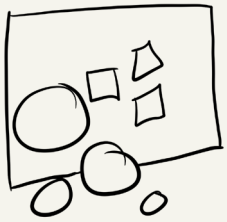
1

From the analysis of the insights gathered, we claim that value can be created with a standardized design process. As opposed to a polished and marketable game concept, a guidance framework for stakeholders can be reused, improved and streamlined, or merged with existing initiatives. By giving users ownership of the process, they can engage existing resources and approach new ones with a detailed task brief.

We propose a game design framework for developing serious games for rehabilitation (Figure 26). The advantages of this framework are that it facilitates continuous stakeholder involvement, fun and interactive co-creation, fast development and implementation, and the creation of useful products that encourage better rehabilitation. It consists of five stages in a design sprint that can be adapted in length and scope to fit the owners' wishes and needs.

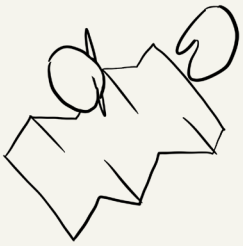
While the delivery resembles earlier attempts to develop frameworks for designing home-based rehabilitation systems (Egglestone et al., 2009) and therapeutic exergames (Pirovano et al., 2016), it is a holistic view on the matter, prioritizing flexibility and adaptability. Additionally, any stakeholder can initiate the process and ownership is distributed between participants.

Patients and physios at rehab clinic want to try VR exergames. They decide on a set of exercises they think are boring in the first place. They reach out to the municipality who puts them in contact with the student organization for informatics at the local college.



The students conduct parallel workshops with the patients and therapists at the clinic and are left with game concepts based on the exercises.

The students get to work on the details and end up with a handful of ideas they want to prototype.



The study organization hosts a hackathon where students and developers create prototypes.

The clinic invites everyone to a game day where patients, therapists, and relatives can try all the prototypes and give feedback and propositions. The patients and therapists get to see their ideas come to life. The therapists evaluate the movement sequences and if they align with the exercises they decided on.

Depending on the potential of the game, it either grows to an independent project – commercial, academic, or volunteer – or is discarded.

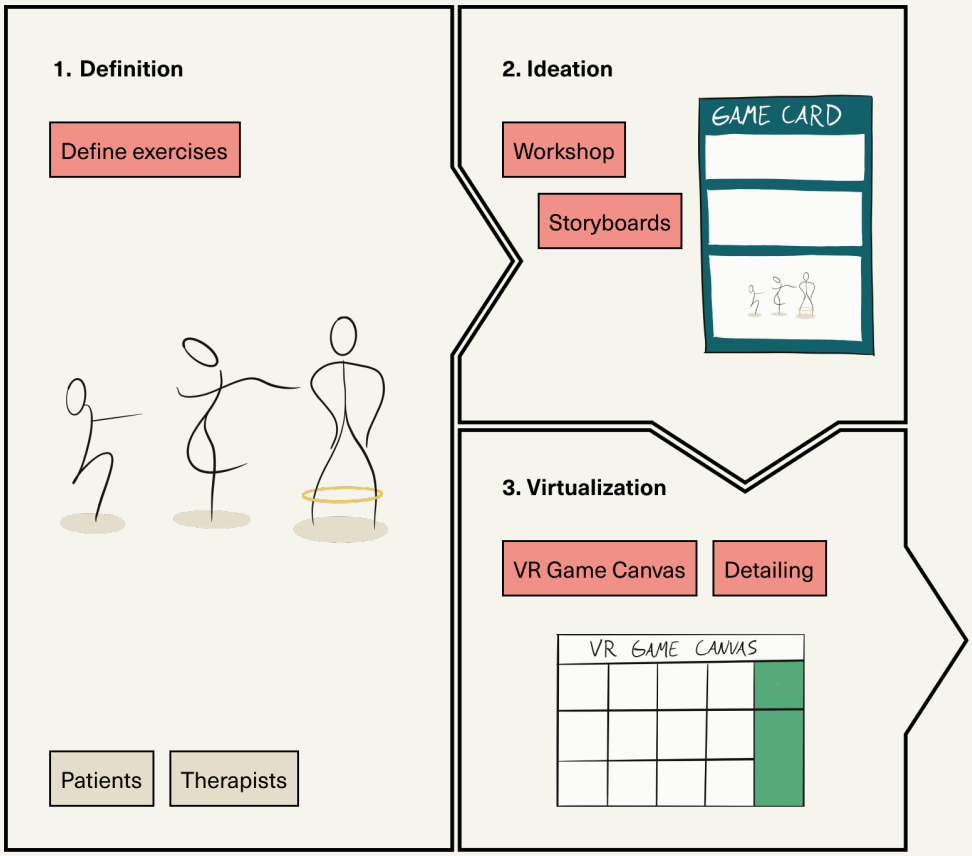
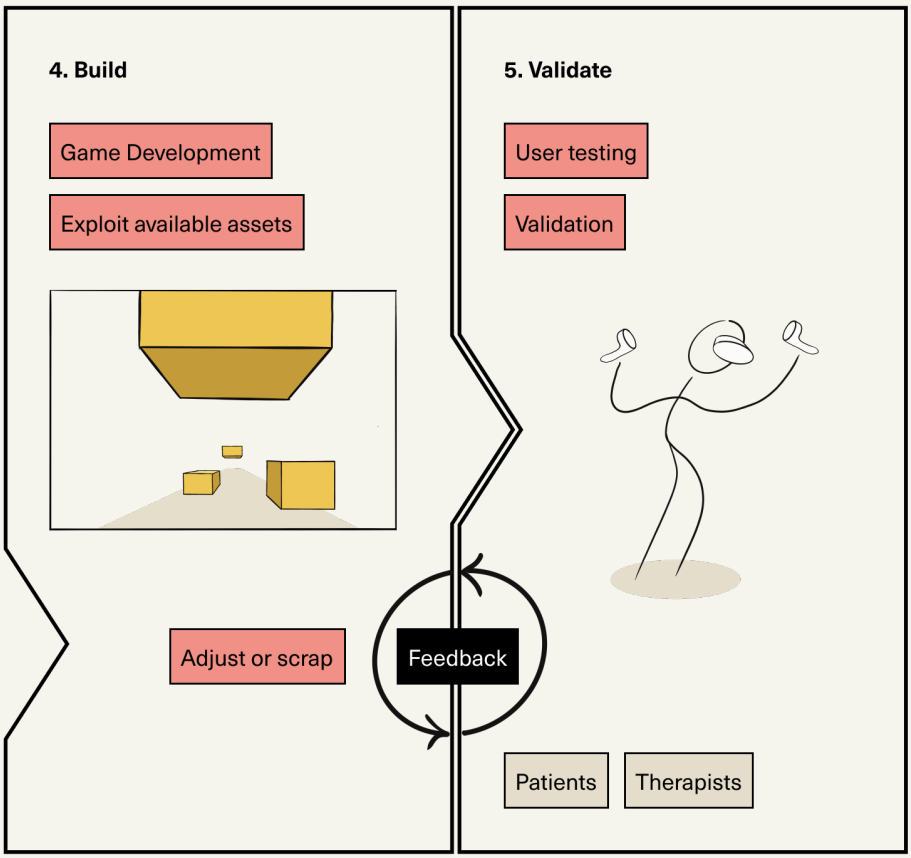


Figure 26: The game design framework exemplified with Daft Punk.


4. Build
Game Development
Exploit available assets
Adjust or scrap
Feedback
5. Validate
User testing
Validation
Patients
Therapists

Stakeholder involvement

The framework engages several stakeholders in the process. Ownership and organizational responsibility is decided by the involved or the initiative taker. Clinics, hospitals, or rehabilitation centres for people undergoing rehabilitation can lay the groundwork by discussing which activities and exercises they want to explore and redefine. Public or private organizations and institutes affiliated with the health facility can connect with resource clusters – companies, schools, clubs and associations, or similar institutions – to gather necessary skills. Alternatively, the exact opposite can happen. Groups or individuals with technical competency can reach out to health facilities directly or indirectly, and introduce them to the process.

The stakeholder involvement (Figure 27) map shows a two-way relationship, with the possibility to involve a host of different intermediators. The process also forms stronger bonds between health facilities and academic institutions or innovation hubs. Hopefully, this can also create more collaboration and knowledge exchange.

Co-creation

Neither therapists nor patients are necessary to complete all stages of the process. However, we believe that inclusion of these groups creates the most interesting dynamic and challenges the developers and designers to empathize and gain an understanding of a new field. There is also great value in patients getting to see their ideas come to life, and getting to feel seen and involved in their treatment.

The practice of co-creation is not straightforward in this case. ABI patients often have difficulties partaking in different social settings because of cognitive dispositions, which can hinder involvement in the early stages. The long duration of the process may also strain their capacity. We would still challenge facilitators in the process to involve patients as much as possible. The insights emphasizes that ownership and inclusion is a motivator in rehabilitation, and should be considered one of the main benefits of such a framework.

Development

The development process in the framework is flexible. While it is possible to merge the process with, for example, a course in game design where game development is narrow in scope and focused on quality, an iterative process with a rapid prototyping mindset is suggested. This lets developers test fundamental mechanics quickly and improve or discard ideas. In general, no more than two to three days should be used to build any game prototype. If basic game mechanics and concepts cannot be

The development process in the framework is flexible. While it is possible to merge the process with, for example, a course in game design where game development is narrow in scope and focused on quality, an iterative process with a rapid prototyping mindset is suggested. This lets developers test fundamental mechanics quickly and improve or discard ideas. In general, no more than two to three days should be used to build any game prototype. If basic game mechanics and concepts cannot be implemented within this time they are probably too complex. However, user testing with patients should be conducted with a high-fidelity prototype. Major bugs and inconsistencies should be intercepted early on and fixed before reuniting the stakeholders for further stages.

Our concept and prototype show that with an effective development environment, a good XR interaction kit, and heaps of free assets, basic prototype development is realistically doable in hours rather than days. If developers are unfamiliar with XR-specific game development, a longer time frame is more suitable.

Useful products

The outcome and value of the framework is to produce many drafts for games. This aligns with a principle of quantity before quality. A wide range of ideas and prototypes to compare will help to make decisions on which games to abandon at an early stage, allowing them to fail fast and often. Rapid development is benefited by spending less time on potentially pointless ventures.

The validation stage and reinclusion of therapists into later stages ensure that the games fulfil exercise goals and are useful for patients. If testing reveals that the game mechanics induce unproductive or dangerous movements, this must be changed, or the concept discarded. An argument against including therapists in the ideation stage is that it can stunt daring concepts due to inherent biases and a clinical mindset. The therapist inclusion, therefore, has to be considered at an individual level.

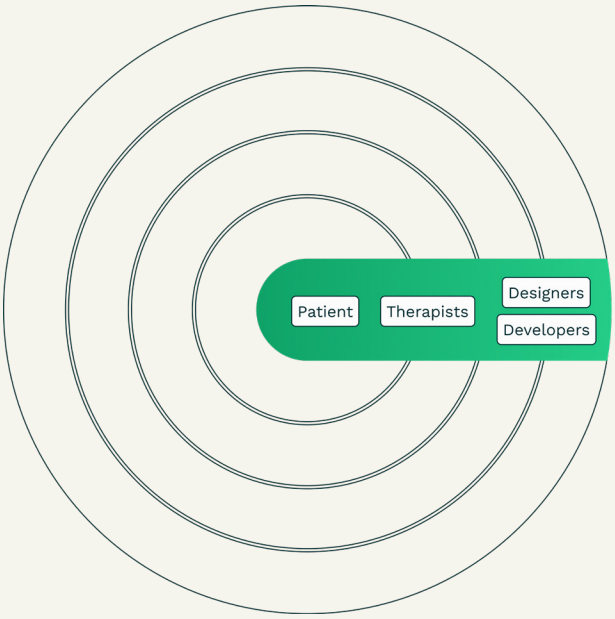
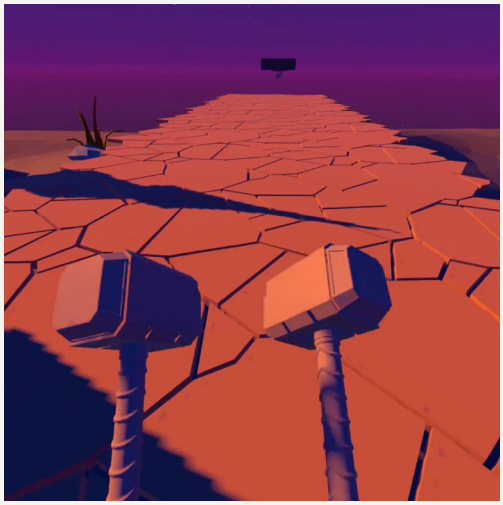


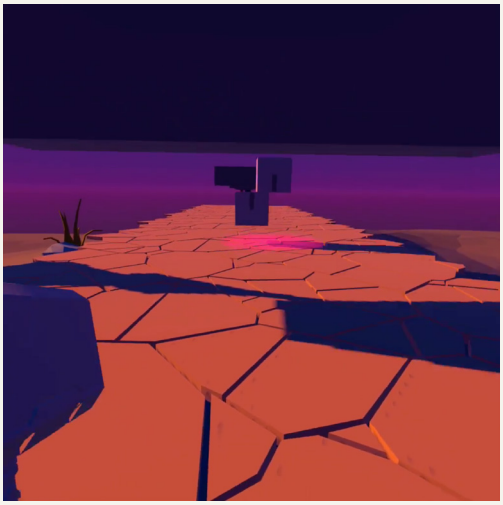
Figure 27: Where in the ecosystem the framework engages stakeholders.

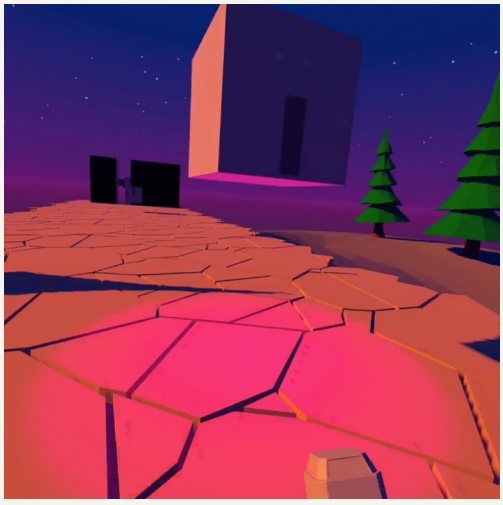
> *T4: On the framework you mention. I like the thought of combining technology, health workers and patients. We obviously don't know how to make games, but we know what's good for the patient. If the game's quick to make, the costs could be relatively low too. You can have a set of movements to build the games around.*

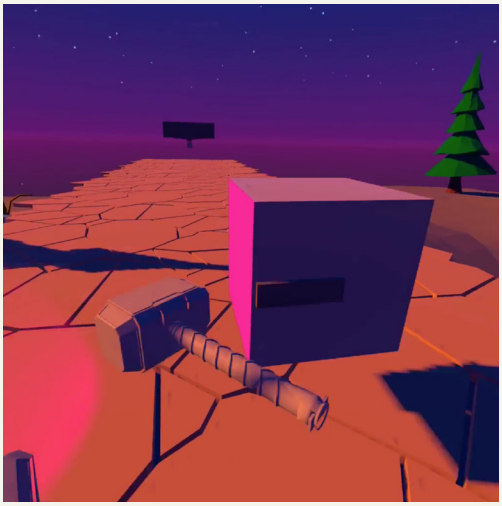
Game concept

2 Going through the game design framework produced one testable prototype.









> *T3: The first thing that comes up is challenging their gait, doing things while walking. Like watching out for hurdles, looking to the side, that type of activity. I think that could work very well. Training attention, reaction, balance. It would be fun if you could create a reality on a treadmill where you include other elements than just walking.*

Link to live gamplay is in the appendix, on page H.

Discussion

This thesis started with a research question: how VR-based serious games can play a part in home rehabilitation for lower limb function, and how this can be incorporated into the rehabilitation ecosystem. The delivery answers the initial research question to an extent, but the shift of focus towards underlying needs is based on the insights. While the shift is significant, it is not unexpected. The choice of semi-structured interviews with user groups as the main tool for insight work steered the project away from the isolated product design path early on. We also designed novel methods for ideating and developing game concepts from physiotherapeutic exercises. The results – the game concept, framework, and underlying requirements – address real issues uncovered while studying the subject matter, and are in line with the explorative design study method. We argue that the delivery could be valuable for other research and actual implementation in the future.

Approach

In comparison with the research reviewed, the thesis takes a tangible approach to the research question. Instead of starting at the beginning, design methodology lets the researcher step back and reconsider the problem itself. Had we not followed this approach, the focus of the delivery would likely be more centred around movement elicitation requirements, comparative

efficacy, and pure interaction design. Efficacy and precise movement elicitation is very present in the interviews, but did not stand out as the most pressing issue in the ecosystem. Considerations regarding efficacy are still represented in the development framework we propose, but are less explicit than what the guidelines and methods detailed in the literature review propose.

Limitations

The study has limitations that reduce its applicability as a definite work. The game concept lacks some key elements we claim to be necessary for a VR-based serious game for rehabilitation. It does not provide sufficient feedback on execution or achievements. For it to be interesting and engaging, the implementation of progress mechanisms and/or level systems is also needed. Finally, it has not been clinically tested.

The game development framework also remains untested in a system setting. Additional stakeholder involvement is needed to validate the feasibility and desirability. It follows that the role of the facilitator also would have to be clarified.

With regards to interview participants, the planned number was not achieved. Only three patients were interviewed, and they had very similar characteristics in terms of age, gender, and pathology. We believe this is the biggest caveat from a HCD perspective. Additionally, there were no participants on the carer side that worked with ambulant teams (going to patients' homes), leading to little testimony on the home settings. The municipality would have been able to provide this expertise.

We argue that the process and product delivered has proven its activating effect to an extent. However, it is far away from being a substitute or even supplement to conventional physiotherapy. It remains to be seen how patients interact with the game in clinical and home settings. The professional judgment of therapists observing gameplay over longer periods will also provide definitive results.

Workshop

The workshops separate the thesis from other research in the field by arguing the value of multi-stakeholder co-design in the field. From before we had seen workshops being used to ideate with patients and others (Ishoel & Kanstad, 2017) . In the literature review there are also examples of workshops and focus groups with therapists, relatives, and patients focusing on sentiment discovery (Egglestone et al., 2009). The thesis proposal is novel in linking physiotherapy and game ideation in the context of a larger framework.

Choosing to omit patients and therapists in the thesis walkthroughs was necessary to mediate time and resources. After the fact, it can confidently be asserted that physical, at-location workshops would work better with the target users.

The exact translation between real exercises and in-game movements was not stressed during the workshops. This raised the concern that the games would not sufficiently reflect productive movement, which is the biggest caveat of the format. Looking at and testing the two final concepts and prototyping one leads us to believe this concern is somewhat exaggerated. If the purpose of the ideation and the game was to achieve exact parity of actual exercise movement and gaming movement, there would be more cause for concern. However, the goal was to find abstractions and analogies for the exercises to be able to build enticing premises around them. Testing the game proves that the one concept that made it through the entire process produces favorable, if not very precise, movement elicitation. In this way, we stand by the statement that the workshop format adds value to the framework and as a standalone template.

Other guidelines and frameworks have been proposed to assist in the development of serious games for rehabilitation and maintenance of motor and cognitive functions. These pertain to exergames for rehabilitation and elders for the most part. The thesis differs on several points. The framework tries to be as concise and clear as possible, containing a few, concrete steps to create games. Of course, it can do this partly because it demands less in terms of clinical accuracy. It is also wide-reaching, including multiple stakeholders and gives an idea where and why they are included. Essentially, the framework fulfills a different purpose altogether. Some research outlines a handful of basic principles (Egglestone et al., 2009), others well over a hundred (Subramanian et al., 2020). They are important and serve their own purpose, as back-of-the-mind motifs, or heuristic evaluators. What the thesis describes is closer to a handbook or canvas.

Genres and mental well being

When ideating and creating games, we noticed early on that some genres and themes were being left out. The workshop premise led mostly to action-packed, dynamic games. Themes like adventure, exploration, and artistic expression were absent. While this was adequate in the scope, it failed to comply with a wish discovered in dialogue with patients and therapists. Many of them liked the idea of “roaming” games, where the environment in itself is a source of gratification. This is

a gap in both the literature review and the competitor analysis. We hypothesise that these kinds of games can have therapeutic value in rehabilitation.

The cognitive effects of ABI are well documented and in many cases severe. Hearing stories from the patients opened our eyes to a related issue, not necessarily caused by these effects, but amplified. In all cases some sort of toll had been taken with regards to mental health, adding insult to somatic injury. These effects were isolated to early phases in some cases, and never went away for others. An ocean of feelings can manifest themselves during the months and years following injury. Oftentimes they stem from concoctions of clinical and circumstantial factors, for example having sudden outbursts of anger or sadness caused by the brain injury, while being isolated and lonely because of immobility and a sedative state. Social interactions can help with this. Looking forward to clinic stays had motivated one patient through hard times. Another found solace in their spouse. But these are not available at all times and for everyone. Supplying this through gaming is a possibility.

There has been research highlighting the potential for games and online interventions for mental health (Fleming et al., 2016). Although it is scarce and real applications are few, the feasibility of translating conventional interventions into game formats is demonstrable. The research calls for “faster iterations, rapid testing, non-traditional collaborations, and user-centered approaches,” (Fleming et al., 2016) coinciding closely with the value proposition this thesis postulates. The potential for mental health interventions are highly interesting for the target group. However, it will be for another study to investigate.

On the topic of using adventure-based, consumer grade games in rehabilitation, physical benefits can be optimized for this purpose by manipulating inputs to better conform with therapeutic practice. It is not inherently difficult to map key functions of movement elicitation to ordinary adventure games. While it requires technical skills, complex tools like omni mills and simple ones like balance boards can be digitally linked to virtual mobility and used for basic activation.

Aspects of other genres: games that facilitate role-playing, collaboration and transactions, building and creating can provide different forms of stimulation that are different from the games we propose.

Conclusion

This thesis sought out to explore and design solutions for VR-based serious games for neurorehabilitation. Through literature review, competition analysis, interviews with therapists and patients, and synthesis of gathered information, new insights were uncovered about several themes. The insights were analyzed and a framework was drafted to continue ideation and game development.

The delivery includes a game concept that was realized as an early prototype, in addition to the refined game design framework. We consider the game to be illustrative of the framework's perks and general flow, maintaining that this process holds value for further academic and possibly commercial work

Further work

Testing

After prototyping game concepts, a necessary stage for a production-ready rehabilitation game is to get raw and unbiased feedback from user tests using VR equipment. This is necessary to better determine if the game serves the intended purpose. A beneficial part of prototyping testable games rapidly is that they can be adjusted fast, or scrapped without remorse based on how it performs in testing.

To reflect today's situation, where VR is not common in every household, the testers should have little to no experience with it. That way it reveals how people without prior knowledge react to the game in a virtual environment.

The main goal of the test would be to observe the movements of the testers, and compare them back to the intended exercises from what the game was built around. This might be one of the most crucial points to see if the game works as planned. Do the testers find input shortcuts where they skip parts of the exercise, or perform other unintended movements?

Other elements that the tests may cover are a feedback loop, intensity, understanding of gameplay, safety concerns, the interaction between input/output and general comments. Testing cards – based on our assumptions of the outcome – can be constructed as preparation for the tests. These cards include a set of hypotheses, how to test them, what will be measured and what needs to happen for the assumptions to be correct (Bland & Osterwalder, 2019).

Technological development

Further development of XR software and hardware will bring about a new age of immersive digital experiences. Increased competition, with more manufacturers and competing products, could push prices down and provide alternatives for more people. Innovative solutions will make HMDs smaller, lighter, add better spatial awareness, and other features to improve the overall usability and fidelity.

AR and MR could become feasible for rehabilitation as developers experiment and the blend of real and virtual environments becomes more seamless. The Microsoft HoloLens has become the market leading MR platform, and Apple has (allegedly) been developing their multiple-use HMD for years. These developments show great promise for the future of XR and will hopefully make the proposed framework more interesting and usable.

This thesis omitted many technologies that could have contributed to innovative solutions.

Motion capture technology is widely used in exergaming, and in its basic forms exist in consumer grade gaming devices like the Kinect and Wii. Complex motion capture is being explored as another way of creating immersive experiences and advanced biofeedback (Sekhavat & Namani, 2018; Vonstad et al., 2020). We cut this possibility short partly due to its complexity and partly because it tends to involve more setup than we were comfortable including in our system.

Electroencephalography (EEG) is a method to capture electrical signals from the brain using sensors on the scalp. Training of mentioned functions like premotor neglect, cognitive capacity, concentration, and emotional development, could be enhanced with EEG feedback. However, it was deemed out-of-scope in our interpretation of the task.

All of the omitted technologies translate between physical and digital information in some way. Machine learning can potentially use this information to evaluate movement elicitation or brain signals to create meaningful interpretations and value for users and carers. It seemed unlikely that we would be able to implement this in such a short time, but should be considered in future work on the user experience and interface.

Reflections

Covid-19 and time management

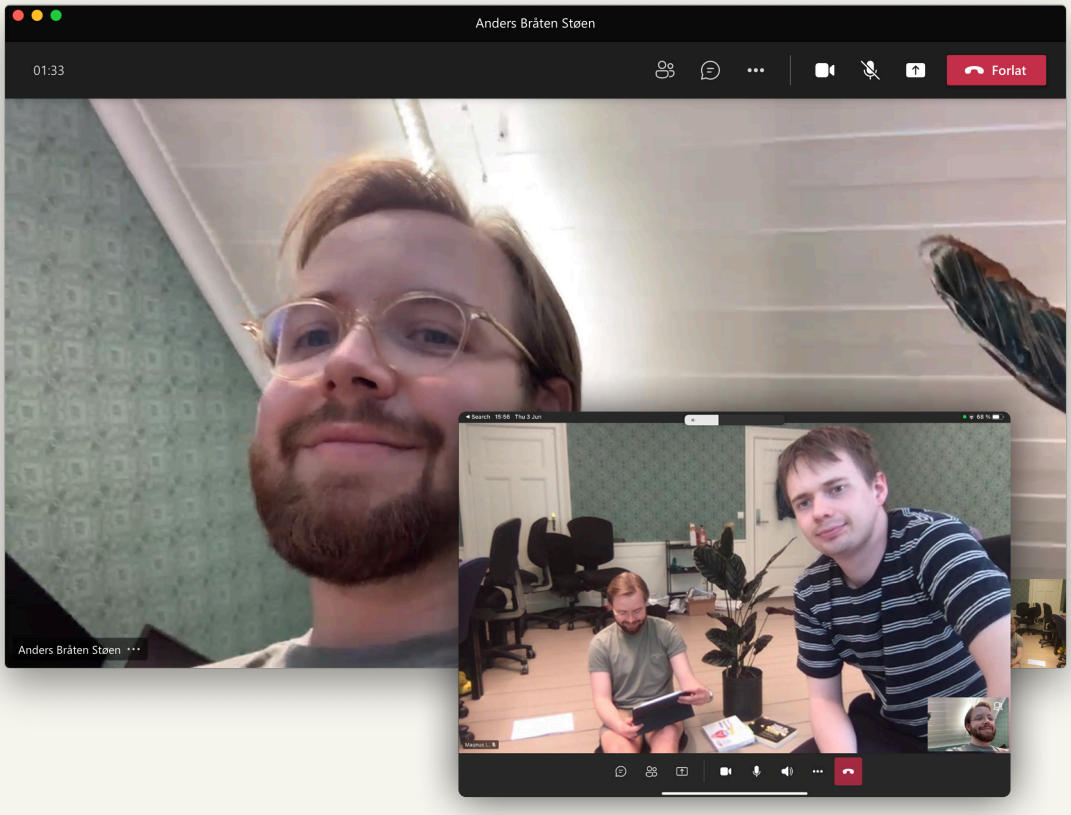
Like everyone else, we also had to overcome obstacles due to the pandemic. The project ended up being much more remote from the users than desired.

As designers we strive to have a close relationship with the people we are designing for. This became even more essential when dealing with struggles we have no prior basis of grasping. To comprehend unfamiliar situations, user observation could be used to better understand reality. During the initial planning phase of the project we proposed conducting user observations supplemented by a diary study at institutions, and in their home, to build the design process around the patients. This would also open the possibility to rapidly build and test prototypes alongside the user segments.

When we had to pivot away from visiting institutions, recruitment for a remote dialogue was initiated. We made contact with therapists through the network of our supervisor, but encountered issues reaching out to patients. Due to the regulations of data security in the health and research sector, we had to go through third parties to establish contact with possible participants. This turned out to be a lengthy and difficult process. The pandemic and technological barriers also made it unsuitable to conduct workshops and user tests on the targeted audience. We needed to think differently, and base much of our patient-insights on the interviews.

Beat Saber 2.0

From the suggested framework, we ended up with a concept. We developed a prototype based on the game canvas and sketches. What started as an idea for a “canoeing/ balance”- game where the player has to dodge incoming arrows, was scaled down to a low level of abstraction. We did this to be able to investigate the fundamental game mechanics in detail, and allow for rapid prototyping of the concept. As a result, the first iteration of the prototype became disturbingly similar to the popular game, Beat Saber. Although this probably would have called for another direction of the game to sufficiently differentiate it, as discussed, the process proved useful as a proof of concept. When we presented the prototype to the intended users, we got a better understanding of what type of value needs to be added in rehabilitation games. A side effect was also the origin of new concepts, based on the same exercises, but with slightly different game mechanics.



The remote authors, together for the occation.

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Video of Daft Skunk:

https://youtu.be/dwj5nXazV10

Workshop template:

https://miro.com/app/board/o9J_lHZjb4s=/

Password: daftskunk

VR game canvas template:

https://miro.com/app/board/o9J_lAkK3EI=/

Password: rehabilitation

REK APPLICATION PAGE 1

#241907 Virtuell og utvidet virkelighet (VR / AR) i nyttige spill for hjemmerehabilitering av underekstremitetene som følge av ervervet hjerneskade

Application Info

Søknadsid:	241907
Utlysning:	Fremleggingsvurdering
Søker:	Ole Andreas Alsos
Prosjektleder:	Ole Andreas Alsos

GENERELLE OPPLYSNINGER

1.3 Prosjekttittel

1.3.1 Norsk tittel	Virtuell og utvidet virkelighet (VR / AR) i nyttige spill for hjemmerehabilitering av underekstremitetene som følge av ervervet hjerneskade

1.4 Prosjektleder

Registrerte opplysninger om prosjektleder

ID	69907
Fornavn	Ole Andreas
Etternavn	Alsos
Epost	oleanda@ntnu.no
Telefon	91544825

1.5 Forskningsansvarlig

1.5.1 Hvilken norsk forskningsinstitusjon er prosjektleder knyttet til i prosjektet (Koordinerende institusjon)?	Norges teknisk-naturvitenskapelige universitet

PROSJEKTOPPLYSNINGER OG METODE

Oppsummering av forskningsprosjektet

2.1 Prosjektbeskrivelse

Prosjektet skal utvikle VR-baserte nyttige spill som kan brukes i rehabilitering av motorfunksjon i underekstremitetene hos personer med ervervet hjerneskade. Det finnes allerede forsking på dette, men videreutvikling av design av slike spill søker å bedre brukervennligheten og dermed gjøre tjenesten mer nyttig.

I denne designstudien skal terapeuter og pasienter intervjues for å skaffe innsikt som skal brukes i en iterativ prosess for spill- og tjenesteutvikling. 4-6 terapeuter og 4-6 pasienter skal rekrutteres fra samarbeidende rehabiliteringsinstitusjoner. Aktuelle pasienter vil identifiseres av administrativt personell og/eller terapeuter ved institusjonene. Informasjon om prosjektet vil sendes på forhånd med forespørsel om frivillig deltakelse.

Ingen personsensitive data utover kjønn, alder og hoveddiagnose skal samles inn. Disse hentes inn direkte fra deltakerne slik at tilgang til pasientens journal ikke er nødvendig.

For terapeuter vil bare yrkestittel, alder og kjønn innhentes.

Prosjektet vil ikke føre til ny kunnskap om helse eller sykdom.

2.2 Begrunn hvorfor du er i tvil om prosjektet trenger forehåndsgodkjenning fra REK?

På grunn av inklusjon av sårbare pasienter.

FORSKNINGSDATA

REK APPLICATION PAGE 2

Innsamling av data

3.1 Skal det samles inn nye data i prosjektet?

Ja

Opplysningene vil være	Indirekte identifiserbare

Tidligere registrerte opplysninger

3.2 Skal det forskes på tidligere registrerte opplysninger?

Nei

Humant biologisk materiale

3.4 Skal det forskes på humant biologisk materiale?

Nei

STUDIEPOPULASJON OG SAMTYKKE

Samtykke

5.6 Vil det bli innhentet samtykke

Ja

5.7 Er samtykke allerede innhentet?

Nei

VEDLEGG

8.2 Forskningsprotokoll	1 vedlegg (Forskningsprotokoll.pdf)
8.11 Andre nødvendige vedlegg	1 vedlegg (Intervjuguide.pdf)

ANSVARSERKLÆRING

Jeg er kjent med at enkelte opplysninger i skjema publiseres i det offentlige prosjetregisteret til REK og at vedtak med begrunnelse og bakgrunnsinformasjon publiseres i møtereferat som ligger åpent tilgjengelig i portalen

Ja

NSD APPLICATION PAGE 1

NSD NORSK SENTER FOR FORSKNINGSDATA

NSD sin vurdering

Prosjekttittel

Virtual and augmented reality (VR / AR) in home rehabilitation of the lower body

Referansenummer

250396

Registrert

09.02.2021 av Emanuel Alexander Lorenz - emanuel.a.lorenz@ntnu.no

Behandlingsansvarlig institusjon

Norges teknisk-naturvitenskapelige universitet / Fakultet for arkitektur og design (AD) / Institutt for design

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Ole Andreas Alsos, oleanda@ntnu.no, tlf: 73591463

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Magnus Lie Fridheim, magnuslf@stud.ntnu.no, tlf: +4740231465

Prosjektperiode

15.02.2021 - 01.07.2021

Status

21.05.2021 - Vurdert

Vurdering (2)

21.05.2021 - Vurdert

NSD has assessed the change registered on 20.05.21.

Our assessment is that the processing of personal data in this project will comply with data protection legislation, so long as it is carried out in accordance with what is documented in the Notification Form and attachments, dated 21.05.2021. Everything is in place for the processing to continue.

NSD will follow up the progress of the project at the planned end date in order to determine whether the processing of personal data has been concluded.

NSD APPLICATION PAGE 2

Contact person at NSD: Karin Lillevold
Good luck with the rest of the project!

26.03.2021 - Vurdert

BACKGROUND
The Regional Committees for Medical and Health Research Ethics (REC) have evaluated the project on 04.03.2021, their reference 241907. REC does not consider the study to be medical or health research. Consequently, as the project is not covered by the scope of the Health Research Act, the project can be carried out without the approval of REC.

Our assessment is that the processing of personal data in this project will comply with data protection legislation, so long as it is carried out in accordance with what is documented in the Notification Form and attachments, dated 26.03.2021, as well as in correspondence with NSD. Everything is in place for the processing to begin.

NOTIFY CHANGES
If you intend to make changes to the processing of personal data in this project it may be necessary to notify NSD. This is done by updating the Notification Form. On our website we explain which changes must be notified. Wait until you receive an answer from us before you carry out the changes.

TYPE OF DATA AND DURATION
The project will be processing special categories of personal data about health, and general categories of personal data, until 01.07.2021.

LEGAL BASIS
The project will gain consent from data subjects to process their personal data. We find that consent will meet the necessary requirements under art. 4 (11) and 7, in that it will be a freely given, specific, informed and unambiguous statement or action, which will be documented and can be withdrawn.

The legal basis for processing special categories of personal data is therefore explicit consent given by the data subject, cf. the General Data Protection Regulation art. 6.1 a), cf. art. 9.2 a), cf. the Personal Data Act § 10, cf. § 9 (2).

PRINCIPLES RELATING TO PROCESSING PERSONAL DATA
NSD finds that the planned processing of personal data will be in accordance with the principles under the General Data Protection Regulation regarding:

- lawfulness, fairness and transparency (art. 5.1 a), in that data subjects will receive sufficient information about the processing and will give their consent
- purpose limitation (art. 5.1 b), in that personal data will be collected for specified, explicit and legitimate purposes, and will not be processed for new, incompatible purposes
- data minimisation (art. 5.1 c), in that only personal data which are adequate, relevant and necessary for the purpose of the project will be processed
- storage limitation (art. 5.1 e), in that personal data will not be stored for longer than is necessary to fulfil the project's purpose

THE RIGHTS OF DATA SUBJECTS
Data subjects will have the following rights in this project: transparency (art. 12), information (art. 13), access (art. 15), rectification (art. 16), erasure (art. 17), restriction of processing (art. 18), notification (art. 19), data portability (art. 20). These rights apply so long as the data subject can be identified in the collected data.

NSD finds that the information that will be given to data subjects about the processing of their personal data will meet the legal requirements for form and content, cf. art. 12.1 and art. 13.

We remind you that if a data subject contacts you about their rights, the data controller has a duty to reply

NSD APPLICATION PAGE 3

within a month.

FOLLOW YOUR INSTITUTION'S GUIDELINES
NSD presupposes that the project will meet the requirements of accuracy (art. 5.1 d), integrity and confidentiality (art. 5.1 f) and security (art. 32) when processing personal data.

Teams is a data processor for the project. NSD presupposes that the processing of personal data by a data processor meets the requirements under the General Data Protection Regulation arts. 28 and 29.

To ensure that these requirements are met you must follow your institution's internal guidelines and/or consult with your institution (i.e. the institution responsible for the project).

FOLLOW-UP OF THE PROJECT
NSD will follow up the progress of the project at the planned end date in order to determine whether the processing of personal data has been concluded.

Good luck with the project!

Contact person at NSD: Karin Lillevold
Data Protection Services for Research: +47 55 58 21 17 (press 1)

RESEARCH PROTOCOL PAGE 1

NTNU
Kunnskap for en bedre verden

Research protocol

Title of the research project:
Virtual and augmented reality (VR / AR) in home rehabilitation of the lower body

Version: 1

Version date: 05.02.2021

NTNU
Kunnskap for en bedre verden

Responsible researcher and personnel

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RESEARCH PROTOCOL PAGE 3

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Background

Every year, millions of people of all ages suffer from acquired brain injuries (ABI) [1]. ABIs are classified either as traumatic brain injuries (TBI), which is an injury sustained from a trauma like a car accident or fall, and non-traumatic brain injuries sustained through a stroke, cancer, or other non-traumatic causes [2]. These injuries can severely impact physical, cognitive, social, and emotional capacity/abilities. However, the brain has the ability to repair and restore some of these abilities – called neuroplasticity. An intensive and multidisciplinary rehabilitation program is vital to the recovery process. Treatment programs can be strenuous and demanding not only for patients and their relatives but also for the healthcare system and society.

Emerging technology such as virtual reality (VR) has the potential to change the way rehabilitation is carried out. With the right application, it could reduce costs and better the quality of treatment [3]. VR-based serious games designed for physical activity, often called "exergames", provide the possibility of task-oriented physiotherapy exercises in customized settings and virtual environments, and can have a positive effect on motivation in training and rehabilitation [4]. VR rehabilitation systems today are being applied adjunctly with conventional therapeutic activities, not as a standalone treatment [5].

While VR technology is seeing an increase in use in the context of neurorehabilitation [6], many facets of how it is designed, delivered, and used in real settings are often overlooked and underreported. Usability as a quality and metric in contemporary VR systems and VR-based serious games for physical rehabilitation has yet to be adequately explored.

This thesis will explore how VR-based serious games could be designed to serve as a tool for rehabilitation and be incorporated into the treatment ecosystem, focusing on usability [7] as a key success metric. The work will focus on the rehabilitation of lower or upper limb motor function abilities for patients in their home environment. The resulting insights and designs can be used to further develop solutions in the broader scope of neurorehabilitation.

Materials and methods

Study design

This proposed study is a qualitative, explorative design study and will take place at the Department of Design, Norwegian University of Science and Technology (NTNU) in Trondheim from January 2021 to June 2021.

Collaborators

The study is part of the final master project in the design of the students Anders Bråten Støen and Magnus Lie Fridheim. It is further part of a larger PhD project at the Department of Computer Science at NTNU, with PhD candidate Emanuel A. Lorenz co-supervising and coordinating it with other research activities. PhD Ole Andreas Alsos is the main-supervisor and project leader from the Department of Design.

External partners include *Avdeling for ervervet hjerneskade* at Lian, *Meråker kurbad* in Meråker, and *Sunnaas sykehus* in Nesodden.

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Participants

The target patient has suffered an acquired brain injury (ABI) and is in an intermediary phase of recovery. The participants are likely to be demographically and pathologically heterogeneous. The study could shift its focus towards either stroke-affected or traumatic brain injury-affected (TBI) patients. Based on existing research, the latter could be more feasible in the context of VR systems.

The clinical and rehabilitation path of both TBI and stroke patients varies greatly. However, the TBI patient pool is generally younger and displays better locomotion performance on admission and discharge to rehabilitation [8]. Both factors are relevant for the study: Better performance in baseline motor function tasks implies better performance in physical games, and a younger patient will more likely have tried or heard of VR and thereby a higher general acceptance towards this technology. Although these are assumptions and not a final decision regarding a final user group, initial outreach will carry an emphasis on TBI patients.

The target therapist is a rehabilitation physiotherapist or occupational therapist working at a dedicated ABI treatment facility. The study will attempt to capture a broad range of experience and specializations.

Recruitment

The study is bilateral as it seeks to involve two groups: therapists and ABI patients. The therapists are recruited from a network of rehabilitation centres listed as external collaborators. Patients will be recruited from the same facilities, subject to guidance from the physiotherapists to find fitting profiles aligned with the target patient. Administrators at the facilities will also aide the study in screening participants and handling initial outreach.

An introduction to the aim and nature of the study will be sent to the participants (therapists and patients) before recruitment, and those who wish to participate will contact the researcher. Patients will receive an additional pamphlet with basic information about the theme of the study.

Procedure

The study will be conducted using two rounds of explorative, semi-structured individual interviews with therapists and patients. A sufficient number of participants from both participant pools would be between 4 and 6, as per established design research practice [9]. If the returns are deemed to be diminishing, or insufficient, before reaching the target threshold, the number of interviews could be slightly altered.

The resulting insights will be processed and incorporated into an iterative design process to develop design solutions based on VR serious games.

The proposed designs will be user-tested with participants, both therapists and patients, to gather feedback and insights for following iterations, resulting in one or several minimum viable products (MVP). Testing will be carried out with participants from the interviews.

Design methodology

The study's approach will utilize methods aligned with Human-centered design (HCD) principles. Data collected through interviews and user testing is key to these methods. The data collected from interviews and user testing is to be used in the mapping of user needs, pain points, user journeys, and other HCD methods. The process is iterative, and the chronology of these methods is decided from the outset.

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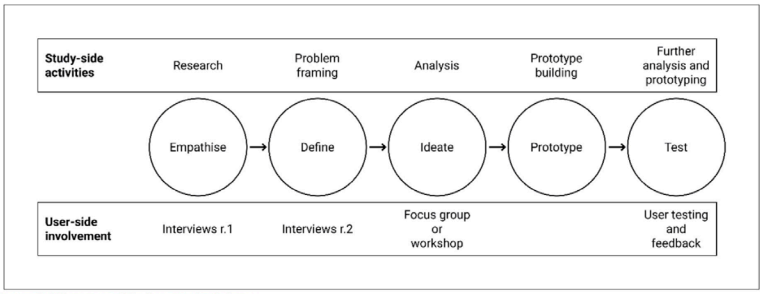

Figure 1: Diagram of design methodology

Interviews

Interviews will be used to develop an understanding of the challenges and goals of the participants. The audio from the interviews will be recorded and transcribed for use in the design process.

A set of questions will be prepared and screened through pilot interviews with physiotherapists and patients for their respective interview guides. The goals of the interviews differ and are documented in the appended guides. Additional questions may be improvised through the course of actual interviews if deemed pertinent to the theme of the study or the design process as a whole.

Data gathered in interviews with therapists will be used to shape the patient interview guide. For patients, to minimize the risk of exhaustion and cognitive strain, an upper limit of 30 minutes per interview has been set.

Prototyping

Prototypes for potential designs will be built to present and test on participants without having to develop a high-fidelity product at every iteration. Prototypes will evolve from non-functional mock drafts initially, to functional games built in the Unity game design engine towards the end of the study. Prototyping serves as a tool to validate hypotheses and generate new insights for future prototypes, leading to final products.

User testing

User testing will be used to assess prototypes and existing technologies and is a tool for uncovering flaws and strengths. Several iterations are needed to develop good solutions. The study proposes two to three rounds of testing. Each iteration of prototyping will be tested approximately five times. User tests will be video recorded for qualitative analysis.

Equipment

Interviews will be conducted and recorded via Microsoft Teams.

Prototyping and user-testing solutions require equipment and tools associated with VR game development. The explorative nature of the study opens the possibility that several technologies could be used, including:

1. VR and/or AR compatible headsets and controllers
2. Gaming interfaces and screens
3. Consumer-grade cameras
4. Motion capture sensors

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5. Electroencephalogram

Other equipment related to game development and testing, including additional hardware and software, could be deemed relevant comes to the development and prototyping phase.

Data management

The interviews will be conducted and recorded using the application of Microsoft Teams. The recorded sound files will be scrambled, encrypted and stored on a secure NTNU secure servers (NICE-1) right after the interview.

Expected deliveries and potential outcomes

The end product of this study will be one or several serious game concepts for use in lower-limb motor function rehabilitation. The game(s) will not have the functional and aesthetic qualities of a commercial game but should serve as an MVP or a proof-of-concept. High-fidelity, consumer-grade game development will remain as a potential task for future studies.

Insights gathered in the study and the output from the design process are also part of the delivery. These could form a baseline for future studies and projects, not only in the domain of game development but in designing services for ABI patients in general.

A review of existing solutions for the rehabilitation of lower-limb motor function aids in the exploration of the quality of existing treatments, and how they can be augmented to adapt them to actual user needs.

Ethical considerations

The patient's gender and age will be recorded for democratic and inclusive purposes. Their general diagnosis and time since the incident will be recorded for contextual purposes. Other than that no health data will be collected and is not needed in the interview guides or the study otherwise. If the interview subject chooses to disclose additional health information, it will not be processed or documented further in the design process.

Several ethical considerations should be considered in interacting with patients in this study. People with ABI are in a vulnerable situation, where prior physical and cognitive abilities may have been impaired or reduced significantly in comparison with pre-injury abilities. Steps are taken in the preliminary phase, with the care providers, to ensure that the interview and user-testing procedure take this vulnerability into account.

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TITLE OF APPENDIX

NTNU
Kunnskap for en bedre verden

Version 0.2

VIL DU DELTA I FORSKNINGSPROSJEKTET «VIRTUELL OG UTVIDET VIRKELIGHET (VR/AR) I BEVEGELSESREHABILITERING AV UNDERKROPP»?

FORMÅLET MED PROSJEKTET OG HVORFOR DU BLIR SPURT

Dette er et spørsmål til deg om å delta i et doktorgrads forskningsprosjekt ved institutt for datateknologi og informatikk, i samarbeid med masterstudenter fra institutt for design ved NTNU. Denne studien vil undersøke hvordan VR-baserte spill kan tjene som et verktøy for nevrorehabilitering. Arbeidet vil fokusere på rehabilitering av motoriske funksjonsevner i underkroppen for pasienter i hjemmet. Den resulterende innsikten og designet kan brukes til å videreutvikle løsninger i det bredere omfanget av nevrohabilitering. Deltakere i studien er ca. fem terapeuter og fem pasienter. Deltakere må være for tiden eller tidligere involvert i hjemme-rehabilitering etter traumatiske hjerneskader (TBI). Hvis du tilfredsstiller disse kriteriene og ønsker å delta i denne studien, kan du lese resten av dette brevet for å få mer informasjon om prosjektet og hva din deltakelse vil innebære.

HVA INNEBÆRER PROSJEKTET FOR DEG?

Studien er hovedsakelig en kvalitativ studie der vi vil intervjue deg om din erfaring med rehabilitering og din mening om bruk av nye teknologier (spesielt Virtual Reality og Augumented Reality) innen dette feltet.

På grunn av den nåværende situasjonen skal intervjuet bli gjennomført online via applikasjonen TEAMS (Microsoft Inc.). Lyden av intervjuet blir spilt inn. Umiddelbart etter intervjuet blir innspillingen kryptert og lagret på et sikkert fillagringsområde på NTNU for å sikre din anonymitet. Under prosjektet har bare de tilknyttede veilederne (Ole Andreas Alsos - NTNU, Institutt for design og Emanuel Alexander Lorenz - NTNU, Institutt for datateknologi og informatikk) og masterstudentene (Magnus Lie Fridheim - NTNU, Institutt for design og Anders Støen - NTNU, Institutt for design) tilgang på den sikkert fillagringsområde og data dine.

Intervjuet består av tre intervjurunder i løpet av en måneders periode. I de to første intervjuene skal du bli spurt om din mening og erfaring på flere punkter angående bevegelsesrehabilitering (semistrukturert intervju). Det siste intervjuet vil du være med å diskutere forskjellige konsepter av teknologibruk innenfor rehabiliteringen. Intervjuene skal bli ledet av to forskere, og hvert intervju skal ta omtrent 30 minutter, men de kan være kortere eller lenger, avhengig av tilgjengelig tid, energi og innspill. I løpet av intervjuene skal vi vise deg bilder eller videoer relatert til noen av spørsmålene, for å avklare dem.

I begynnelsen av det første intervjuet skal vi i tillegg gå gjennom dette skjemaet sammen, og svare spørsmålet du har angående denne studien. Etterpå skal vi be deg om å uttrykke ditt samtykke til å delta muntlig.

Det andre intervjuet skal omfatte innhentet innsikt fra den første studien og stille mer spesifikke spørsmål.

Basert på det to første intervjuene skal vi utvikle konsepter for bedre integrering av ny teknologi i rehabilitering.

Det siste intervjuet vil innebære å diskutere de konseptene som er blitt utviklet.

TITLE OF APPENDIX

MULIGE FORDELER OG ULEMPER

Det forventes ingen ulemper eller sikkerhetsrisiko ved gjennomføring av studien. Personopplysningene dine er behandlet dine konfidensielt og i samsvar med databeskyttelseslovgivningen og derfor risiko for datainnbrudd er lav.

FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE DITT SAMTYKKE

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg. Dersom du trekker tilbake samtykket, vil det ikke forskes videre på dine helseopplysninger. Adgangen til å kreve sletting eller utlevering gjelder ikke dersom opplysningene er anonymisert eller publisert. Denne adgangen kan også begrenses dersom opplysningene er inngått i utførte analyser.

Dersom du senere ønsker å trekke deg eller har spørsmål til prosjektet, kan du kontakte prosjektleder (Instituttleder, ID, NTNU – Trondheim, E-post: oleanda@ntnu.no; Tlf.: +47-73591463).

HVA SKJER MED OPPLYSNINGENE OM DEG?

Opplysningene som registreres om deg skal kun brukes slik som beskrevet under formålet med prosjektet til august 2021, og planlegges lagret anonymisert etter at all identifiserbar informasjon er fjernet for 5 år (August 2026) på et adgangsbegrenset, sikkert fillagringsområde på NTNU. I løpet av prosjekt behandler personopplysningene dine konfidensielt og i samsvar med databeskyttelseslovgivningen (generelle databeskyttelsesforordningen og personopplysningsloven). Dersom prosjektet er en del av et større PhD-forskningsprosjekt om nye teknologiske applikasjoner for rehabilitering, forbeholder vi oss muligheten til å gjenbruke anonymiserte opplysningene dine videre for et relatert prosjekt innen de fem årene. Etter denne periode alt opplysningene dine er slett irreversibel. Eventuelle utvidelser i bruk og oppbevaringstid kan kun skje etter godkjenning fra NSD (Norsk senter for forskningsdata) og andre relevante myndigheter.

Du har rett til innsyn i hvilke opplysninger som er registrert om deg og be om sletting opplysningene eller rette eventuelle feil i de opplysningene som er registrert. Du har også rett til å få innsyn i sikkerhetstiltakene ved behandling av opplysningene og rett til å be om en kopi av de innspilte dataene dine. Du kan klage på behandlingen av dine opplysninger til datatilsynet og institusjonen sitt personvernombud (for kontaktinformasjon se nedenfor på kontaktopplysninger).

Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger.

Endelig publisering av våre resultater er en nødvendig del av forskningsprosessen. All publisering skal gjøres slik at enkeltdeltakere ikke skal kunne gjenkjennes, men vi plikter å informere deg om at vi ikke kan utelukke at det kan skje.

FORSIKRING

NTNU har ansvar for skader som følge av testsituasjonen, og dekker utgifter til medisinsk behandling hvis dette skulle oppstå.

GODKJENNINGER

Norsk senter for forskingsdata (NSD) har vurdert prosjektet og tilhørende datalagring og behandling.

TITLE OF APPENDIX

Etter ny personopplysningslov har behandlingsansvarlig NTNU og prosjektleder instituttleder Ole Andreas Alsos et selvstendig ansvar for å sikre at behandlingen av dine opplysninger har et lovlig grunnlag. Dette prosjektet har rettslig grunnlag i EUs personvernforordning artikkel 6 nr. 1a og artikkel 9 nr. 2a og ditt samtykke.

Du har rett til å klage på behandlingen av dine opplysninger til datatilsynet.

KONTAKTOPPLYSNINGER

Dersom du har spørsmål til prosjektet kan du ta kontakt med instituttleder Ole Andreas Alsos (E-post: oleanda@ntnu.no, Tlf.: +47-73591463).

Hvis du vil sende en klage angående behandlingen av personopplysningene dine, kontakte:

- Personvernombud ved institusjonen Thomas Helgesen (thomas.helgesen@ntnu.no)
- NSD - Norsk senter for forskingsdata AS (E-post: personverntjenester@nsd.no, Tlf.: +47 55 58 21 17)

JEG SAMTYKKER TIL Å DELTA I PROSJEKTET OG TIL AT MINE PERSONOPPLYSNINGER BRUKES SLIK DET ER BESKREVET

Jeg samtykker til å delta i prosjektet og til at mine personopplysninger brukes slik det er beskrevet. Muntlig samtykke til deltakelse er også mulig under det innspilte intervjuet.

Sted og dato

Deltakers signatur

Deltakers navn med trykte bokstaver

Jeg bekrefter å ha gitt informasjon om prosjektet:

Sted og dato

Signatur

Rolle i prosjektet

PATIENT FLYER

Vil du delta i et forskningsprosjekt om bruk av VR-spill (virtuell virkelighet) i bevegelsesrehabilitering av underkropp?

Vi er to masterstudenter ved Institutt for design, NTNU som vil undersøke hvordan VR-baserte spill kan tjene som et verktøy for nevrorehabilitering. Virtuell virkelighet (VR) er en teknologi som gjør det mulig for folk å tre inn i et tredimensjonalt digitalt miljø, ved å benytte VR-briller som fungerer som en skjerm. Se video som forklarer VR her.

Arbeidet vårt vil fokusere på rehabilitering av motoriske funksjonsevner i underkroppen for pasienter i hjemmet. Den resulterende innsikten og designet kan brukes til å videreutvikle løsninger i det bredere omfanget av nevrohabilitering.

Vi ønsker å prate med personer som for tiden eller tidligere har vært involvert i hjemme-rehabilitering etter traumatiske hjerneskader (TBI).

På grunn av den nåværende situasjonen vil kommunikasjonen gjennomføres digitalt. Dataene blir lagret anonymisert på et adgangsbegrenset, sikkert lagringsområde på NTNU.

Hvis dette virker interessant tar du kontakt med oss, enten på e-post eller telefon.

Magnus Lie Fridheim
Tel.: +47 40 23 14 65
E-post: magnuslf@stud.ntnu.no

Anders Bråten Støen
Tel.: +47 93 00 28 41
E-post: anderbst@stud.ntnu.no

Norges teknisk-naturvitenskapelige universitet - NTNU
Institutt for design
Kolbjørn Hejes vei 2B
7034 Trondheim

FACEBOOK POST

EXPERT 1 INTERVIEW

Spørsmål

- Starte med å fortelle om seg selv og hva han driver/har drevet med.
- Prate litt om hvordan man interagerer med pasienter
    - Hvordan gi feedback
    - Hva trenger de hjelp til
    - Hvordan utføres hjelpen
    - Hvordan er et typisk pasientforløp for en pasient?
        - Hvilke variabler spiller inn?
- Hvordan måles progresjon?
    - Kvalitative og kvantitative metrikker
        - Fysisk evaluering, visuelle kjennetegn, haptiske reaksjoner osv.
    - Hvordan oppbevares/loggføres progresjonen?
- Hjemmebehandling - hvordan fungerer det?
    - Hva gjør de selv? Hva er de stand til å gjøre?
    - Påvirker overgangen til hjemmebehandling rehabiliteringen?
- Tanker rundt VR/AR i forhold til lower extremity
    - Brukes denne teknologien i dag?
- Er det gunstig å avgrense problemstillingen til lower extremity?
    - Isolerer man trening til lower limb?

- Bonusspørsmål
    - Vi må nå ut til flere terapeuter i feltet. Noen vi kan kontakte? Opprette en mailingliste?
        - Fokusgrupper, dybdeintervju
    - (Emanuel: hvordan kan dette settes opp med ML?)

- Hvordan motivere pasienter?
- Er det en “mellom”-institusjon?

EXPERT 2 INTERVIEW

Spørsmål

- Starte med å fortelle om seg selv og hva hun driver/har drevet med.
- Fortelle om erfaringer innen treningsspill
    - Erfaringer innenfor balanse- og/eller gangtrening?
    - Erfaringer med hva man må ta hensyn til med slag og TBI? Og hvilke forskjeller det er? Bør vi fokusere på en av de?
- Erfaringer med VR innenfor treningsspill? (Potensielt AR?)
    - Forskjellen på dette mtp motorikk i overkropp og lower limb
- Hvordan teste prototyper på vanskeligstilte pasienter?
    - Hvordan jobbe smidig og iterativt med spill og VR ift. prototyping?
- Hva er viktig når det kommer til motivering gjennom spill?
- Hvordan måle progresjon gjennom spill?
- Hjemmebehandling med spill?
- Er kognitiv belastning noe vi må ta hensyn til utover tidsbruken i intervjuene (<1 time)?
- Spørsmål til pasienter?
- Kan vi få tilgang til forskningen din?

- Noen du mener vi bør kontakte?

EXPERT 3 INTERVIEW

Spørsmål

- Introduksjon
    - Hva vi jobber med og målsetting for prosjektet
        - TBI, lower limb, XR-spill

- Starte med å fortelle om seg selv og hva hun driver/har drevet med

- Fortelle om erfaringer innen treningsspill
    - Erfaringer med balanse- og gangtrening?

- Fortell om hvilke parametre dere arbeider med og ser etter hos brukerne
    - Hvordan ser du på data som et ledd i utforming av spillene?

- Antakelse (stopp meg hvis jeg tar feil): forskningen din ser på MoCap som et verktøy for å skape og formidle(?) en slags feedback til bruker og behandler
    - Vi ser et potensial i å bruke feedback-loopen slik at vurderinger av vanskelighetsgrad og utvikling kan bakes inn i spill.
        - **Hvordan kan vi utforske dette temaet i intervjuet?**
    - Du skriver litt om "marker-less systems" som et steg videre for å gjøre treningsspill mer tilgjengelig og brukbart
        - Hvordan ser du for deg at dette kan utvikle seg, både teknologisk og praktisk?
        - Det finnes løsninger for dette innen f.eks. sportsverden
    - Ser *Systematic Review of Design Guidelines for Full-Body Interactive Games* nettopp ble publisert. Kan du si litt mer om hva motivasjonen for denne artikkelen var?

- Observasjoner rundt motivasjon under forsøkene?
    - Våre brukergrupper er litt forskjellige, men kan du fortelle litt om dine erfaringer i møtet med eldre personer og treningspill?

- Hvordan ser du på overgangen til hjemmebehandling med spill?
    "results are promising for making exergames more accessible and easier to use, thereby increasing their availability for in-home exercise"
    - Hvilke utfordringer følger med overgangen?
    - En åpenbar utfordring er å utforme system slik at hjemmebruk blir mer gjennomførbart.
        - Hva er dine tanker rundt hva som mangler i dagens marked og forskning?

- Erfaringer med XR innenfor treningsspill?
    - Er dette noe du har sett på en ressurs eller potensiell løsning i forskningen?

- Spørsmål til pasienter?

THERAPIST INTERVIEW 1

Alltid send egen møteinnkalling i Teams for opptak

Målet med disse intervjuene er å skaffe innsikt i hva terapeuter tenker og føler rundt interaksjonen med pasienter samt hvilke verktøy og metoder de bruker i behandlingen. Målet er å danne sammenlignbar informasjon. Dette skal vi benytte både for å forstå mulighetene og utfordringene fra behandlerens ståsted, men også som en hjelp til å utforme spørsmål for pasienter.
Prosjektet går ut på å finne en løsning som skaper verdi for behandlere og pasienter, så terapeutens opplevelse er også viktig.

Introduksjon

1. Takk deltaker for å bruke tiden sin for å stille til intervjuet.
2. Gå gjennom samtykkeskjema og be om samtykke for å delta.
    a. At det er greit at vi tar opp lyd og video. Etterpå kommer vi til å transkribere til tekst og slette opptaket. Alt av persondata anonymiseres. Alt lagres på en trygg kryptert server i mellomtiden.
3. Introdusere oss selv og vår rolle i prosjektet og intervjuet.
    a. Magnus og Anders. Master i Interaksjonsdesign.
4. Forklar målet til studiet:
    a. Denne studien vil undersøke hvordan VR-baserte spill kan tjene som et verktøy for nevrorehabilitering. Arbeidet vil fokusere på rehabilitering av motoriske funksjonsevner i underkroppen for pasienter i hjemmet. Den resulterende innsikten og designet kan brukes til å videreutvikle løsninger i det bredere omfanget av nevrohabilitering.Prosjektet går ved siden av et større prosjekt som omhandler samme tematikk.
5. Forklar hva vi skal gå gjennom i intervjuet.
    a. Generell bakgrunn, hvordan du jobber med pasienter, hvordan man måler ting, behandling i hjemmet og erfaringer med teknologi og VR.

Spørsmål

1. Starte med å fortelle om deg selv
    a. Yrke, arbeidsplass, hvor lenge, spesialisering
2. Hvordan jobber du med pasienter?
    a. Hvilken behandling eller trening, og hvordan gir du feedback?
3. Hvordan måler du progresjon?
    a. Kvalitative og kvantitative metrikker
        i. Fysisk evaluering, visuelle kjennetegn, haptiske reaksjoner osv.
    b. Hvordan evaluerer du og gir tilbakemelding om progresjon til pasienten?
4. Hva synes du er de mest utfordrende aspektene ved jobben din (pasienter med ABI)?
    a. Hvilke utfordringer møter du på i kommunikasjon med pasienter?
5. Hvordan forbereder dere pasienter for hjemmebehandling?
    a. Hvilke verktøy utstyres pasienten med ved overgang til hjemmet?
        i. Utstyr, rutiner og planer, kontaktpersoner, informasjon og kommunikasjon generelt
    b. Hvordan motiveres pasientene til å fortsette rehablitiering på egenhånd? (Hvordan gi de trygghet til å stole på at de klarer seg selv)
6. Erfaringer med teknologi i behandling?
    a. Bruker du teknologi i behandlingen av pasienter? Hvilken?
    b. Har du erfaringer med treningsspill eller VR?
        i. Tanker rundt disse i forhold til underkroppen spesielt?
        ii. Hvilke hensyn er man nødt til å ta?
    c. Bruker du teknologi for å følge opp hjemmebehandling?
    d. Hva skal til for at du tar i bruk ny teknologi/verktøy i behandlingen?

THERAPIST INTERVIEW 2 PAGE 1

Intervjurunde 2 - Terapeuter

Estimert tid: Ca. 30 minutter
Introduksjon: Gå gjennom hva vi pratet om sist, og status for prosjektet i dag.

Hvordan jobber man med pasient for å sette mål realistiske mål?
- **Og hvordan hjelper man pasienten følge opp sine egne målsettinger?**
- **Hvordan gjøre realistiske målsetninger (som er mindre ambisiøse enn pasienten egentlig ønsker) interessante/motiverende?**

Hvorfor: Innsikt tilsier at pasienter har en tendens til å sette seg urealistiske mål. Hva skjer med motivasjonen når de må nedjustere disse?

Pasienter kan slite med å se eget behov for videre rehabilitering. Hvordan hjelper dere de å se sine egne behov?
Hvorfor: Hva gjør terapeuter for å hjelpe pasienter forstå sine egne behov.

Under trening; hvordan jobber man opp mot pasientens grenser?
- **Hvordan foregår dette når pasienten er frisk nok til å trene alene?**
- **Hvilke øvelser for balanse og gange kan pasienter gjøre selv?**

Hvorfor: Treningen har størst effekt når øvelsene er passe utfordrende. Hvordan styres dette trygt?

Hvordan la pasienter fortsette å utforske sine interesser? (Flyttet)
- **Hender det at man tar dette inn i rehabiliteringen?**

Hvorfor: Se om det finnes inspirasjon til hvordan å ta i bruk andre impulser for å øke glede og motivasjon til pasient.

Hvordan bistår pårørende?
- **Får de noen opplæring?**

Hvorfor: Nettverket til pasienten, og hvordan de opererer, kan ha stor betydning på rehabiliteringen.

Det virker vanlig med en tverrfaglig rapport som overleveres når pasienten forlater institusjon. Hva inngår i denne rapporten som pasienten kan dra nytte av selv for videre rehabilitering?
Hvorfor: Hvor "hands-on" er egentlig pasienten i sin egen rehabilitering.

Hva ønsker terapeuter at pasientene skal fokusere på når de er hjemme?
La oss si at rehabiliteringen til pasienten ble loggført mens de er hjemme. Hva slags informasjon hadde vært relevant å følge med på?
Hvorfor: Se om terapeutene har noen tanker rundt hva som hadde vært nyttig ift. oppfølging.

Hvilke hjelpemidler for gange- og balanseøvelser i hjemmet er vanlig å benytte under trening, eller hvilke enkle hjelpemidler kan man anskaffe?
Hvorfor: Forstå hva som regnes som trygge hjelpemidler, og hvor tilgjengelige/normalt det er å ha i hjemmet.

THERAPIST INTERVIEW 2 PAGE 2

Hvis du skulle laget et spill for pasienter med gange- og balansevansker, hva ville det vært?

- **Hvordan ville det sett ut?**
- **Hvordan ville man gitt tilbakemeldinger?**
- **Hvordan ville man sørget for at øvelsene som spillet la opp til ble gjort på riktig måte?**

PATIENT INTERVIEW PAGE 1

Introduksjon

1. Takk deltaker for å bruke tiden sin for å stille til intervjuet.
2. Introdusere oss selv og vår rolle i prosjektet og intervjuet.
3. Forklar målet til studiet:
    a. Denne studien vil undersøke hvordan VR-baserte spill kan tjene som et verktøy for nevrorehabilitering. Arbeidet vil fokusere på rehabilitering av motoriske funksjonsevner i underkroppen for pasienter i hjemmet. Den resulterende innsikten og designet kan brukes til å videreutvikle løsninger i det bredere omfanget av nevrohabilitering.
4. Forklar hva vi skal gå gjennom i intervjuet.
    a. Livssituasjon, rehabilitering i hjemmet og tanker om teknologi og VR.
5. Gå gjennom samtykkeskjema og be om samtykke for å delta.
6. Du kan avbryte når som helst. Du trenger ikke å svare på et spørsmål om du ikke vil. Det er viktig at du ikke sitter inne med noe om du har lyst til å si det. Vær så ærlig du kan og vil!

Livssituasjon

1. **Hvor gammel er du og hvilken skade har du?**
   Hvorfor: For å danne et sammenlignbart grunnlag må vi vite helsesituasjonen.
2. **Hvor lenge siden er det du fikk skaden?**
   Hvorfor: Komparativt grunnlag for studien.
3. **Har du/hvor lenge har du bodd hjemme siden skaden?**
   Hvorfor: Forstå hvor lenge de har drevet med rehabilitering i hjemmet.
4. **Kan du fortelle hvordan en vanlig dag ser ut for deg?**
   Hvorfor: Danne et bilde av hverdagen til pasientene for å forstå hvordan deres livssituasjon er. Samtidig er det et åpent og lett spørsmål for å få i gang samtalen.
    a. **Hvilke utfordringer møter du når skal bevege deg rundt i hverdagen?**
       Hvorfor: Forstå pasientenes pain points.

Rehabilitering i hjemmet

5. **Bor du for tiden hjemme? (a/b)**
    a. **Har du et treningsprogram du følger? Får du hjelp med å følge opp dette?**
       Hvorfor: Finne ut av hvor/når/hvordan/hvor ofte foregår rehabiliteringen.
        i. **Hvordan oppleves treningen?**
           Hvorfor: Forstå hvilke følelser som er knyttet til rehabilitering i hjemmet.
        ii. **Hva motiverer deg når det kommer til trening? (Og hva er demotiverende?)**
           Hvorfor: Forstå målet og ønskene til pasienten.
        iii. **Benytter du noen hjelpemidler eller utstyr? (Ja/Nei, utdyp)**
           Hvorfor: Forstå bruken av utstyr / verktøy / plass / positive og negative opplevelser i hjemmet.
        iv. **(Hvordan) kan du vurdere din egen fremgang med tanke på de tingene du trener på? (Ja/Nei, utdyp)**

PATIENT INTERVIEW PAGE 2

Hvorfor: Forstå pasientenes tanker knyttet til progresjon (spesielt opp mot motivasjon)

b. **Hvordan ser du på å fortsette rehabiliteringen hjemme?**
Hvorfor: Undersøke om pasienten har noen initielle tanker rundt hjemmerehabilitering basert på hva man har hørt etc., hvilke følelser som assosieres med denne overgangen.

Tanker om teknologi og VR

6. **Hva tenker du om bruken av nye teknologiske hjelpemidler i rehabiliteringen din?**
Hvorfor: Finne ut om pasientens tanker, om de har vært benyttet det, eller vet om muligheten.
Vis en kontekstuell video som forklarer hvordan VR-spill fungerer, hvordan man tar på masken og hvordan man setter opp systemet.
    a. **Har du noe forhold til VR, altså "virtuell virkelighet"?**
    Hvorfor: Forstå den mentale modellen de har av VR.
    b. **Ser du noen spennende muligheter med bruk av VR?**
    Hvorfor: Det er de som sitter inne med erfaringen, og kan ha mange tanker om bruksområde.
    c. **Dersom det fantes et VR-spill for trening av balanse og gange som man kunne brukt i hjemmet, hva slags univers/miljø ville du ønsket at det skulle fremstilt? (Eller hva slags følelse du ønsker at det skal gi). Og hvordan skulle spillet fungert?**
    Hvorfor: Åpne opp for kreative idéer og tanker. Det trenger ikke være noe konkret - like interessant hvis de kan beskrive følelsen de ønsker å oppnå.

FEEDBACK INTERVIEW

Intervjurunde 2

Hensikt

Få tilbakemeldinger fra stakeholdere, og skape diskusjon rundt konseptene som har blitt skisset opp basert på gjennomført innsiktsarbeid og idégenerering.

Plan

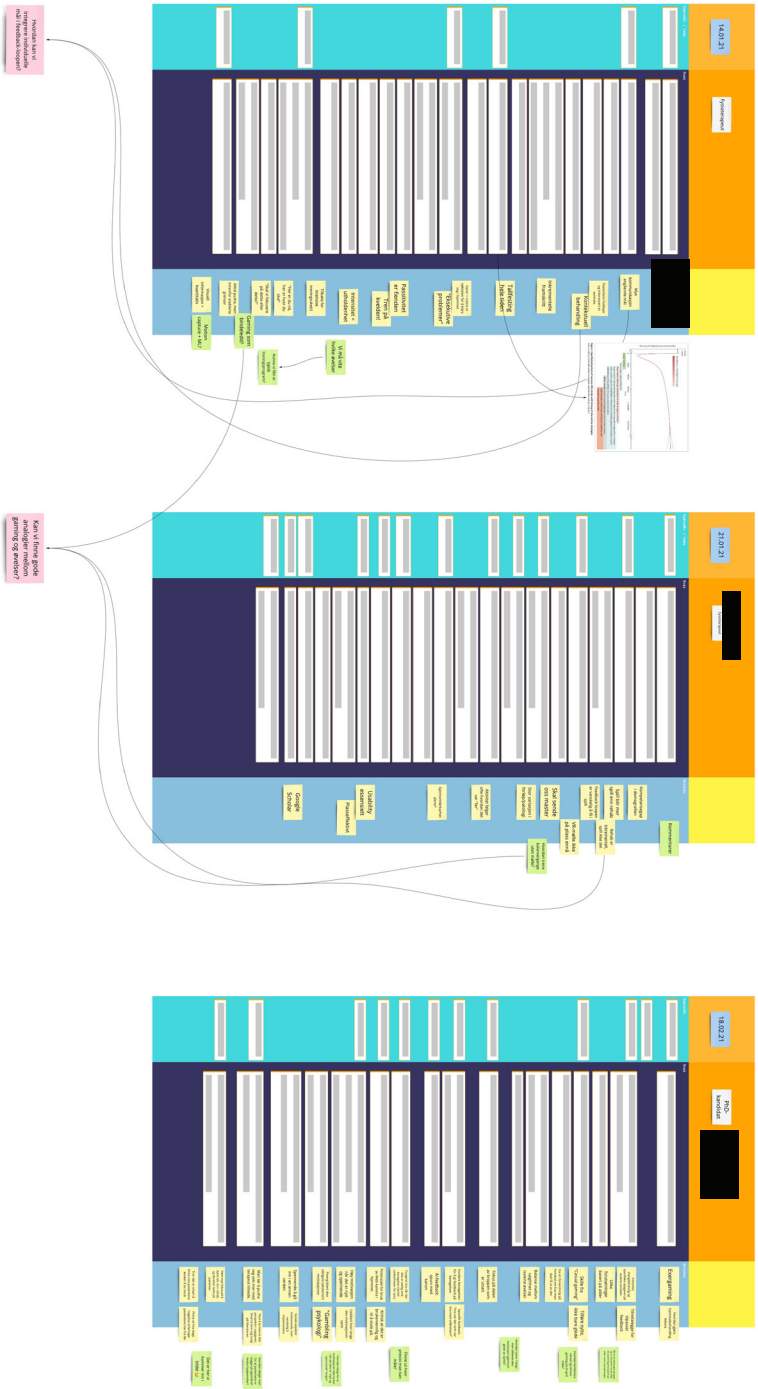
- Gå gjennom de konsept til VR-spill steg for steg.
    1. Story & miljø
    2. Input (bevegelser) / Output (game actions)
    3. Progresjon
    4. Sosialt aspekt
    5. Mål med spillet

- Samle tanker og følelser knyttet til disse konseptene.

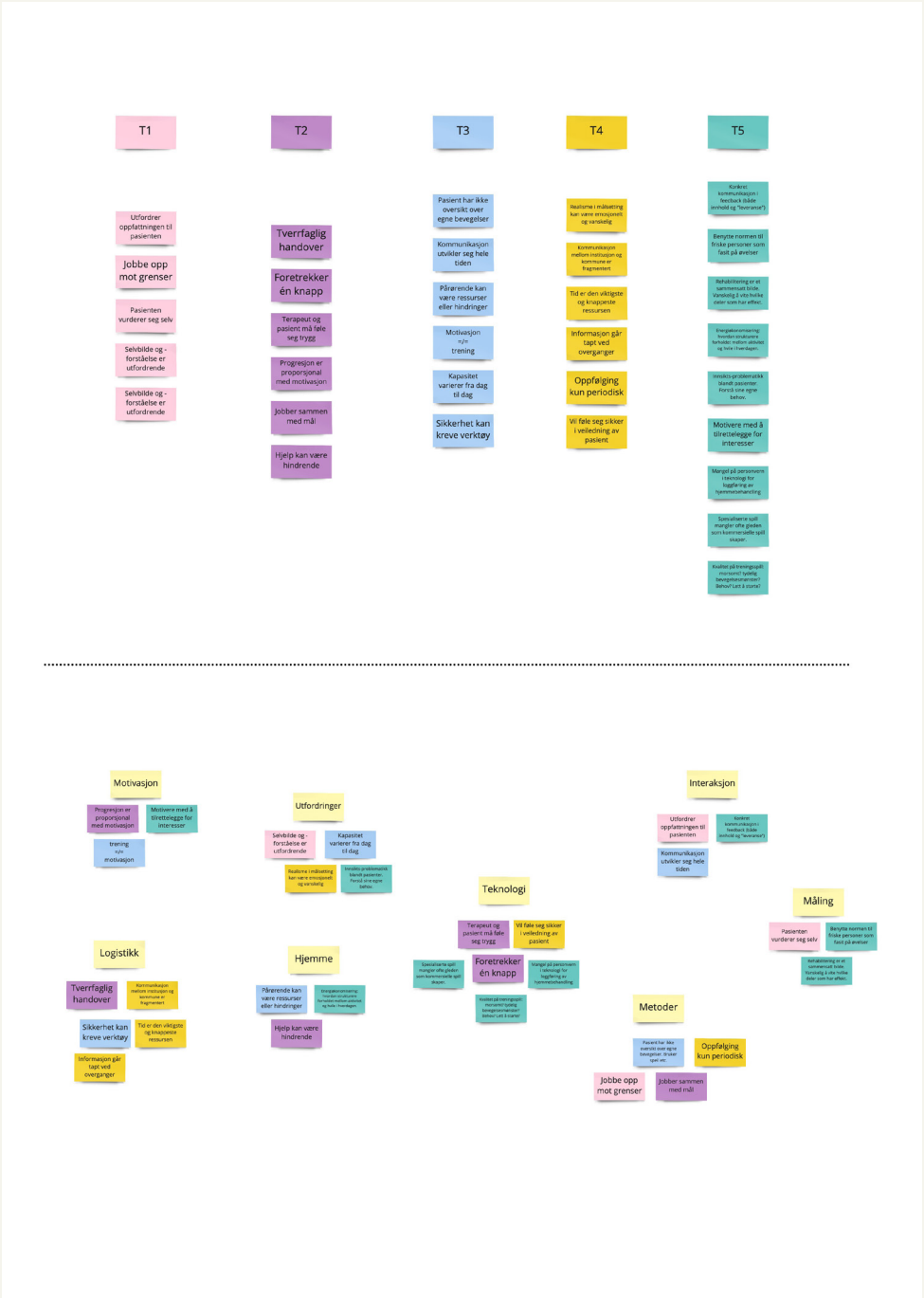
Spørsmål

1. Initielle tanker om et slikt konsept
    a. Hvordan relaterer det til treningen?
    b. Hvordan ville det påvirket motivasjonen?
2. Gjennomførbarhet (i hjemmet)
3. Svakheter med konseptet
4. Forslag til forbedringer

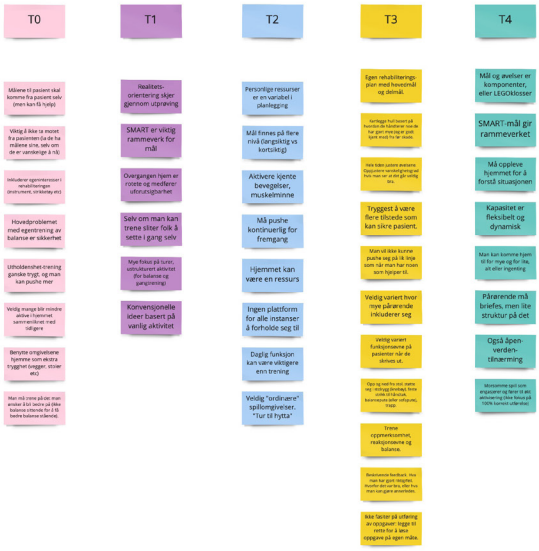
EXPERT INTERVIEWS



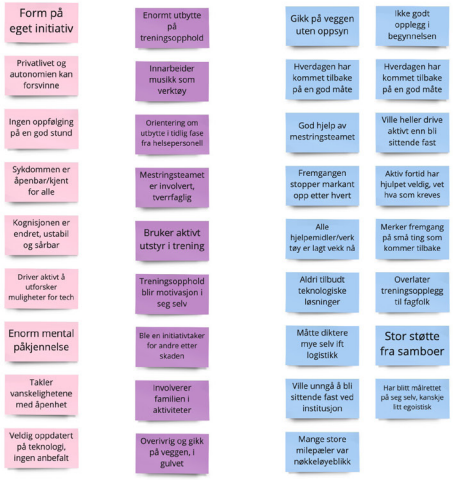
THERAPIST INTERVIEW 1 TAKEAWAYS

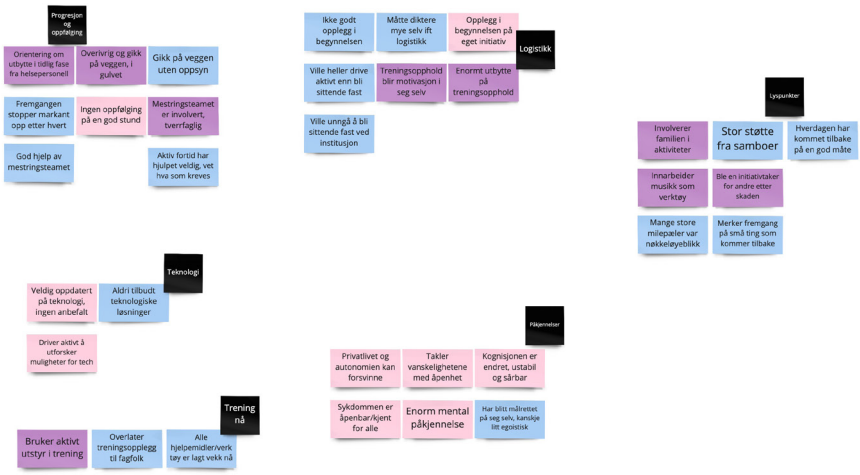


THERAPIST INTERVIEW 2 TAKEAWAYS

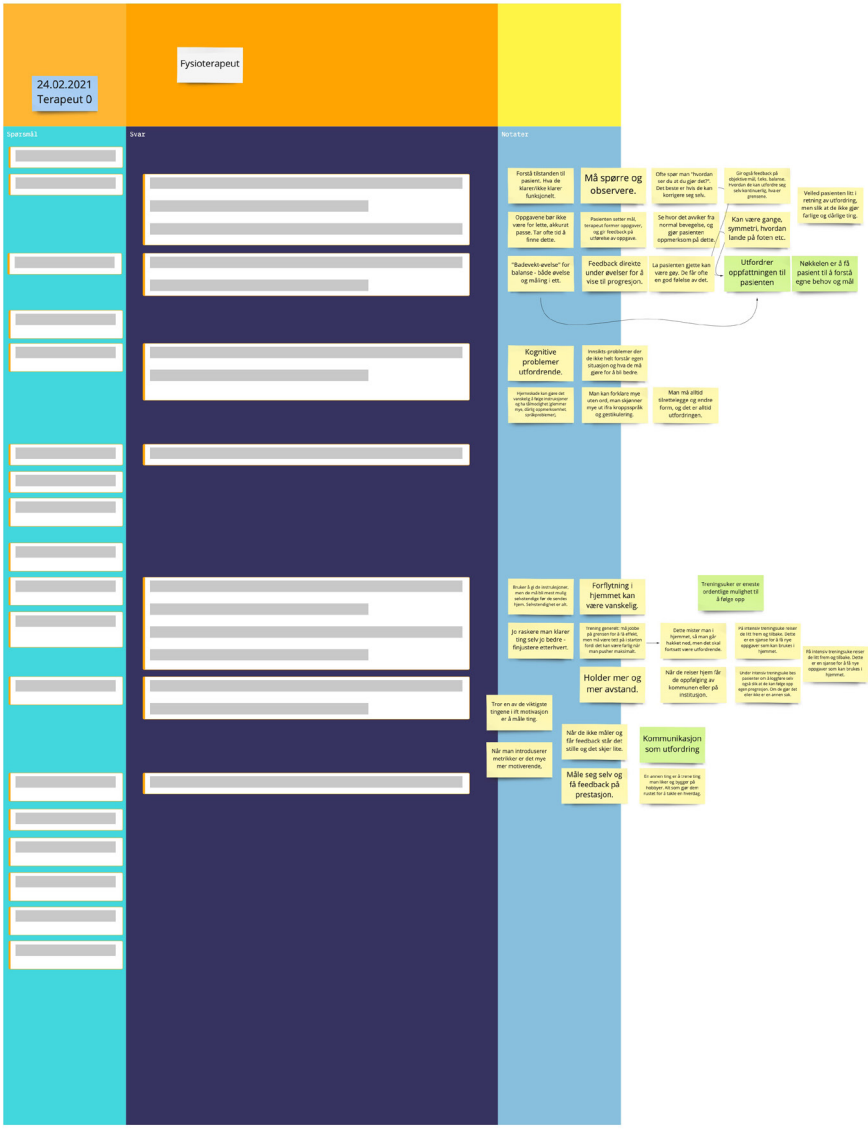


PATIENT INTERVIEW TAKEAWAYS

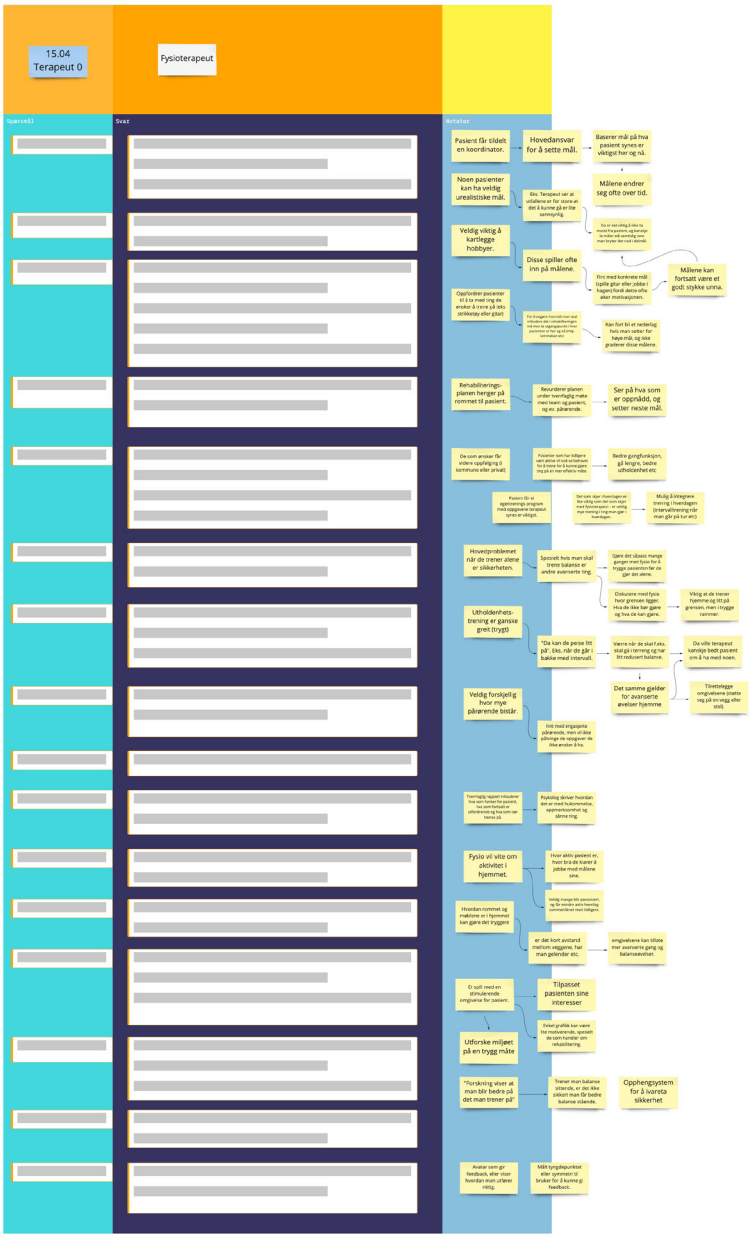




THERAPIST 0 INTERVIEW 1



THERAPIST 0 INTERVIEW 2



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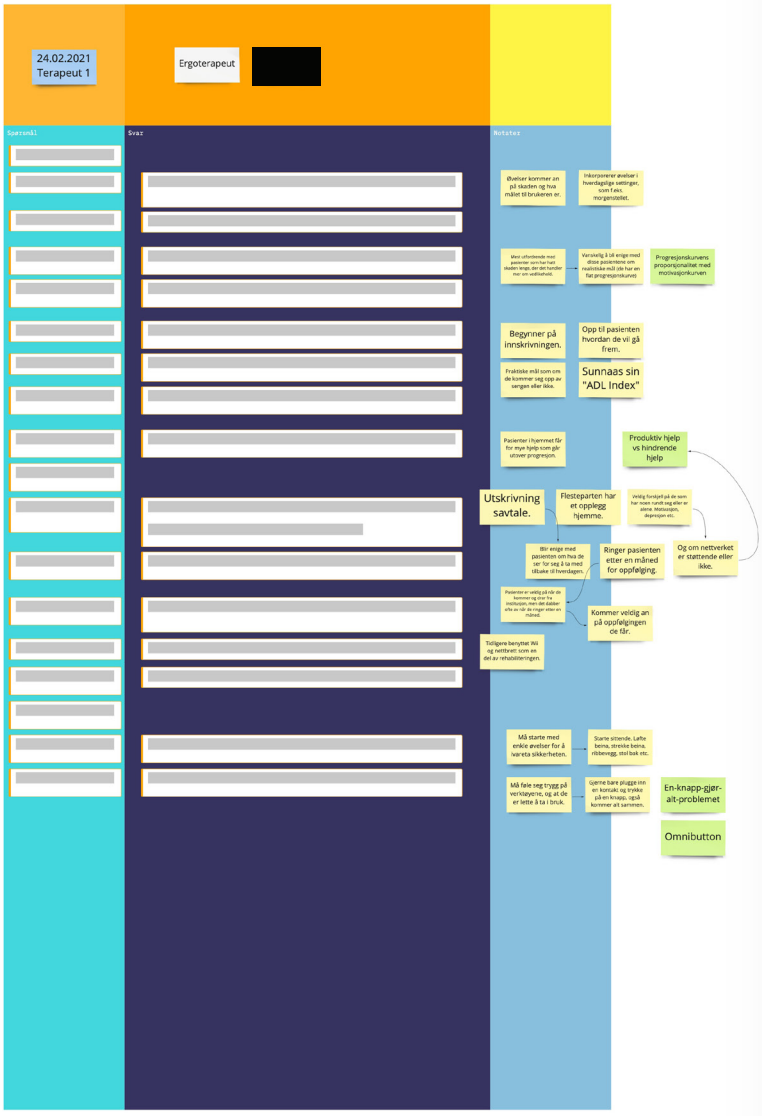

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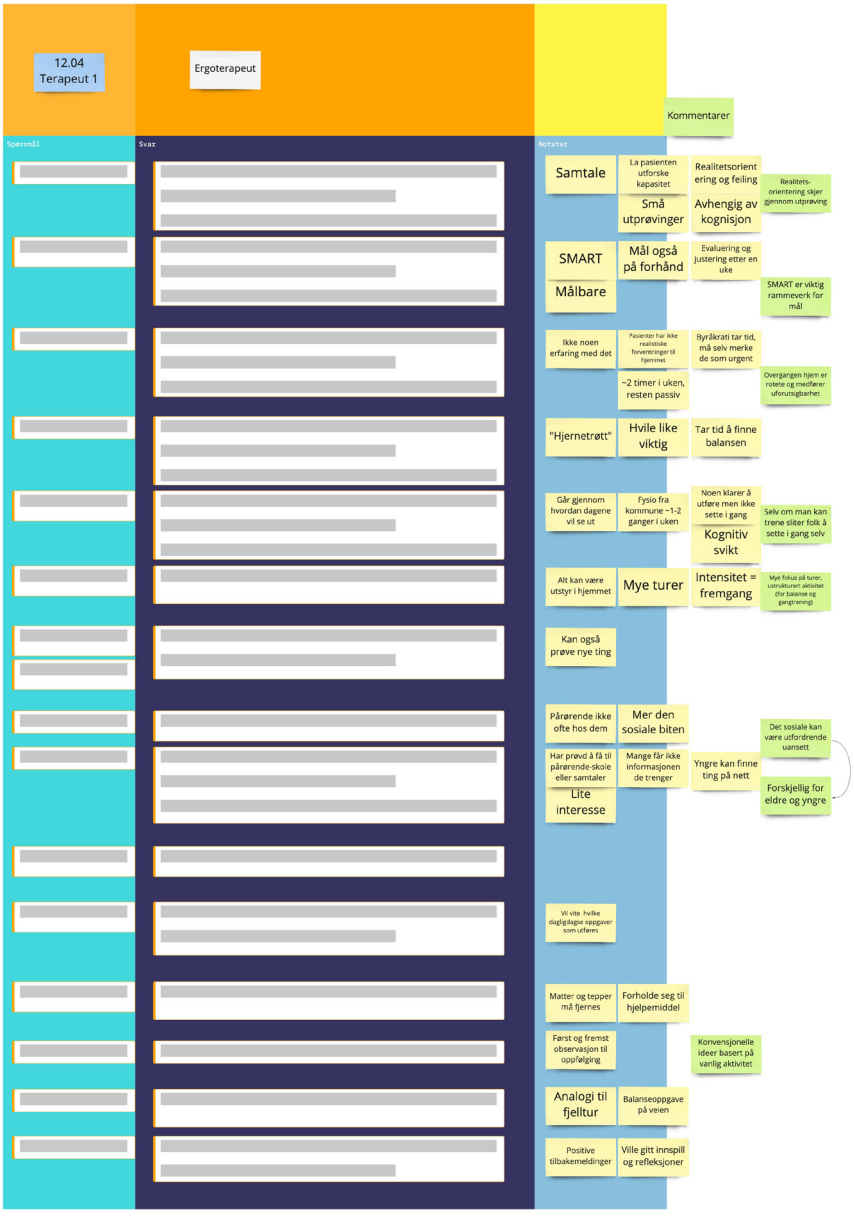

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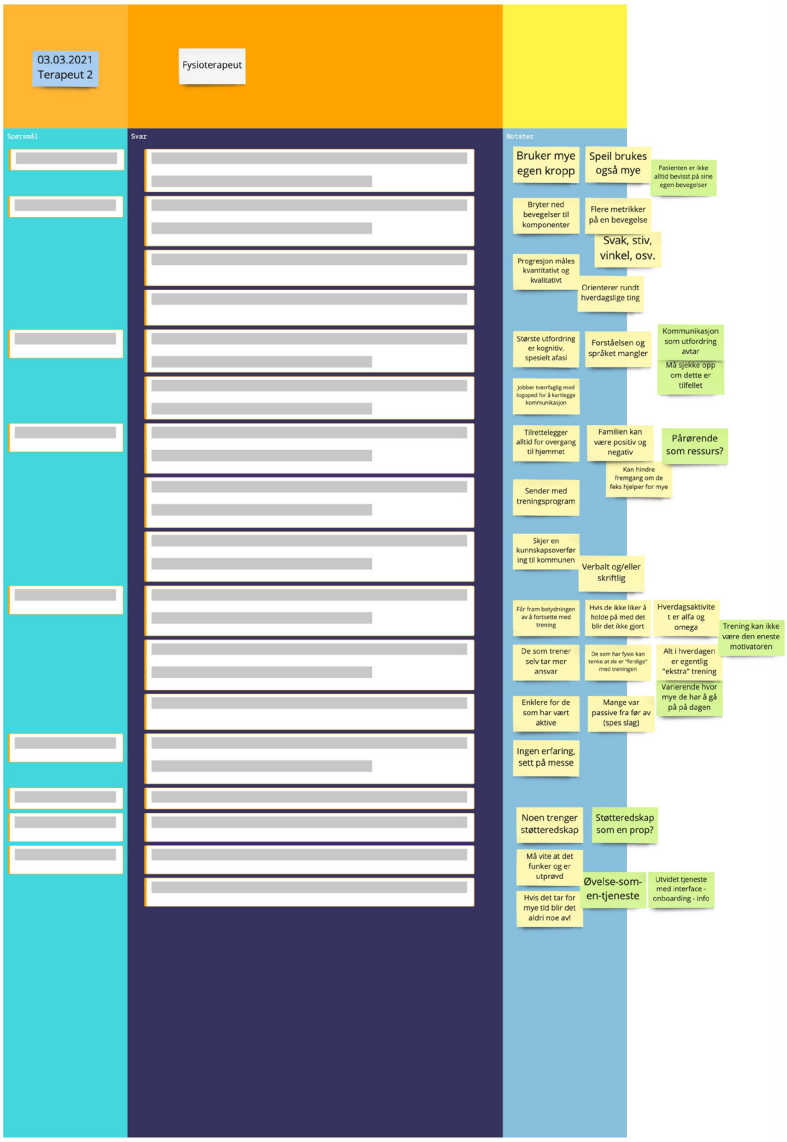

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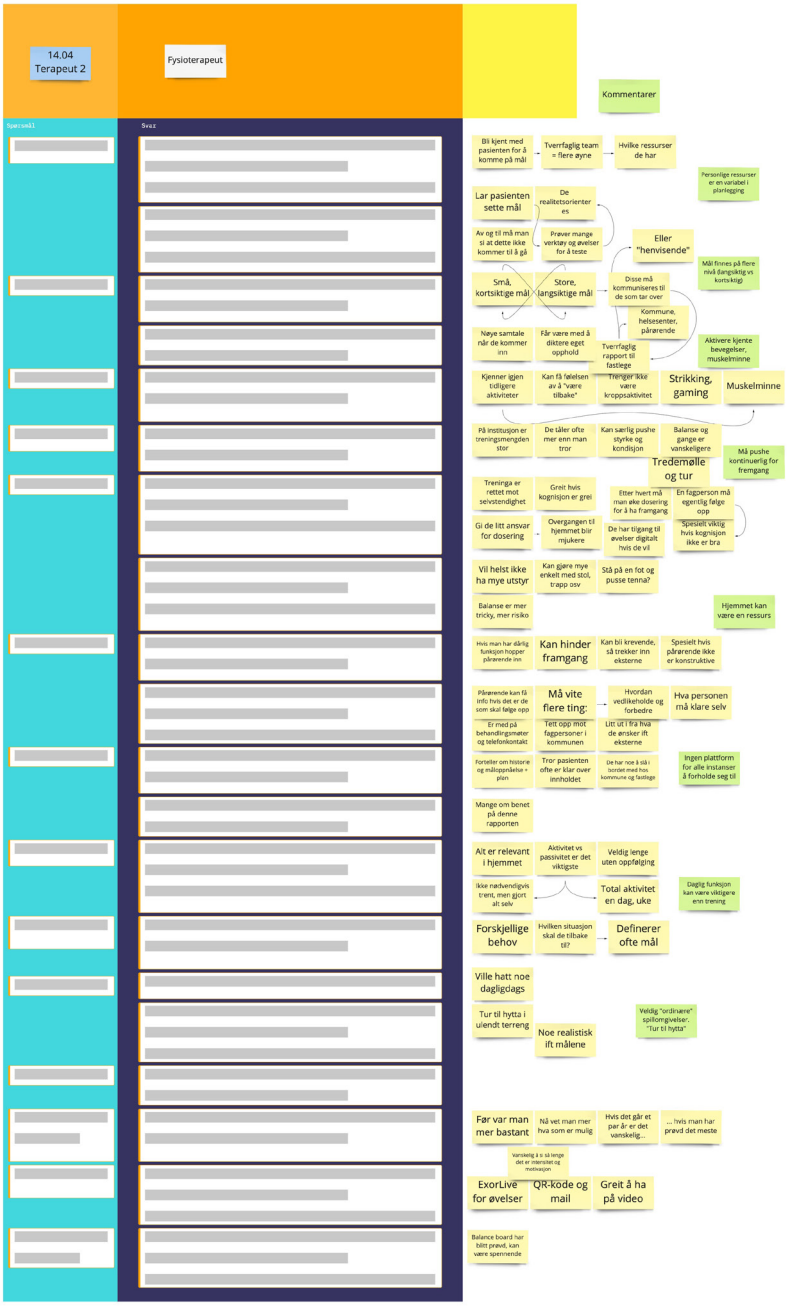
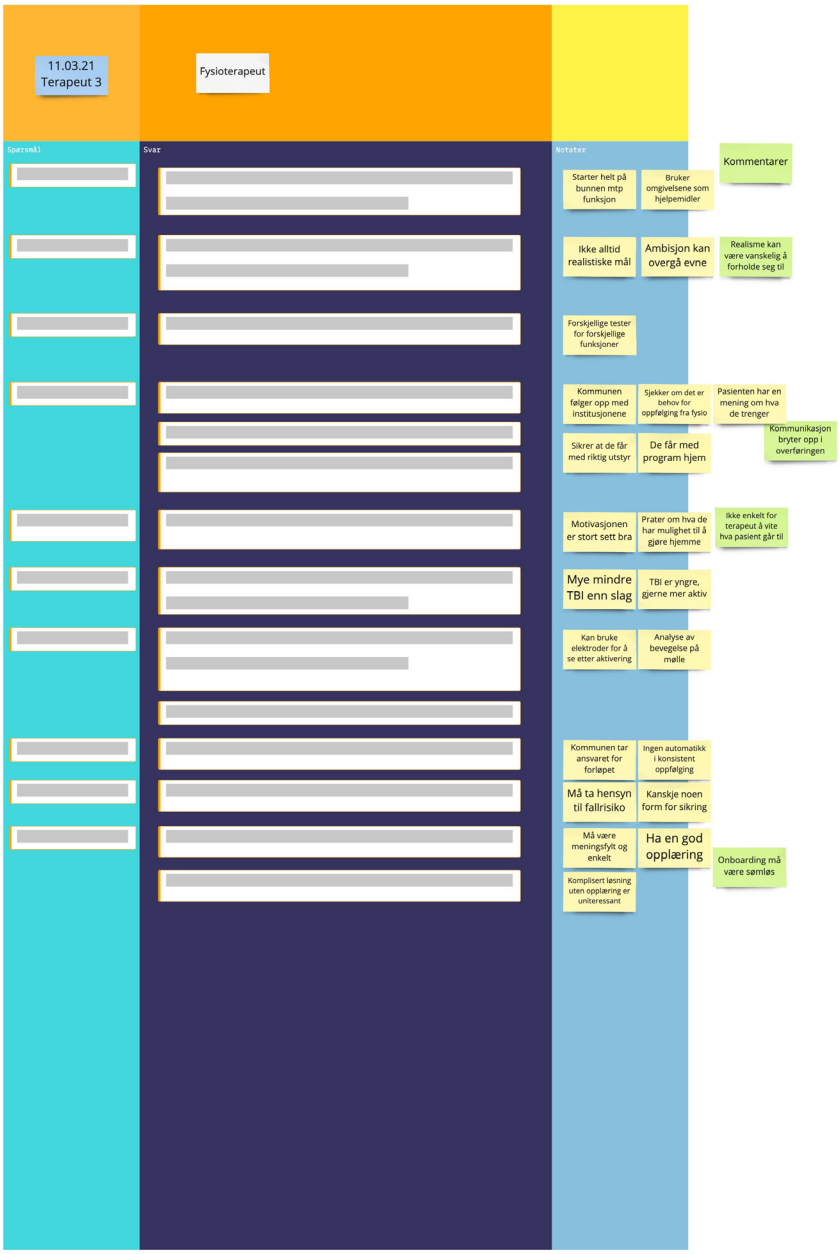
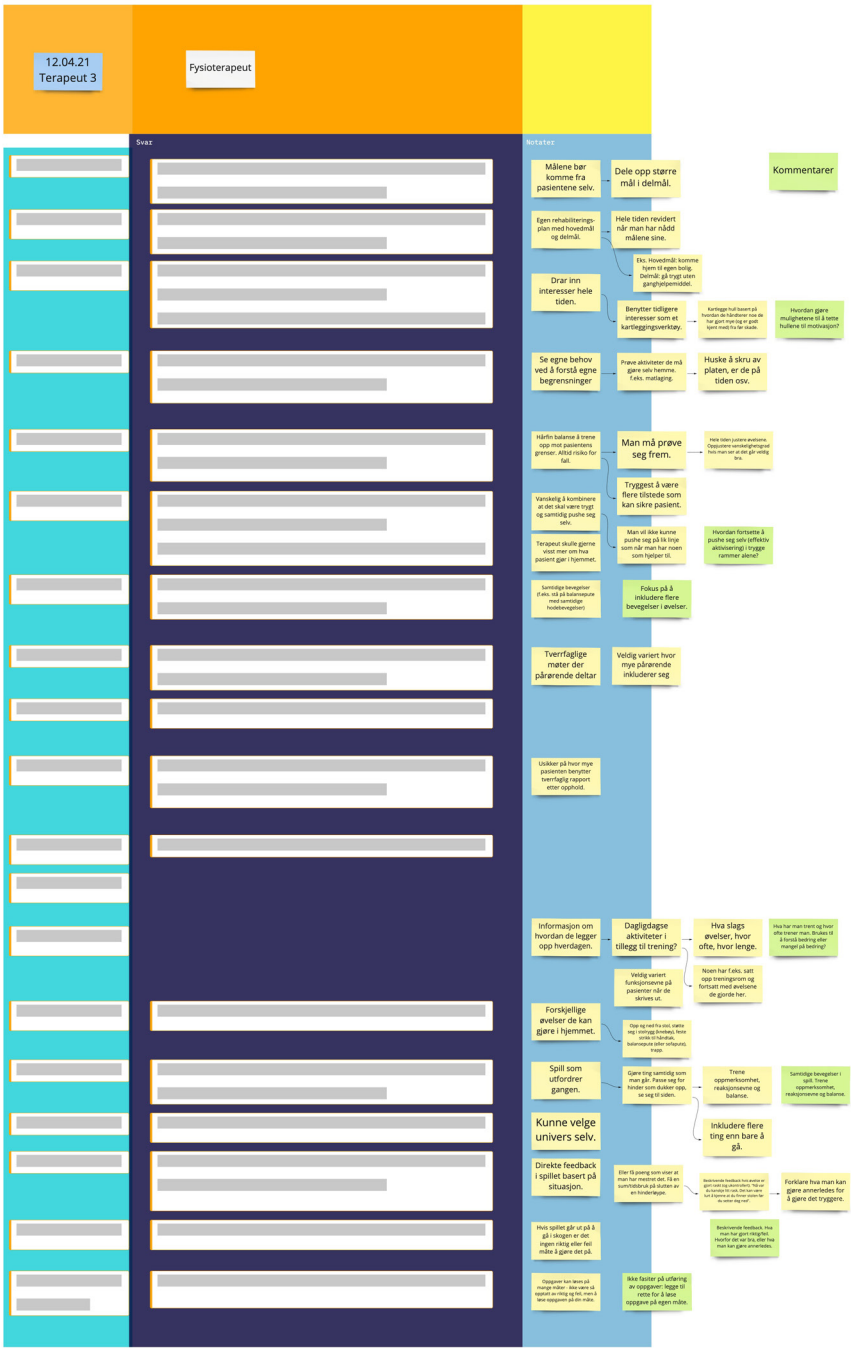


THERAPIST 3 INTERVIEW 1

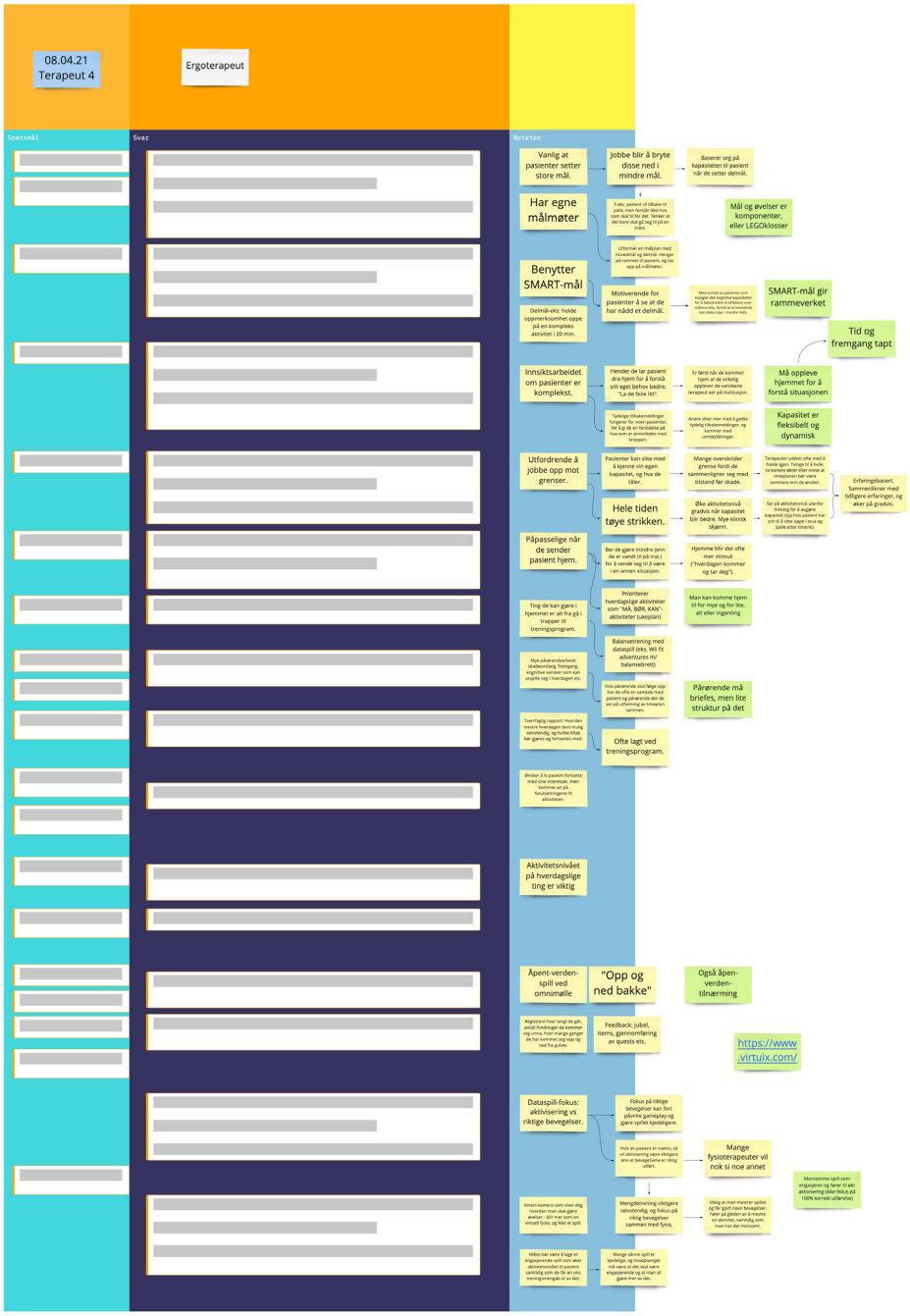


THERAPIST 3 INTERVIEW 2

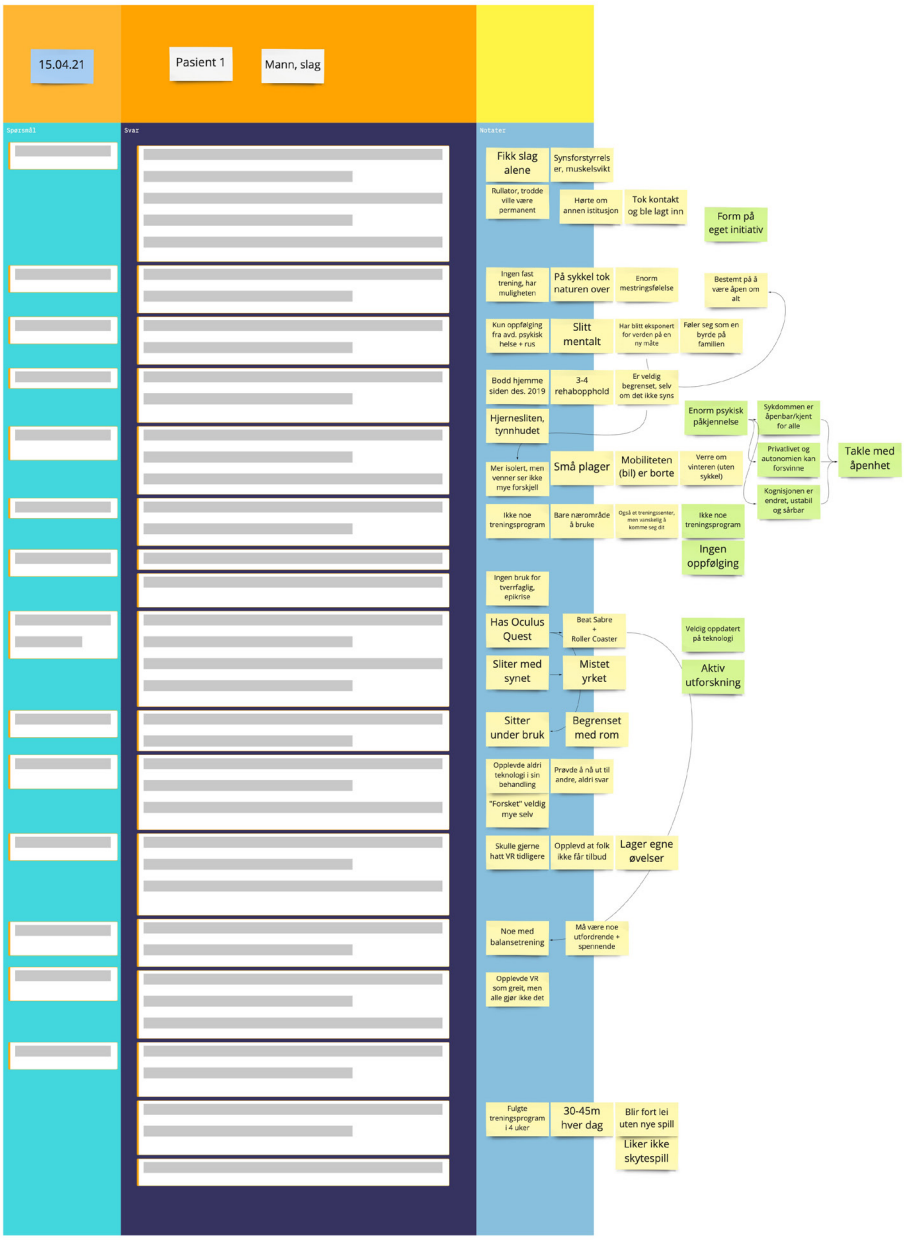


THERAPIST 4 INTERVIEW 1

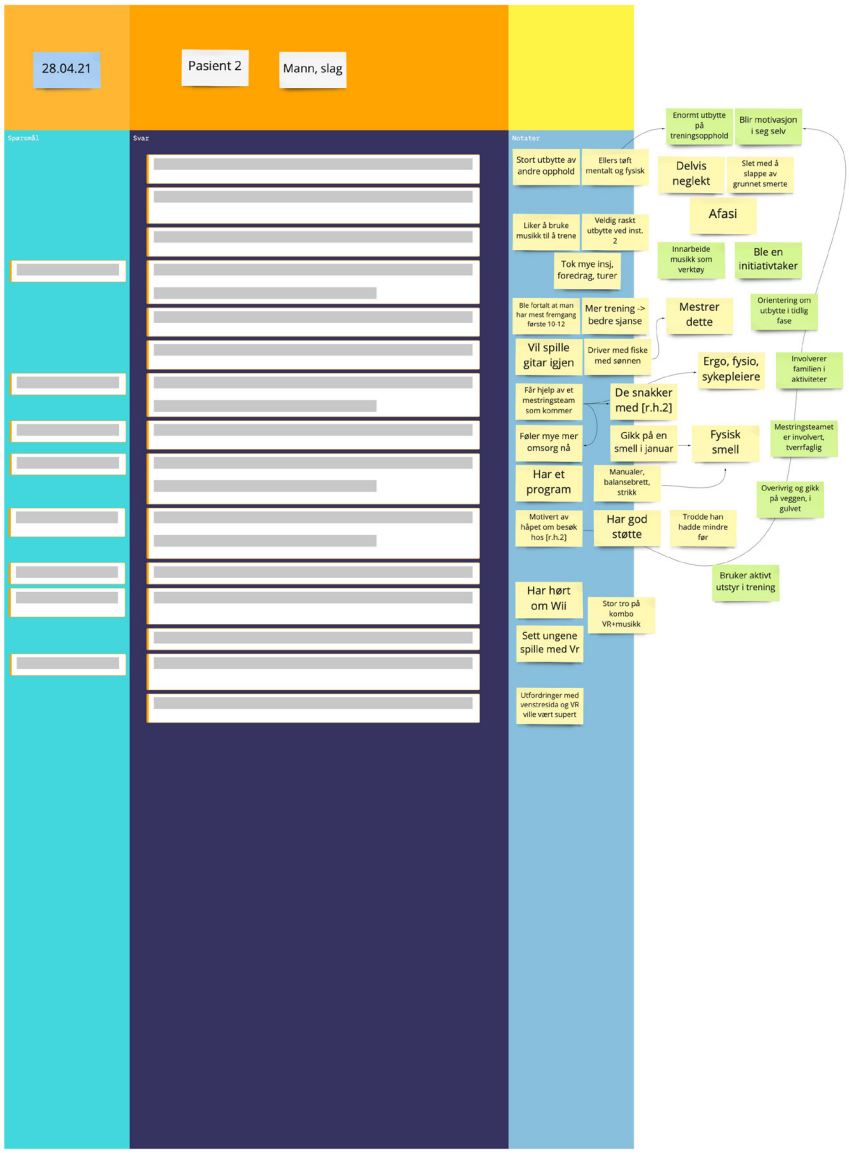
THERAPIST 4 INTERVIEW 2



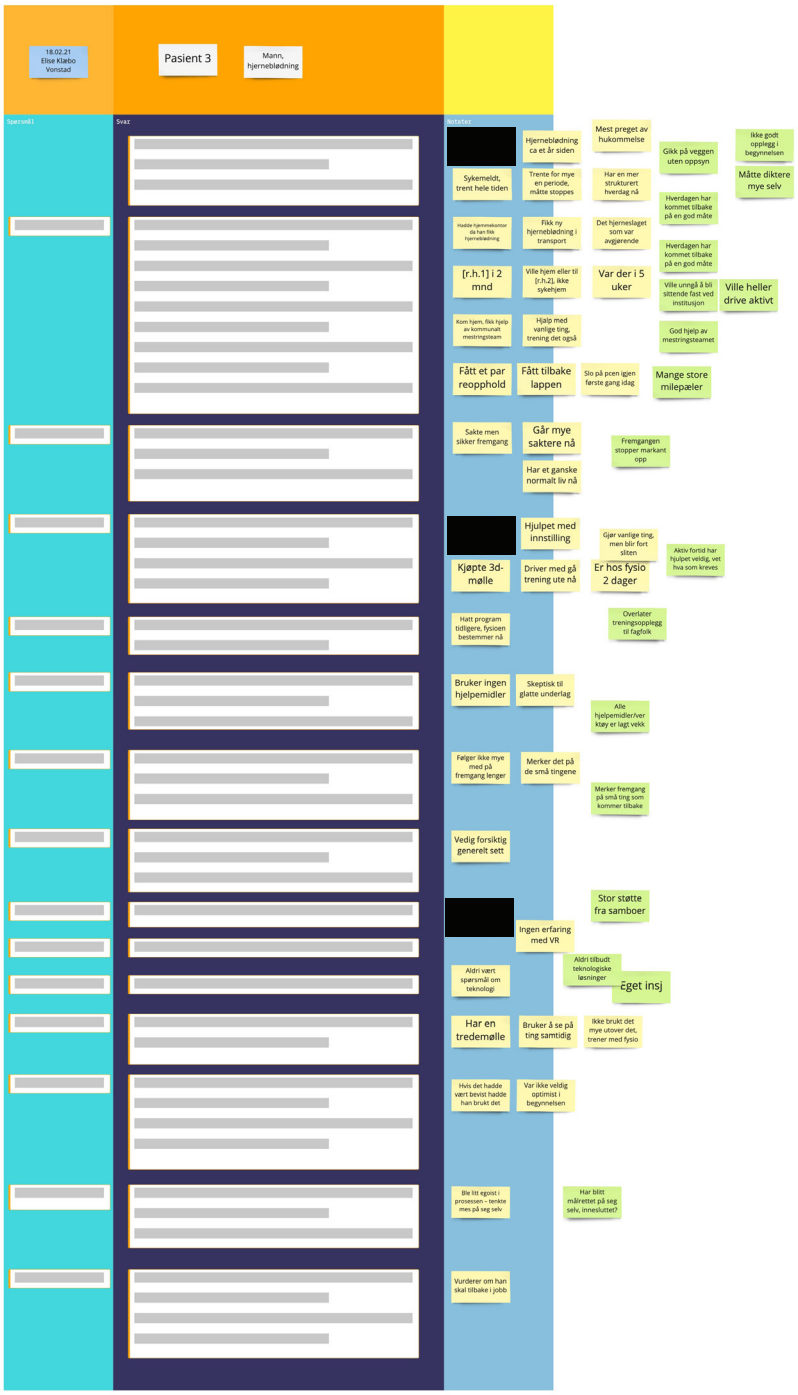
PATIENT 1 INTERVIEW



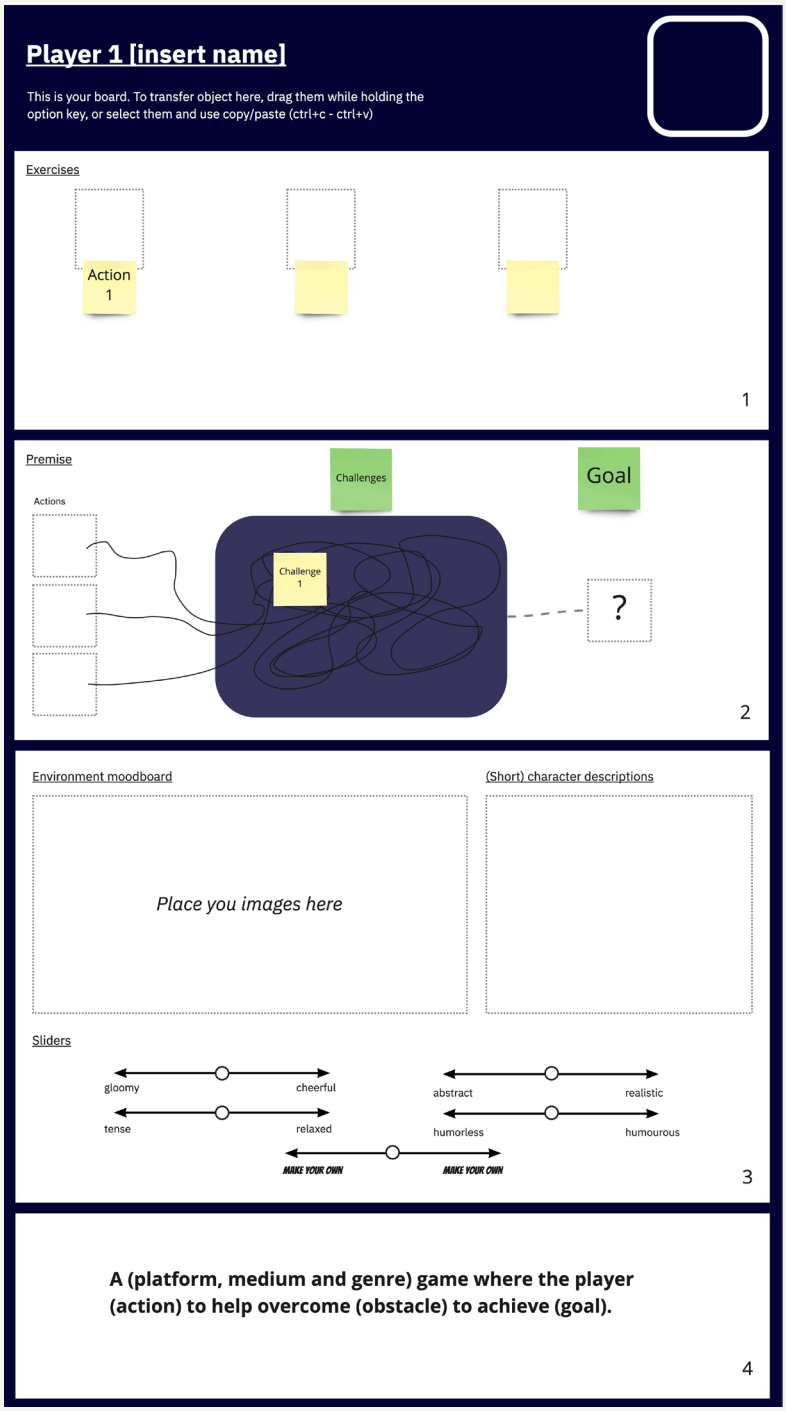
PATIENT 2 INTERVIEW



PATIENT 3 INTERVIEW



PLAYER CARD TEMPLATE



FINAL GAME CARD TEMPLATE

Final game

Come together and fill in the details of the game!

What's the backstory?

From what perspective do we view the player?

How do you control the player?

Who is the antagonist, if any?

Does it have a reward system?

How do you win in the game?

Does the game have levels? How do you progress?

What genre is the game?

WORKSHOP 1 PLAYER 1 CARD

Player 1

This is your board. To transfer object here, drag them while holding the option key, or select them and use copy/paste (ctrl+c - ctrl+v)

Exercises


Hip control with a swiss ball

Kick the mule

Push a car

Controll a rubber duck don a river

Holding back a wild dog


Jumping on the spot

Crushing grapes

Kenga line

African jumping dance (in a circle with masai

Holding a baloon into the air


Standing up and sitting down

Sit down to pee

Riding a horse

Will mister reskit please stand up (monty pyton) hcamo - hiding

1

Premise

Actions

Challenges

Goal

Thai back massage

Try to see in a crowed

Walk on jelly

to cure corona backs (fast order chef style)

straighten backs curved in different directions

to hear the back pops (5 props per back for max score)

17 mai toget

To avoid thrown beer (pub)

To find George

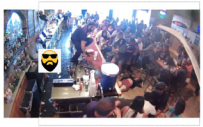
to make it to the center creampuff

to pick up candy

to get to the dock/boat/

2

Environment



Characters

Sliders

gloomy — cheerful

energetic — peaceful

tense — relaxed

try-hard — casual

archaic — futuristic

abstract — realistic

humorless — humourous

? make your own — make your own

3

A first person beer fight game where the player stands up to see cups coming and ducks to stay beer-free to win

or

a Thai massage game where the player pushed at backs to win pops and clears the waiting room to win (fast food chef style)

4

WORKSHOP 1 PLAYER 2 CARD

Player 2:

This is your board. To transfer object here, drag them while holding the option key, or select them and use copy/paste (ctrl+c - ctrl+v)

Exercises

Ankle dorsiflexor strengthening in sitting without weights

Steeping on Lego

Avoid a spid

Avoid tickeling

pat the cat

Straight leg raise with Theraband

Swimming

Scare away birds

Football to the moon

Kick away stuff

Squatting with theraband around knees

Sitting down on a hot surface

Squeezing fruit with your butt

Ski jumping

1

Premise

Actions

Challenges

Goal

Downhill skiing

Go down to get faster

Avoid trees by leaning

Avoid stones by jumping

Walking in water

Get your surfboard out first

Don't step on sea urchins (?)

Be aware of the jellfish

Surfing

Get the best wave first

Make a sick trick

Stay on the board as long as possible

Win the Slip & Slide Cup

2

Environment

Characters

Sliders

gloomy — cheerful

energetic — peaceful

tense — relaxed

try-hard — casual

archaic — futuristic

abstract — realistic

humorless — humourous

single player — multiplayer

3

A (first person ski and surf simulator) game where the player (moves his legs & core) to help overcome (the dangerous animals and snowmans) to achieve (the 1st place of the Slip & Slide Cup against other players).

4

WORKSHOP 1 PLAYER 3 CARD

Player 3:

This is your board. To transfer object here, drag them while holding the option key, or select them and use copy/paste (ctrl+c - ctrl+v)

Exercises

Leaping from a standing start and landing on both legs

Stand on unstable surface

Reaching for a target on the wall

Jumping on the moon
Touching the void
Skiing
Long jump
Snake pit
Standing on top of a pole
Grape pressing
Walk the plank
Painting a masterpiece
Wave away flies
Salute the dictator
Push down the wall
Pick cherries or apples
Pain the house wall
Hold a ping pong ball into the air

1

Premise

Challenges

Goal

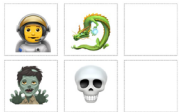
Actions

The floor is lava
Don't fall into lava
Avoid burning yourself
Get points for geting over the lava pit
Hold a badminton feather into the air
Reach a specific number of hits
Set a new personal best
Switch from balloon (slow) to tennisball (fast)
Get trough the obstacle course
Stand in a canoe
How long can you balance?
Avoid getting wet
Get down the river

2

Environment

Characters



Sliders

gloomy — cheerful
energetic — peaceful
tense — relaxed
try-hard — casual

archaic — futuristic
abstract — realistic
humorless — humourous
make your own — make your own

3

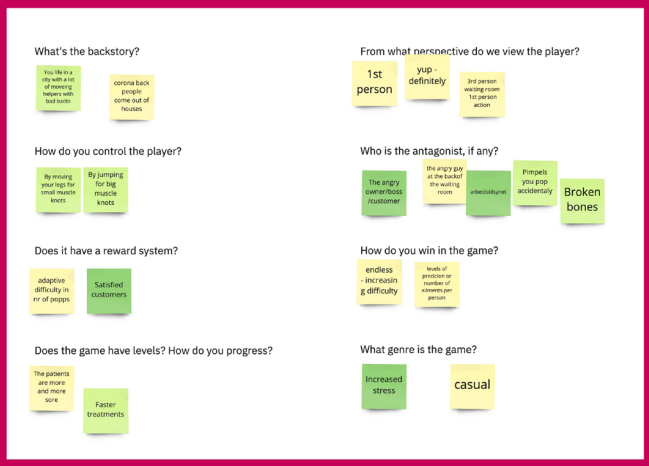
A first person adventure game where the player jumps over and avoids obstacles to get through an obstacle course and avoid the hot lava pit and score points

4

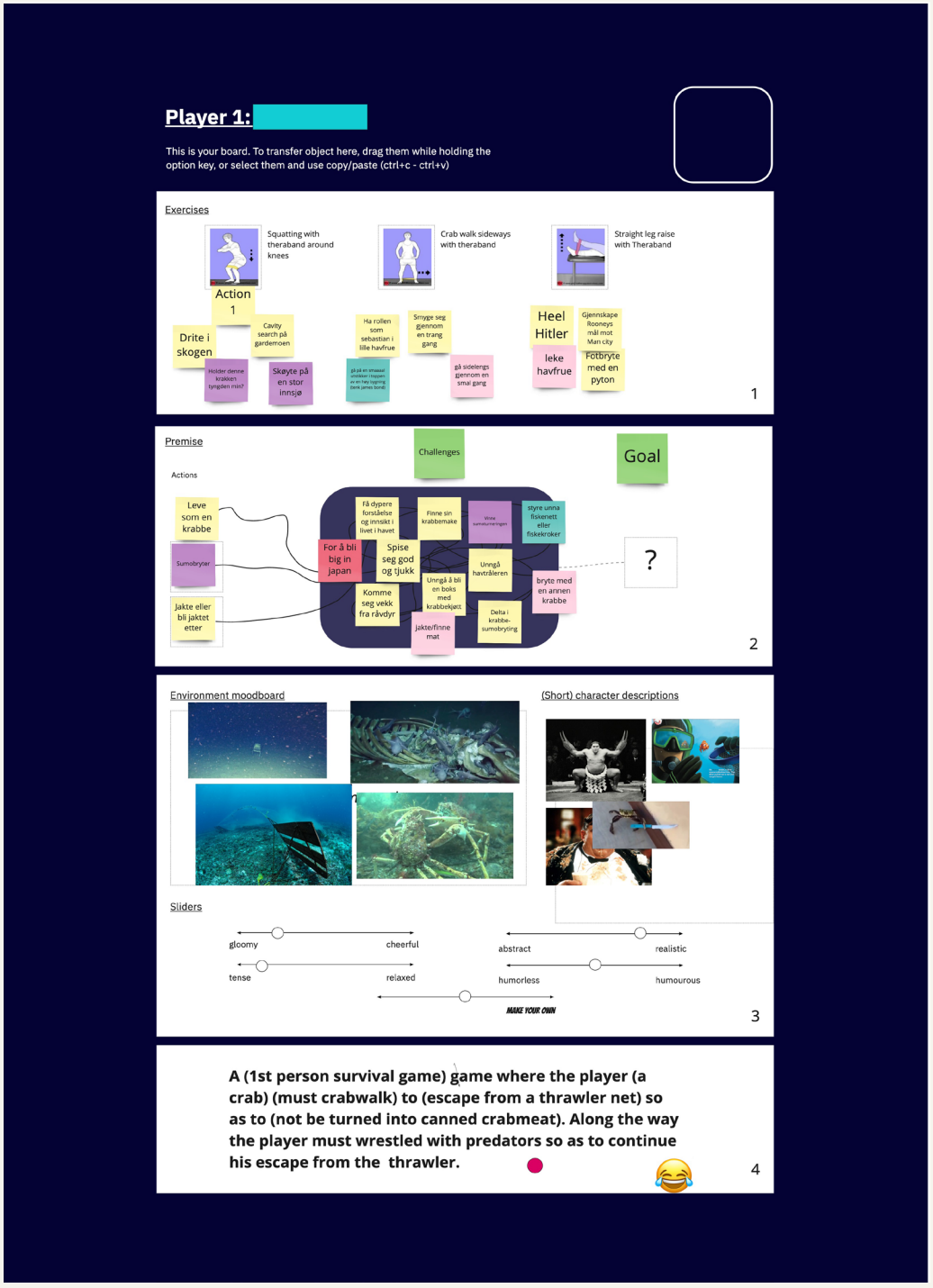
WORKSHOP 1 FINAL GAME CARD

Final game

Come together and fill in the details of the game!



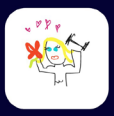
WORKSHOP 2 PLAYER 1 CARD



WORKSHOP 2 PLAYER 2 CARD

Player 2

This is your board. To transfer object here, drag them while holding the option key, or select them and use copy/paste (ctrl+c - ctrl+v)



Exercises

Hip control with a swiss ball

Dytting av seng

Varme tærne på noen

dytte vekk overgriper

Leaping from a standing start and landing on both legs

Løpe, og bråstoppe foran en vegg

Hoppe over bekk

Hoppe over en slange

Hoppe paradis

Hoppe av disse

entré på en scene

Stand on unstable surface

surfe

stå på ski

bli dyttet av elefanter

stå i senga på madrass

stå i båt

1

Premise

Actions

hoppe i blomsterenga

se på skyer

dirigere noe? trafikk ellernoe

Challenges

unngå at traktoren kjører over piknikken

styre slik at bier ikke stikker bestemor

ikke ødelegge blomster

trampe på insekt

se om det kommer regn

se hvilken vei viden går

finne en spesiell sky

sliten

lei av å stå

hjelpe maur til å finne maten

late som man er en kanin

passe på at kuene ikke løper ned blomstene

finne et kodeord

Se etter ansikt på gamle flosser

finne mønstre / figurer i skyene

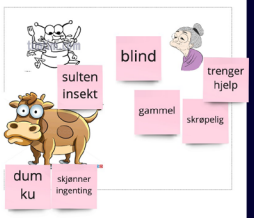
Goal

?

2

Environment moodboard

(Short) character descriptions



Sliders

gloomy — cheerful

tense — relaxed

abstract — realistic

humorless — humourous

MAKE YOUR OWN

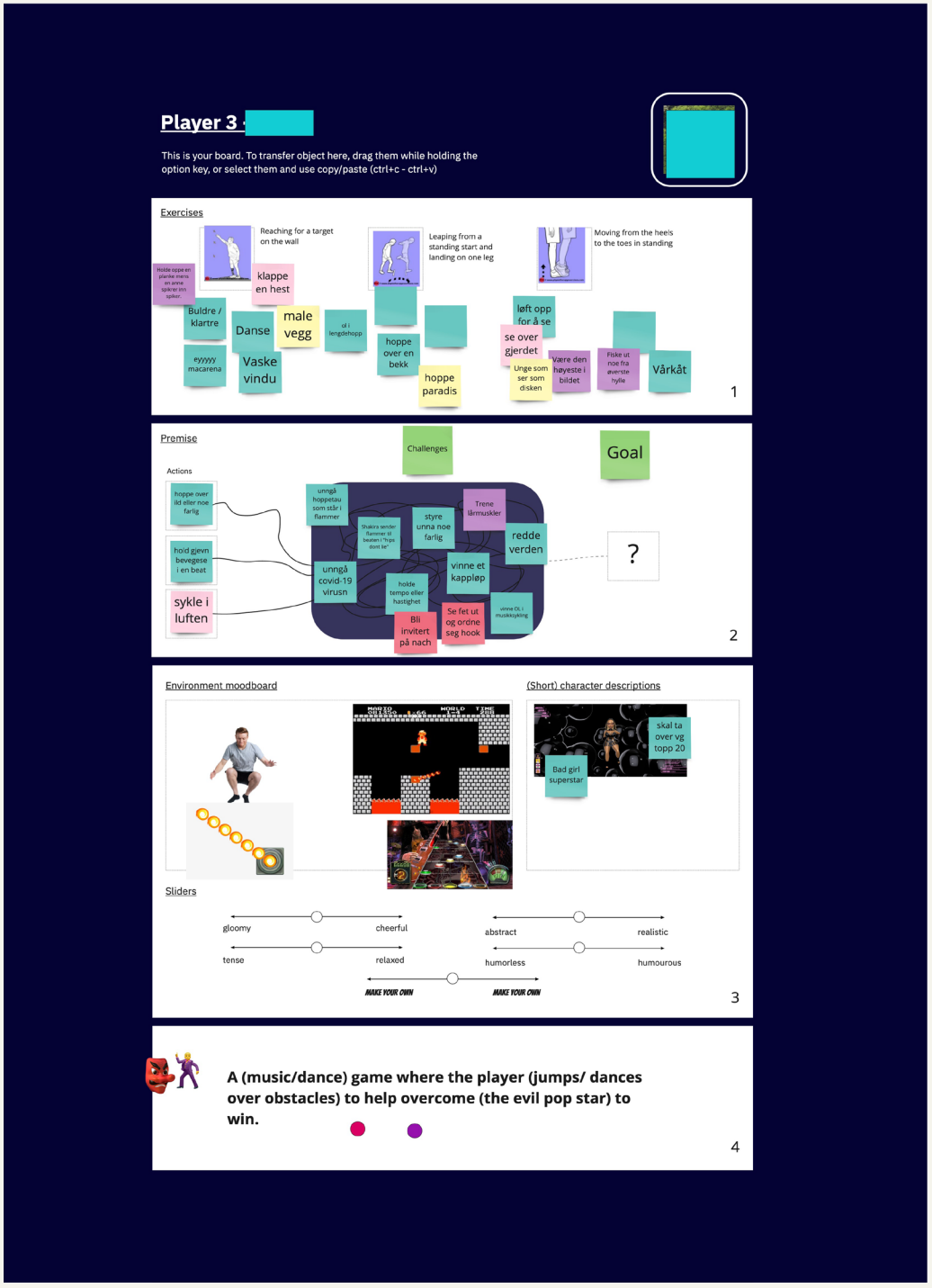
MAKE YOUR OWN

3

Du skal ut på piknik med bestemor. Underveis må du passe på at kuer og insekter ikke spiser opp maten og løper dere ned, slik at du og Bestemor kan nyte pikniken ute på blomsterenga.

4

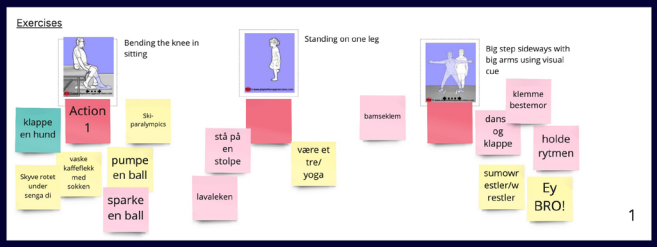
WORKSHOP 2 PLAYER 3 CARD

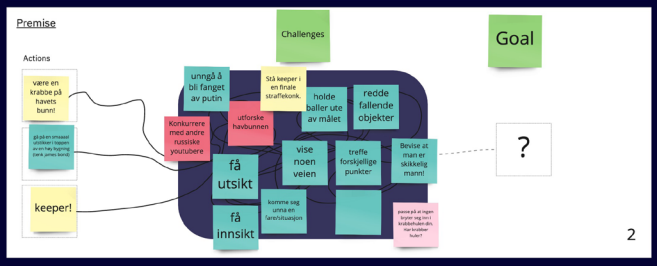


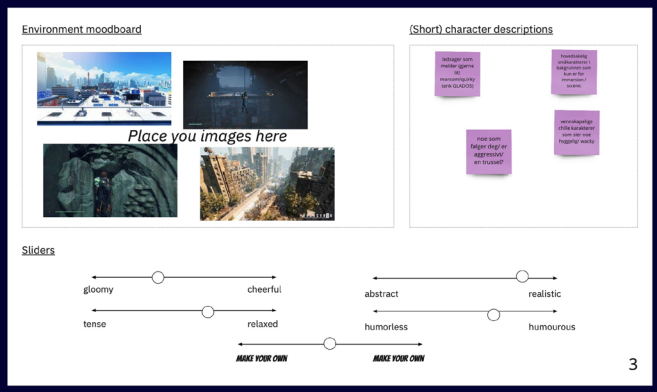
WORKSHOP 2 PLAYER 4 CARD

Player 4

This is your board. To transfer object here, drag them while holding the option key, or select them and use copy/paste (ctrl+c - ctrl+v)







Et "platformspill" hvor du må finne ut av/ følge en rute gjennom puzzles/ bevegelsesutfordringer, for å komme deg til slutten av nivået. Inneholder karakterer og "lore" som gir en følelse av dybde og skaper engasjement.

4

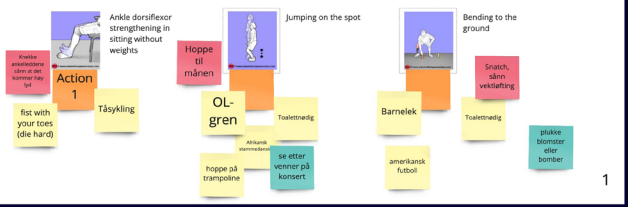
WORKSHOP 2 PLAYER 5 CARD

WORKSHOP 2 PLAYER 6 CARD

Player 3

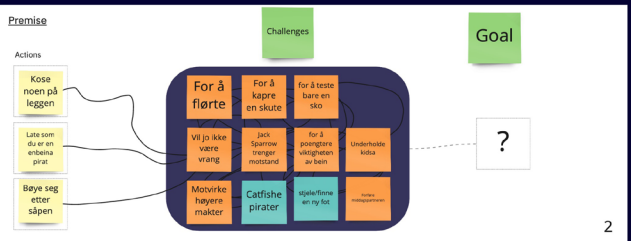
This is your board. To transfer object here, drag them while holding the option key, or select them and use copy/paste (ctrl+c - ctrl+v)

Exercises



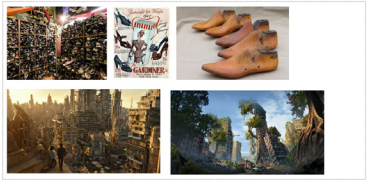
1

Premise

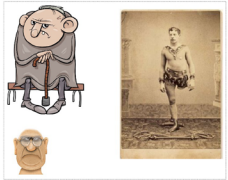


2

Environment moodboard



(Short) character descriptions



Sliders

3

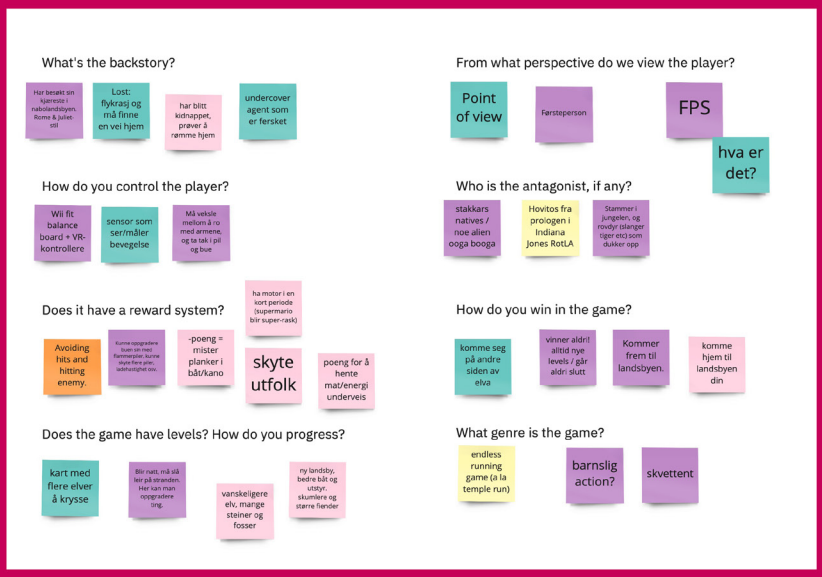
Et voksent strategispill, hvor karakteren utgir seg for å være en enbeina pirat, som prøver å kapre en skute, for å poengtere viktigheten av beinas funksjon.

4

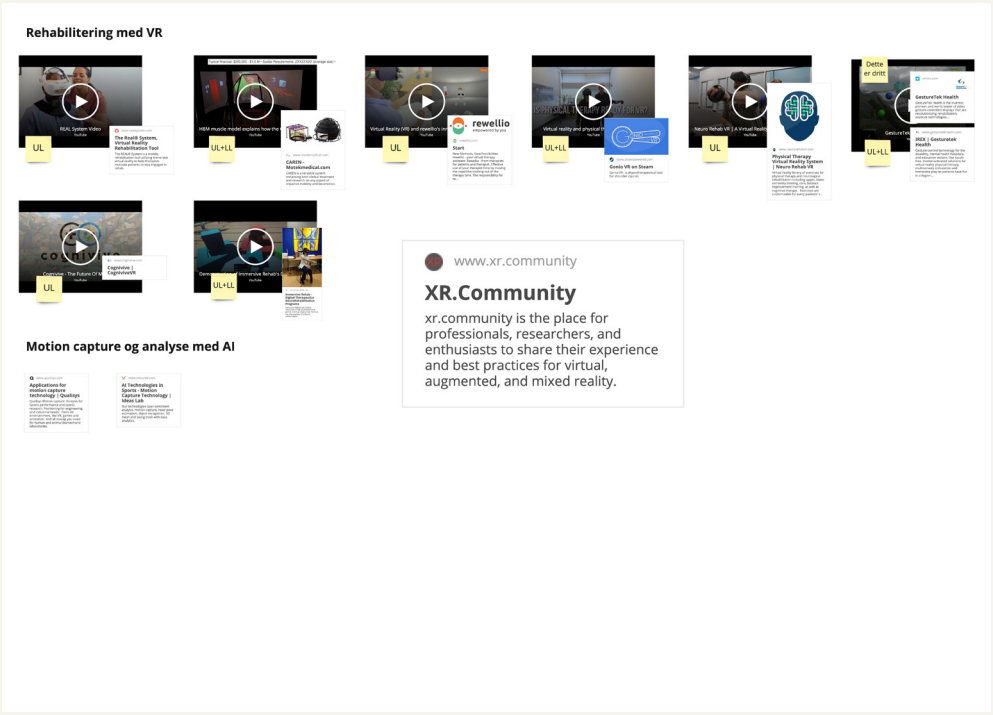
WORKSHOP 2 FINAL GAME CARD

Final game

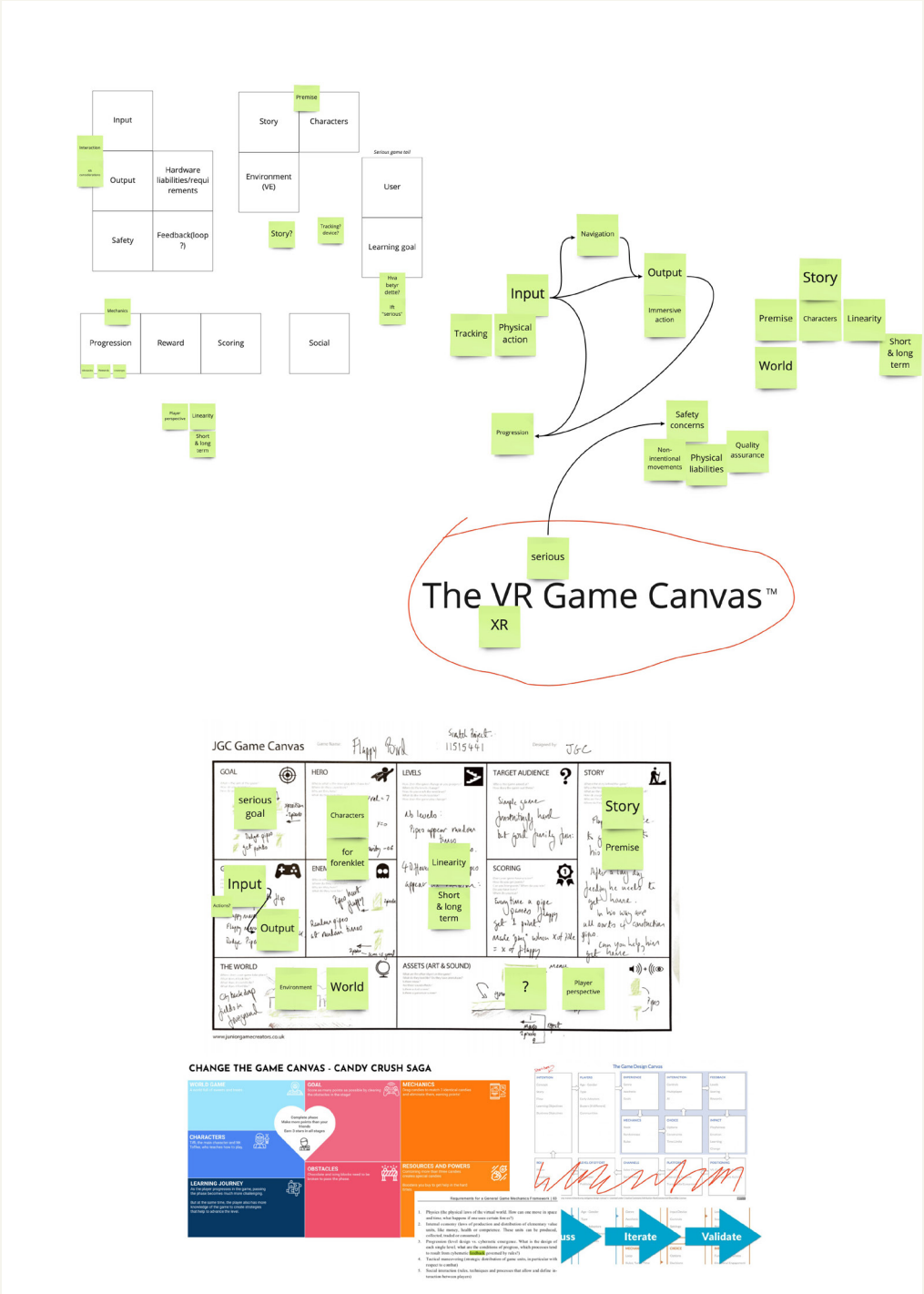
Come together and fill in the details of the game!



COMPETITORS



VR GAME CANVAS INPIRATION AND PROCESS



A. B. Støen & M. L. Fridheim

VRehab – Designing for VR-based serious games in neurorehabilitation

NTNU

Norwegian University of
Science and Technology