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CorpOperatio

Game-inspired App for Encouraging Outdoor Physical Activity for People with Intellectual Disabilities

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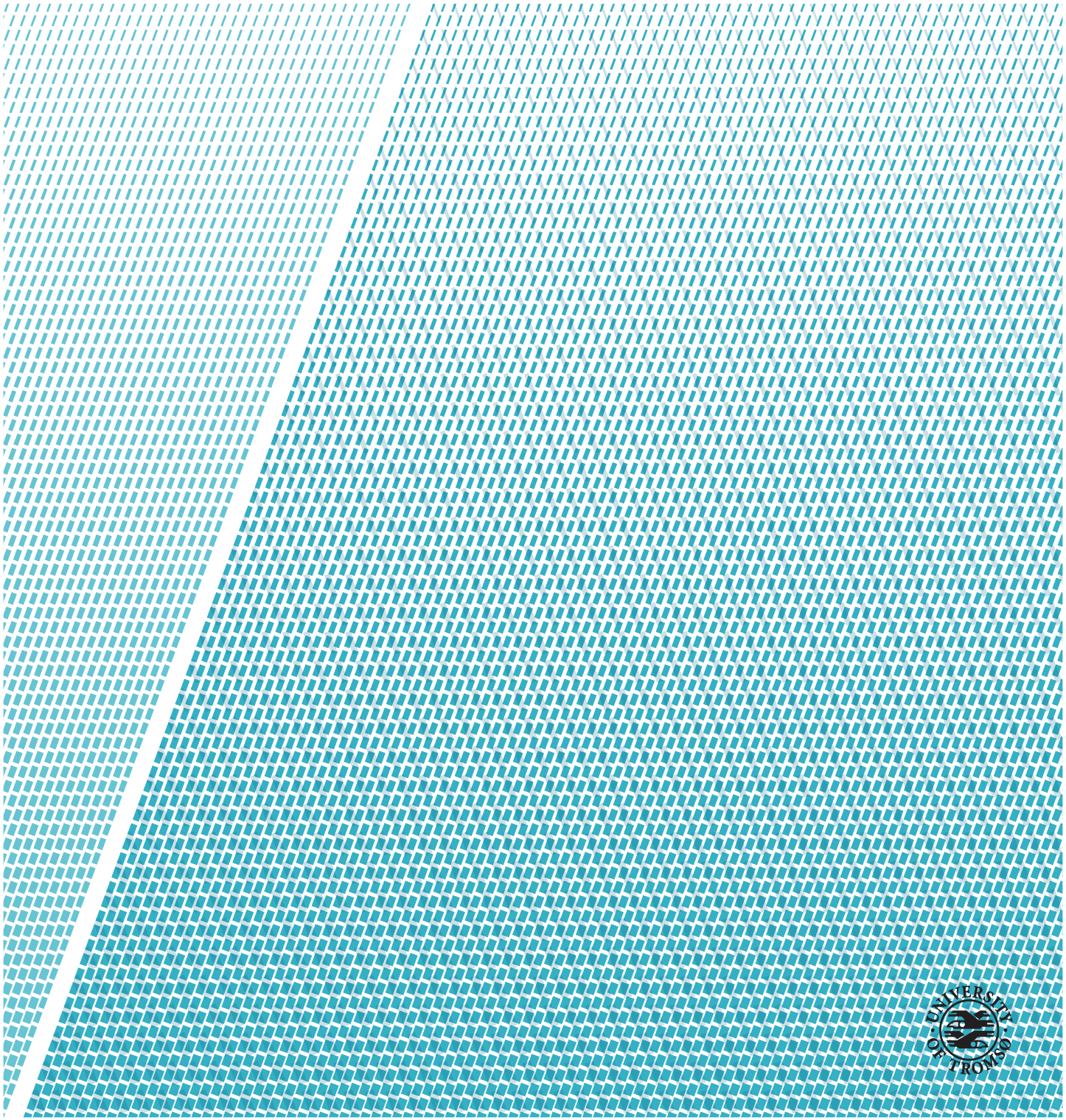

To my family, friends, and girlfriend

For being available and reliable at all times.

“Wikipedia is the best thing ever. Anyone in the world can write anything they want about any subject, so you know you are getting the best possible information.”
–Michael Scott

Preface

How do we help the people that society forgot? That's the question that has been ringing in my ears over the last five months.

When I started on my master thesis five months ago, I had expectations to what it would be like. Expectations I got from fellow students, professors at my institute, family, friends and relatives. The expectations mainly consisted of hard work, unexpected turns and a deep understanding of self-consciousness.

Even before the thesis started I knew that I would be creating something for people with intellectual disabilities, a group partly forgotten by a large part of general society, a group that is not in the center of attention when large corporate organizations create their products, a group of people like you and me, living their lives, but as studies show, not to the fullest extent. I wanted to change that.

I had done a short project for people with intellectual disability before starting my master thesis, and the experiences from that was nothing short of amazing. The feeling I got when our project was presented, and we were told that our application possibly could help people quite immediately was something I had not experienced before.

Over my five years here at the university I have done numerous practical assessments, as parts of courses. Things that are technically tough, demanding hours and hours of hard work and deep concentration, but when the assessment is done, the system or solution created has had no impact on anybody. So when I encountered a course where the main assessment was something that could help people increase their quality of life, I encountered a feeling I had not yet encountered over my years at the university; the feeling of making an impact.

I would like to thank Professor Gunnar Hartvigsen for being my supervisor for the last five months. His engagement over this period has helped me immensely, by putting off time every week for progress meetings, revisions and meetings to improve the worked upon solution is quite impressive. Taking off time both

during and after work hours, if that was necessary. Thank you.

My co-supervisors, Prof. Javier Gomez Escribano, Miroslav Muzny and professor and senior doctor Audny Anke, also deserves a thank you for attending my supervisions, arranging test facilities and sharing conversations.

I want to direct a special thank you to the four guys I've been sharing office with. Sverre Coucheron, Valter Berg, Marius Wiik and Tobias Borgen Olsen. Without you the time at university would not have been the same. Thank you for the discussions, the arguments over Game of Thrones, the laughs and the motivation. Really, thank you.

A big thank you goes out to Elisabet Andresen for enabling testing of our game-applications at Tindfoten dagsenter, and for being so positive from start to end, she became the face of what solutions like these can affect and create. She made a bad situation into a great one.

My girlfriend Carine, thank you for holding up with me and my mood changing with the weather and the progress of the thesis. I'm looking forward to helping out around the house again.

Lastly I want to thank my family for enabling me to do what I want, not only for the last five months or five years, but for my life. I'm immensely grateful for the lengths they've gone to help me.

I think that's everyone.

Vebjørn Haugland Tromsø. 2019

Abstract

This thesis presents a serious mobile exergame for people with intellectual disabilities, to help people with intellectual disability be more physically active. Exergames are games with the purpose of physically engaging the user in the gameplay, and intervenes with sedentariness and repetitive behavior. The game is based around the use of augmented reality, which is described as bringing 3D virtual objects into a 3D real environment in real time.

As the field of physical activity in people with intellectual disabilities is a low-research field, the project aims to create a technical solution to them improve their physical health. There are few solutions tailored for people with intellectual disabilities to aid in physical exercise, something we wanted to change.

A physical activity mobile game was created using the Unity game engine and augmented reality. Requirements and design choices came through literature review, reference meetings and meetings with professional psychologists. The game was tested by intellectually disabled users in a controlled, randomized trial over the course of four days, with interviews after testing to get results.

While evaluation of the application rvealed areas of potential improvement, the application is already usable for people with intellectual disabilities. Augmented reality proved to be challenging to understand initially, but also fun, once the concept was understood.

We have created an application for encouraging physical activity for people with intellectual disabilities. The application shows promise, but also improvement points for it to be deployed to the public market.

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1 Introduction

Figure 1.1: The author of this thesis in action with 'Dyrejakten'.

1.1 Background

People with intellectual disabilities make up around 2-3% of the world's population[1]. In 2019 that percentage accounted for between 154 million and 231 million people. Viviene Temple[2] estimates that only 20-30% of adults with an intellectual disability meet the current physical activity goal set by the

World Health Organization (WHO), which is 30 minutes of daily moderately intense physical activity or 10000 steps each day. This means that 70-80% of adults with an intellectual disability live a sedentary lifestyle where they spend much of the day engaging in activities where they are not required to engage physically, such as watching TV, playing games, or being physically still.

H. Bergström et al. find that: "People with intellectual disabilities are at high risk of several behavioral risk factors for ill-health such as poor dietary habits, low physical activity, and weight disturbances, increasing the risk for chronic diseases."[3], so even though life on the couch or in front of a screen seems like a comfortable lifestyle for some of us, it can have fatal consequences.

In Norway, the government reports that roughly 18.000 adults with intellectual disability require health and social services. It is reported the health of individuals with an intellectual disability is poorer than that of the general population[4, 5, 6], their health care needs are less often met and they have a harder time accessing health care[7, 8, 9]. People with intellectual disability are more prone to weight disturbances and low physical activity than the general population[10, 11, 12, 13, 14]. In a recent review, it was found that 9% of people with intellectual disability worldwide achieved the World Health Organization's minimum physical activity levels[15]. Meeting these physical activity guidelines was positively correlated with male gender, younger age, milder intellectual disability, and living without supervised care[15]. In the Norwegian population, sedentary lifestyles are a more pronounced problem in younger people[16], and this problem is assumed to be more prominent in the population of youth with intellectual disabilities[17]. The low levels of physical activity shown in individuals with an intellectual disability could be due to barriers, such as scarcity of available resources and opportunities or a lack of motivation[18, 19, 20].

Sundblom et al. suggest that a more flexible approach is needed to increase the physical activity level for people with intellectual disability[21]. E-health support can provide such possibilities for motivating and monitoring people in self-management of chronic diseases[22, 23, 24]. Games directed to improve health situations can change behavior and promote health by influencing the health determinant physical activity[25]. To make a theoretically right solution into a practically good solution, they have to meet the users needs[26].

The touch screen interface of the mobile platform has been shown to have a low level of cognitive demand, and is thus a viable platform for developing systems that can be used to improve adherence to physical activity[27].

1.1.1 Context

CorpOperatio is a sub-project to the project "*Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.*", where the main objective is to enhance the physical activity in youths and adults with intellectual disability. Low physical activity is a determinant of health, and increasing activity has positive effects on cardiovascular and psychosocial health, identifying effective interventions for use in everyday settings is exceedingly essential. The aims for the project "*Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.*" is threefold:

1. To integrate theory with users' needs to design a flexible person-centered physical activity program using motivational e-health support in natural settings.

2. To investigate the effects of this physical activity program in youth and adults with intellectual disability in a randomized controlled trial.

3. To increase research activity and national and international cooperation in this, in Norway, low-research field.

The technical contribution of the research project "*Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.*" shall be the development of tools that can contribute to increased physical activity.

To create such a solution, we want to create a smartphone exergame that can contribute to the research project. The game shall be based around the use of augmented reality to encourage the user and contribute to their physical activity performed outdoors. The idea is that the mobile game can supply the users with positive associations to the activity of outdoor walking.

In Figure 1.1 on page 1 the screen-shot is from a video created by Mirek Muzny[1] for "*Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.*". The video demonstrates the different solutions proposed from the project, CorpOperatio supplies one of those proposals.

1.2 Scope and Research Problem

For this project, we want to develop a game application that encourages and motivates physical activity for people with intellectual disability. The goal of

1. Full video can be found at `https://vimeo.com/334266373`

the game is to create an incentive for users to perform outdoor physical activity, with emphasis on outdoor walking.

In this thesis, we attempt to solve the following research problem:

> *RP: How can we design and implement a mobile game to encourage physical activity for people with intellectual disability?*

1.2.1 Sub-Problems

We further divide this problem into sub-problems.

As we are creating a game application that is set to encourage and motivate users to exercise, aspects of persuasive design become relevant. B. J. Fogg describes persuasive technology as "*interactive computing systems designed to change people's attitudes and behaviors*"[28]. In essence, we are creating a system to positively change the behavior of the users, where the goal is to make them increase their physical activity levels. We word the first sub-problem as follows:

> *RP1: Which motivational theory is most applicable when designing a mobile game for people with intellectual disabilities?*

Secondly, we want the users that have already started a physical activity session in the game-application to continue it until the end, instead of starting it and walking away from it after just a brief amount of time. WHO's recommendations for physical activity[29] is 150 minutes of moderate physical activity throughout the week, accounting for just above 20 minutes of moderate physical activity (such as walking) distributed across each day of the week. We want the user to fulfill at least on average the 20 minutes they have started on the given day of exercise.

We state the second research sub-problem as follows:

> *RP2: How do we encourage the user to continue the physical activity until the end of the session?*

As we are creating a game application for a specific user group, We'll have

to take their special needs into consideration. The game has to have a user interface tailored to the user group, and we have to found the design choices in principles for this group. This leads us to research sub-problem 3:

> *RP3: What special techniques do we have to use, when designing a game-application for people with intellectual disabilities?*

1.3 Method

Over the course of the project, the main research paradigm utilized is the *design* aspect, which is the most common among engineers. It consists of (1) stating requirements, (2) stating specifications, (3) designing and implementing the system, (4) testing the system. The steps are iterative, so that new requirements and specifications are stated after testing the system. Denning et al. argues that in computing, the design aspect is intertwined with the aspects of theory and abstraction, which to a degree have been used as well.

The work performed during the project period was as follows:

- Review of relevant publications.

  Review of relevant publications where we search journals and databases to establish the proper theoretical background, and to find similar approaches to ours.

- Iteratively work towards a viable solution using the literature as a cornerstone.

  The iterative process, described by Denning et al.[30], is used in the process of creating the game. Based on feedback on requirements and specifications, new solutions are created.

- Regular conversations with trained professionals within the field of intellectual disability.

  The feedback from trained professionals give an indication to how good specifications and requirements are.

- Meetings with employees at the facility where we evaluated the product.

One meeting was conducted with the employees of the daycare center we deployed our solutions on. They had feedback to the presented game-application.

- Deployment of game application for test use.

  The application was deployed, where the employees got an introduction to the product. During the test phase we weren't present at the institution.

- Retrieval of evaluation data through interviews with employees at the institution.

  After the finished trial of the game, we interviewed the employee in charge of testing the application.

- Analysis of evaluation data.

  The test data was evaluated and this is presented in Chapter 7 on page 65

The evaluation of the game created is a usability test of the game-application. The user's satisfaction with the game is recorded through interviews after a product testing phase.

The relevant literature produced in the systematic literature review laid the foundation for the development of the game application. Many of the aspects considered in the development of the game came through the literature. Discussions with professionals of intellectual disability, and relatives of people with intellectual disability were also a good resource for requirements for the game.

The main critique to the methods used is the short testing period, due to the short project period. The people replying are not the ones who actually tested the game, so that is worthy of some critique as well.

1.4 Assumptions and Limitations

The user group which this project is aimed at is quite a small subset of the overall population, making up around 2% of the general population in Norway. With a population in the city of just above 76000 people[2] there is not an abundance of available testers in the local area. However, the main problem for

2. `https://www.ssb.no/kommunefakta/tromso` [accessed 04/05/2019]

a system developer and researcher is the availability of the user group; people with intellectual disabilities are thankfully protected by substantial privacy regulations, and reaching them for experimentation and testing, is not a walk in the park.

The limited timeframe of the thesis also mean that the evaluation phase of the project is limited. The evaluation of the game-application is based on the interview of five people, where only one of the respondents has seen the game in physical use, and the other four base their responses on a presentation and demo of the game.

In this project the targeted audience is a subset of people with intellectual disabilities, namely the moderately intellectually disabled. The people in this subset need constant supervision when outside their residential homes. The game-application proposed in this thesis is for this specific user group. In Section 2.1 on page 11, intellectual disability and severity levels are described.

Having five available respondents means that the evaluation satisfies the recommendation of five people that Jakob Nielsen argues is needed to test a system[31]. Spool and Schroeder, however, argue that testing with five users is nowhere near enough[32]. Therefore, we list the low number of testers as a limitation.

In this project, we solely focus on the subset of people with intellectual disability who need constant supervision when outside their residences. This means that the project isn't focused on the intellectually disabled who can manage themselves. Though this somewhat narrows the user group for the project, the author hopes that the game application and game-applications based on this work can be applicable for all user groups both with and without intellectual disability – in all age spectrums.

Also, the main focus is to create a viable solution for the research project *Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.* where the aim is to increase and record the physical activity of people with intellectual disabilities.

The evaluation of the game is done by measuring the usability of it. Even though usability consists of (1) effectiveness, (2) efficiency, and (3) satisfaction, in this project we only cover satisfaction in the evaluation of the game. The results from the evaluation performed in this project is presented in Chapter 7 on page 65.

1.5 Significance and Contribution

The main objective of this project is to provide a viable technical solution for people with intellectual disabilities to make them more physically active. The technical solution is a mobile game application that can be used at any geographical location and is tailored for a user group that previously have had no specially tailored solution with the same objective. The contribution can not only contribute to the physical activity of people with intellectual disabilities, but as a side effect, it can also contribute to their physical and mental health, as well as improving their health and lifestyle situation.

Positive results can contribute to the aforementioned project *Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities* through supplying a viable solution for encouraging physical activity. Relevant literature is identified, and knowledge acquired throughout the project period is documented and can be used for future projects concerning people with an intellectual disability or gamification, using augmented reality.

The research problems listed in Section 1.2 on page 3 can be used for future work.

1.6 Organization

This section covers the organization of the rest of the thesis.

Chapter 2: Theoretical Framework
This chapter gives an insight into intellectual disability. Important game features are addressed, in addition to the current state-of-the-art augmented reality games. Also, the literature review performed in this project is presented.

Chapter 3: Method
In this chapter, the research paradigm, as well as research methods used during the design, implementation, and evaluation of the project is presented.

Chapter 4: Requirements Specification
In the requirements specification, the functional- and non-functional requirements are described.

Chapter 5: Design
In chapter 5, the overall design of the game-application is described. Choices made, and why is clarified.

Chapter 6: Implementation
Implementation specific details are described in chapter 6. A detailed description of the development process.

Chapter 7: Discussion and Results
In chapter 7, the evaluation results are presented and discussed. Also, the future work and challenges and issues met over the project phase is discussed.

Chapter 8: Concluding Remarks
The concluding remarks to the project are presented.

2

Theoretical Framework

In this chapter, we cover the theory behind this thesis, and give brief introduction to intellectual disability, serious- and exergames.

The literature review performed for this project is presented, and some of the most profiled augmented reality games available to the open marked is presented.

2.1 Basic knowledge About Intellectual Disability

NHI (Norwegian Health Informatics) describes intellectual disability as a condition where the individual has a prevented or incomplete sense, characterized by degraded intelligence (IQ) in such a degree that the individual requires treatment, special services or training (paraphrased)[33].

There are three main criteria for an individual to be identified with intellectual disability:

1. Intellectual capacity is well below average.

2. Adaptive behavior is lacked in terms of social and independent skills compared to the individual's age and cultural group.

3. The condition is present during the infancy and youth of the individual.

2.1.1 Four Types of Intellectual Disability

Table 2.1: Severity Categories, their distribution, and criteria based on IQ, daily skills and intensity of support needed[34].

Severity Category & Approximate Percent Distribution of Cases by Severity	**DSM-IV Criteria (Severity levels were based only on IQ-categories)**	**DSM-5 Criteria (severity classified on the basis of daily skills)**	**AAIDD Criteria (severity classified on the basis of intensity of support needed)**
Mild 85%	Approximate IQ range 50–69	Can live independently with minimum levels of support.	Intermittent support needed during transitions or periods of uncertainty.
Moderate 10%	Approximate IQ range 36–49	Independent living may be achieved with moderate levels of support, such as those available in group homes.	Limited support needed in daily situations.
Severe 3.5%	Approximate IQ range 20–35	Requires daily assistance with self-care activities and safety supervision.	Extensive support needed for daily activities.
Profound 1.5%	IQ <20	Requires 24-hour care.	Pervasive support needed for every aspect of daily routines.

As we can see from Table 2.1, we can divide intellectual disability into four categories of severity, where the groups are differentiated based on their approximate IQ, their daily skills, and the support needed.

Mild

The largest group in terms of numbers of affected people is the group consisting of people with mild intellectual disability. They make up 75%-90% of people with intellectual disability [34][35]. Typical characteristics of a person with mild intellectual disability are; IQ from 50–70, or two-thirds of people at the same chronological age[34][35], and may be slow in all cognitive areas[35], and they can acquire useful reading and math skills up to grades 3 to 6[35].

Other than that, they can conform socially, work, and be integrated into general society. Mildly intellectually disabled people need a minimum of support to live an independent life.

Moderate

The second largest group, accounting for 10%-25% of people with an intellectual disability, is the group with moderate intellectual disability. Traits are that they function at one third to one half of chronological age or equivalently have an IQ of 35-50 [34, 35]. They are more noticeably slow or delayed, and this especially becomes clear when it comes to speech.

Where mildly intellectually disabled could acquire practical skills, the moderately intellectually disabled can learn some simple communication [34, 35]. They cannot learn reading and mathematical skills as well, but they can learn essential health and safety habits. They can participate in simple activities and self-care[35], and while they may struggle to integrate into general society, they can travel to familiar places, and their daily situation requires limited support. People with moderate intellectual disability may be able to live independently with moderate levels of support, such as living in group homes.

Severe

People with severe intellectual disability makes up 3.5% of all people with intellectual disability according to Boat and Wu[34] while Donna and Ardinger have not separated on the three levels of intellectual disability that are not mild; they just state that people with intellectual disability make up a sub-group of the 10%–25% that is not mildly intellectually disabled.

The criteria for being severely intellectually disabled is an IQ between 20 and 35 or the functionality of one fifth to one-third of people at the same chronological age. They have apparent delays and may walk late. Also, communication skills are lacking or of poor quality[35]. They can be taught daily routines and

repetitive activities and self-care [35]. For social activities, they need close direction and supervision.

For all actions and activities outside their residential homes, they need close supervision.

Profound

The smallest group of intellectually disabled is the most profound group. This group is identified with IQ below 20 or below one-fifth of functionality compared to someone at the same chronological age as themselves.

People with profound intellectual disability require 24-hour support according to DMSM-5 Criteria [34]. They are not capable of self-care and need close supervision in the majority of daily activities. They can, however, respond to regular physical activity and social stimulation[35].

2.2 Serious Games

Through gamification, an activity that may not seem fun or essential can be much more rewarding and fun to do. One of the most important aspects of serious games is that the learning achieved in the game has real-life outcome[36]. For instance, for a child reluctant to do physical activities, you can use gamification and serious games to make the 'boring' activity more fun for the participant. Serious games often share the basic functionality with regular games, but while regular games are designed for entertainment, serious games are designed for the acquisition of real-life skill[36]. So even though two different types of games offer the same reward; i.e., an in-game artifact or a currency of sorts, the player's way to the reward is entirely different. The serious game makes the player reach the reward through real-life skills, while the way of the regular game focuses more on entertainment.

Boyle et al. state that "[...] learning is most effective when it poses significant, contextualized, real-world situations and provides resources, guidance, and instruction to learners as they develop content knowledge and problem-solving skills"[37]. These aspects can all be addressed in serious games and can be tailored to fit the intended user group and the specific learning case.

Another vital aspect with serious games is the privacy of the game environment – the game creates a safe space for practicing and learning these new skills[36].

2.2.1 Exercise Game

Exercise games or exergames are a sub-category of serious games and addresses active video games that also is a form of exercise[38]. However, rather than having the games learning focus on cognitive abilities, the skills intended to acquire through the gameplay is made for intervening sedentariness and repetitive behavior[36]. So in essence, making exergames is turning an activity primarily associated with obesity (compared to other more physically active activities)[39][40] into an activity based upon making the subject of combining technology and gaming with body movement[41].

2.3 State of the Art

2.3.1 Data Sources and Exclusion Criteria

The following databases were queried in the literature review:

- PubMed[42]
- Scopus[43]
- IEEE Xplore[44]
- PsycInfo[45]
- Web of Science[46]
- ACM Digital Library[47]
- Science Direct[48]

Exclusion Criteria

There were four main exclusion criteria:

- The paper had to be in English.
- The paper had to contain physical exercise
- The full text of the paper had to be available

- The paper had to include motivation OR behavior change

The publications went through three screenings:

1. Screened based on the title
2. Screened based on abstract
3. Screened based on content

Item 3. came to account if the content of the paper was not evident through the title and abstract.

2.3.2 Search Method

The literature review was performed in February of 2019. A query containing the desired content was created with logical operators.

The query was built up in three parts:

- The included literature had to contain intellectual disability of sorts.

  "Intellectual disability", "downs syndrome", "autism"

- The included literature had to contain some kind of "gamification" aspect.

  "serious game", "gamification", "exergame", "video game"

- The third condition for being relevant was the activity and motivational aspect.

  "activity", "walking", "motivation"

The literature desired was of that character that it contained at least one term from each of the categories. This desire lead to the following query:

("intellectual disability" OR "downs syndrome" OR autism) AND ("serious game" OR exergame OR "video game") AND (activity OR walking OR motivation)

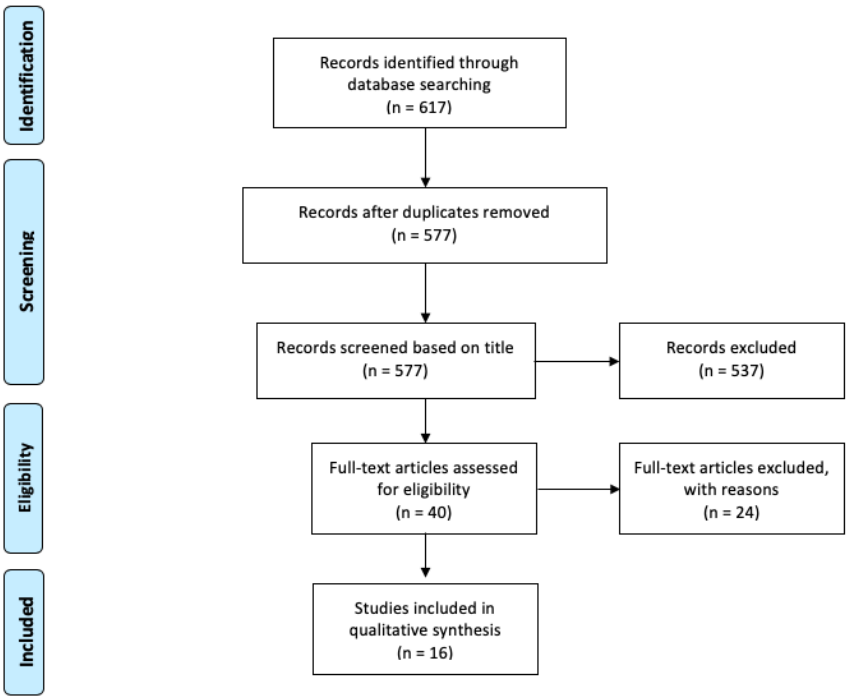

Figure 2.1: Diagram explaining the inclusion/exclusion process. Based on the PRISMA Flow Diagram[49]

Search Results

The results from querying the databases accounted for a total of 617 papers initially, and ended up with 16 included papers:

Table 2.3: Included literature from literature review

Author	Target Group	Findings
(Caro et al., 2016)[50]	Children with ASD	An exergame designed to improve eye-body coordination. Results show that exergaming affected both attention and limb movement control.
(Cunha et al., 2016)[51]	Children with ASD	An AR-based serious game for training children with ASD to recognize and acquire emotions.

(Fang et al., 2018)[52]	Children with ASD	Exergaming caused improvement in physical fitness and increased participation in moderate-to-vigorous physical activity.
(Finkelstein et al., 2010)[53]	Children and adults with ASD	Motivating exercise using a virtual reality exergame. Found positivity in the use of exergames as a method for exercise.
(Gao et al., 2018)[54]	Preschool children	Exergaming showed positive effects on moderate-to-vigorous physical activity.
(Hocking et al., 2018)[55]	People with developmental disabilities	Active video games (exergames) show effectiveness for gross motor skills for people with developmental disabilities.
(Jozkowski et al., 2019)[56]	Young adults with ASD	The social aspect through exergaming is an effective way of increasing intensity and duration of physical activity.
(Keay-Bright et al., 2012)[57]	People with ASD	Simplicity may be a basic approach when designing interfaces for young people with learning difficulties. Important to remove unnecessary information.

(Lee et al., 2018)[58]	Adults with ASD	Proposes an exergame to increase physical activity in adults with ASD. Interface design features; minimal navigation elements, visualized user instruction, gamified feedback.
(Memari et al., 2017)[59]	Children with ASD	Poor cognitive or social skills led to more sedentary an inactive behavior. Exergaming proposed as a solution to improve motivation.
(Ruiz-Ariza et al., 2018)[60]	Adolescent youth	Pokémon Go increased the amount of daily exercise, positively affect cognitive performance, and improve social relationships.
(Silva et al., 2017)[61]	People with Down syndrome	exergaming can be an effective tool to improve physical fitness. Exergames can be an appealing alternative for adults with Down syndrome to engage in physical activity.
(Strahan et al., 2015)[62]	Youth with ASD	Alternative methods, like active video games, can be used to improve health situations for overweight/obese adolescents with ASD.
(Takahashi et al., 2018)[63]	Children ASD / ID	Proposes an interactive school gymnasium. Used to help children with special needs with visual aids, through projection.

(Whyte et al., 2015) [36]	Individuals with autism	Proposes serious-games as a viable solution to reduce the cost for children and adults with ASD.
(Yalon-Chamovitz et al., 2008) [64]	Young adults with physical and intellectual disabilities	VR systems appeared to provide varied and motivating opportunities. VR made participants maintain a high level of interest throughout the intervention period.

2.4 Mobile Games

2.4.1 The Magnitude of Mobile Games

Statistics from statista[1] shows that the 'Game' category on Google Play is clearly outnumbering every other category, beating 'Tools', 'Entertainment', 'Communication', 'Photography' and 'Social' every quarter since the start of 2016. Statista reports that during the final quarter of 2018, the 'Game' category had almost five times as many downloads as the second biggest category which was 'Entertainment' (7.25 billion downloaded games vs. 1.41 billion downloaded tool applications).

For the first quarter of 2019, Statista reports that Google Play offers approximately 327 thousand applications in the 'Games' category[2]. Also, as of June 2017, it was reported that 'Puzzle' had the broadest market reach (in the UK) within the 'Games' category, making up over 62% of all downloaded games. On 10th place was the category 'Simulation' with almost 14%, and on 15th place on the same list comes education with just above 7% of all games downloaded in the UK[3].

This gives us a perspective of how big the mobile game industry is.

1. https://www.statista.com/statistics/256772/most-popular-app-categories-in-the-google-play-store/ [accessed 10/05/2019]
2. https://www.statista.com/statistics/780229/number-of-available-gaming-apps-in-the-google-play-store-quarter/ [accessed 10/05/2019]
3. https://www.statista.com/statistics/516316/uk-reach-popular-android-game-genres/ [accessed 10/05/2019]

2.4.2 Augmented Reality Games

Table 2.4: Three augmented reality games, their download count (on Google Play), and a description.

Game Name	Downloads	Description
Pokémon GO	> 100 million	Adventure game revolving around the world of Pokémon. The players catch and upgrade their Pokémon, and are able to use them in combat.
Ingress	> 10 million	Adventure game based on players playing on one of two teams. Capture the flag competition in local area, with a global competition.
ARrrrrgh	> 10000	Surroundings are turned into a quest area, where the user is playing against virtual enemies in a known environment.

In this project we are creating an augmented reality game, so a systematic review of relevant augmented reality games was performed as well.

From Table 2.4 we see that the most known and downloaded augmented reality game for mobile is Pokémon Go (in numbers from Google Play). In many ways, Pokémon Go is the main inspiration for this project, and the idea was to create a game that could bring some of the functionality and gameplay from Pokémon Go into a game tailored to the user group at hand.

Pokémon Go on Android uses Google's ARCore library to augment the Pokémon creatures in a real-life environment.

Another important aspect is that the game content of Pokémon Go requires the user to be physically active to play the game. This is an aspect that has been adapted into the game created in this project. The Pokémon creatures displayed in-game are semi-randomly spawned, so the user can always assume that there is a creature in close vicinity. Also, by using known landmarks, the players can visit "hot-spots", which are geographically bound.

So why can't we use Pokémon Go, instead of creating an all-new game? There are both pros and cons with Pokémon Go when we are addressing people with intellectual disabilities:

Pros

- Fun, which in itself is rewarding.
- Clearly defined goals.
- Social.
- Virtual "animals" are appropriate for all age spectrums.
- Encourages physical activity.

Cons

- Not comprehensive for people with intellectual disability
- Too complicated user interface for people with an intellectual disability.

As we can see from the lists above, the pros outnumber the cons, but in many ways, one could say that the cons *outweigh* the pros, because if the cons make the player unable to play, the player won't even be able to reach the pros.

2.5 Summary

In this chapter we have described intellectual disability and it's severity categories. We have clarified, serious games and the sub-category of exergames. The literature review founding the basis for the project, and a review of mobile games and augmented reality mobile games is described.

3 Method

In this chapter we describe the methods used throughout the project. The research paradigm used, the materials and the data collection is described. Evaluation, test setup and the critique of the methods are also covered.

3.1 Research Paradigm and Tools

Computing as a Discipline[30] describes three main approaches to work in research:

Theory:

1. Characterize objectives of study (definition).
2. Hypothesize possible relationships among them (theorem).
3. Determine whether the relationships are true (proof).
4. Interpret results.

Abstraction:

1. Characterize objectives of study (definition).

2. Construct a model and make a prediction.
3. Design an experiment and collect data.
4. Analyze results.

Design:

1. State requirements.
2. State specifications.
3. Design and implement the system.
4. Test the system.

The implementation phase of this project is closest to the *design* approach, but as Denning et al. states; in the discipline of computing, these paradigms and approaches are intertwined. The theory that lays the foundation for the implementation lays closest to the *theory* approach, while we constructed a "model" early in the project, and designed an experiment, collected data and analyzed the results, which lays within the *abstraction* paradigm.

So in many ways, one could say that in this project the approach used is a combination between *theory*, *abstraction*, and *design*; with weight on the engineering design approach.

With the engineering approach, the four steps are iterated to improve the product.

3.2 Materials

To create the solution proposed in this project, several tools were used. To develop the game, the following software and hardware were used:

- Unity[65], a cross-platform game engine created by Unity Technologies. The version used was v.2018.3.5f1.
- Visual Studio for Mac 2019(v.8.0.6), was used as the text editor for the scripting functionality in Unity. All things not specified in the Unity editor is specified in the code-behind scripts written in C#.

- Google ARCore for Unity[66].

- Samsung Galaxy S9, used for testing and launch of the game application. The physical device that development has taken place on, and the device that was deployed on the institution where testing took place.

3.3 Data Collection and Experiment Methods

3.3.1 Literature Review

The literature review carried out in this project was a light version of a Systematic Review, where already existing literature was identified through a literature search.

The included literature is listed in Section 2.3 on page 15.

The main points from the literature review are:

1. Exergaming can have a positive effect on the motivation for being physically active for people with intellectual disabilities.

2. Simplicity is necessary when designing interfaces for people with intellectual disabilities.

3. Feedback on user interaction is important.

4. Alternative solutions are needed for people with intellectual disabilities; exergames can be such a solution.

3.3.2 Discussion with Trained Professionals of Psychology and Intellectual Disability

An excellent source for requirements for this project were the people in charge of the project "*Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.*", they are respectively Audny Anke and Henriette Michalsen. Through numerous meetings with them, we could get immediate responses to ideas for the game, early versions.

A vital aspect they brought to the project was the ability to understand the user's needs and wants. I.e., the simplicity of user interfaces, the use of symbols and audio instead of text. The size of text where text was used, among other

things.

Through conversations with the psychologists, it also was discovered that the attention span of the users should be viewed by default as quite short, so the stimulation from the game should be near constant to keep the users interested.

3.4 Evaluation Method

In this section, the evaluation setup and methods to measure the value of the game is described.

3.4.1 Evaluation Setup

The evaluation of the game is solely a usability test performed on relevant users with intellectual disabilities and people with a close relation to people with intellectual disability.

The first phase of testing was carried out at a local daycare institution for people with an intellectual disability, where the agreement was that we would deliver the hardware (mobile phone) with installed software (the application 'Dyrejakten') to the employees at the institution. Simultaneously we would give the employees, responsible for carrying out the trial of the equipment, an introduction to the applications and all information needed. Also, they were given a user manual with a walk through the application. Also, we gave the employee's contact info, in the case that something severe would happen during the test phase.

We were never in touch with the actual users due to the issue of privacy. Therefore the only people we were in touch with were employees at the daycare center.

The tests lasted four days, Monday through Thursday. As the daycare center is open during regular work hours, we assume that the evaluators had 8 hours available each day, where they could use the application.

After complete physical evaluation of the application, we went to the institution to retrieve the devices. Also, during that time, we were allowed to interview the caretaker responsible for evaluation.

The usability evaluation results are based on the feedback from the care-

taker.

A second phase of user satisfaction came through a reference group meeting[1]. During this meeting, the application was pitched to the reference group, and they were given a thorough walk-through of the game. After the presentation of the game, they were given the same questionnaire as the caretaker from the daycare institution.

3.4.2 Testing Procedure

To evaluate the application, a usability evaluation procedure was used, which consists of methodologies for measuring the usability aspects of a user interface of an application, and uncover specific problems with the game[67]. Usability design and evaluation are described by ISO 9241-11 "*[...] designing and evaluating visual display terminals for usability is to enable users to achieve goals and meet needs in a particular context of use.*"[68].

Usability is divided into three main aspects[68];

1. **Effectiveness**: To what extent the user can achieve a goal with accuracy and completeness.

2. **Efficiency**: The level of effort and resource usage which is required by the user in order to achieve a goal concerning accuracy and completeness

3. **Satisfaction**: The positive associations and absence of discontent that the user experiences during the performance

As we weren't able to attend testing, due to the privacy mentioned in Section 1.4 on page 6, both effectiveness, and efficiency were hard to measure with clear metrics. The main focus of the evaluation has been point three; satisfaction. We wanted to find out how content or discontent the users were. The System Usability Scale (SUS) was used to get a useful metric on how satisfied the users were with the game.

1. The project "*Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.*" has a reference group consisting of parents of people with intellectual disabilities and staff at institutions for people with intellectual disabilities.

3.4.3 System Usability Scale

The system usability scale (hereby referred to as SUS) is a ten-item scale mapping a global view of subjective aspects of usability[69].

SUS is a Likert scale where the interviewee is presented with a statement and is asked to what degree they agree with that statement from "*strongly disagree*" to "*strongly agree*" on a five (or seven) point scale. Translating the results Likert scale answers into points would look something like "*strongly disagree*" = *1*, "*strongly agree*" = *5* and "*neither agree or disagree*" = *3*.

What separates SUS from any other Likert scale, is that the questions are arranged in such a way that you remove the answer biases, caused by respondents not having to think about each statement. Organization of questions is done so that to rate the application as extremely positive, you would have to answer "*strongly agree*" to 50% of the questions, and "*strongly disagree*" to the other 50% of the questions, because the statements proposed to the interviewee is polarized.

An example of two polarized statements is:

1. "I think that I would like to use this system frequently."

2. "I found the system unnecessarily complex."

If you loved the system and every aspect of it, you would have to agree to the first statement strongly, and strongly disagree with the second one.

SUS is usually used after the respondent has had time to try out and test the system in question for some time. After their trial, they are asked to record their response to each item immediately[69].

The SUS-questionnaire used in this thesis can be found in Chapter B on page 105

3.5 Critique of Methods Used

One point of critique of the methods used is that there should probably have been more scheduled meetings with the psychologists and responsible people of the project "*Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.*". More meetings like this would make the iterative engineering process more concrete, by stating requirements and having them

approved, disapproved, or adjusted based on the feedback from experts in the field. More frequent reference group meetings could also be a good way to state requirements and specifications.

Even though there are five respondents in the evaluation of the game, only one of the respondents saw the game played by actual users, and none of the respondents are the actual evaluators of the game. This again is out of the control of the author and is a clear limitation because of time and the privacy of the user group.

It can be discussed if the literature included is grasping too broad, because 9/16 included papers, have a target group of people with Autism Spectrum Disorder, which is not directly considered an intellectual disability, but it was argued that solutions and research conducted for this user group could be relevant for people with intellectual disabilities as well.

3.6 Summary

In this chapter we have described the research paradigm and the materials used in development. The main findings from the literature review, and revelations through discussions with trained professionals in the field of intellectual disability is presented. The evaluation setup and procedure is described in detail, while results are presented in Chapter 7 on page 65. We ended the chapter with a brief critique of the methods used.

4

Requirements Specification

In this chapter, the requirements specification is described, both functional and non-functional for the mobile game. To list the requirements, the Volere Shell template[70] is used.

4.1 Source of Requirements

The requirements listed came from basic knowledge about system development, as well as relevant literature and other augmented reality applications and physical games (listed in the technical framework section of this thesis).

Functional requirements are things the product must have, or actions it must take to provide useful functionality for the user[70]. These requirements bring the usefulness to the user.

Non-functional requirements are properties that the product must have[70]. They are usually attached to the functionality of the product. Non-functional requirements can, i.e., be the color scheme used throughout the application – it does not bring extra functionality to the user, but it is attached to the product package. The non-functional requirements came from the author's previous experience with software development, in addition to relevant literature from chapter 2 in this thesis.

4.2 Scenario

The idea of scenarios has been borrowed from theater, opera, and film, by requirements analysts to aid discovering requirements[70]. The scenarios are used to illustrate a situation and bring the product to life.

We use this technique to describe a scenario:

Jon is a young individual with an intellectual disability. He likes YouTube, movies, and sometimes he likes walking outside with his mother. Three times a week he goes to a day-care center to be with friends, and do activities with them, but he has grown increasingly interested in playing on the computer indoors and lost his interest in going for walks with his friends and the staff. The reason is that he has seen the surrounding area many times, and it does not interest him anymore. The care staff and his family says Jon has to do physical activity to stay healthy and robust, but Jon does not want to, he gets no motivation from being outside, going for boring walks.

4.3 Functional Requirements

With basis in the above scenario, we define the main requirement as follows:

> *Create a game that can help motivate individuals with intellectual disabilities to be more motivated for walking outdoors.*

Below are all the functional requirements listed for the game-application 'Dyrejakten'.

The requirement specifications are adapted from the Volere shell [70], but not every aspect of it is incorporated in the requirements specification. These are the items that have been used to create the requirements specification for this project:

- **Requirement Number:** An unique identifier for the requirement so that it can be referenced and traceable throughout the development of the product.

- **Requirement Description:**[1] The intent of the requirement. States, in

1. Req. Description

the user's words, what is required by the system.

- **Rationale:** The reason behind the requirement's existence.
- **Source:** The source of the requirement.
- **Fit criteria:** Quantified goals that the solution has to meet.
- **Customer satisfaction:**[2] A scale from 1-5 of how happy the client will be if the requirement is implemented successfully.
- **Customer dissatisfaction:**[3] A scale from 1-5 of how unhappy the client will be if the requirement is not implemented successfully.
- **Dependencies:**[4] Other requirements that have an impact on the one in question.

The following table described the requirements specification:

2. Cust. Satisf.
3. Cust. Dissatisf.
4. Dep.

Req. #	Req. Description	Rationale	Source	Fit Criterion	Cust. Satisf.	Cust. Dissatisf.	Dep.
1	The game should be able to start	If the game can't be started, the system will be useless	Author	The user can utilize the game content	0	5	
2	The user should be able to define the number of animals to catch	If the user can't set the number of animals to catch, the physical activity required from the user cant be tailored to the different levels of physical fitness	Author	The user can press the settings button, and fill in their desired animal count in the input field. That number is also reflected in the game content	1	4	1
3	The should be able to start a game session	If the user can't start a game session, the system is useless	Author	The user can press the play button, and that action takes the user to the selection screens	3	5	1
4	The user should be able to define the contents of the game	Bring a level of customization to tailor the game experience for the user	Author	The user can choose one out of multiple textures, and is brought to the animal selection screen where they can choose >1 animal.	5	2	1,2,3
5	The user should be to see ground planes in the game world	Visualize the ground planes, to make the world easier to understand for the users	Author, advisors	The user can orientate the world with the camera device, and where the application detects ground planes, there is laid texture over	4	1	1,3
6	The application should be able to place 3D	Users get a sub-goal to reach, and is forced to move.	Author	The user can tap on the screen to lay out animals, and move towards them	5	3	1,2,3,4

	content in the world-space						
7	The system should be able to record the physical activity of the user	Project leaders and care-staff, as well as users get an overview of the physical activity performed on specific days	Author, supervisor	The system records step-count through the internal step-counter in the mobile device	3	2	1
8	The system should upload the physical activity data to safe storage	The users physical data is stored in private storage, which enables evaluation of physical activity data.	Author, supervisor	The data is uploaded anonymized to a cloud database	2	3	1
9	The user interface should be in Norwegian	The users understand the messages they are given, and can easier understand instructions in their mother tongue	Author	Every instruction displayed or played to the user is in Norwegian	5	5	1
10	The system should be easy to understand for people with a moderate intellectual disability	The user is able to understand the game with a minimum amount of instruction from care staff	Author	Reduce frustration from not being able.	5	5	
11	The system should be based around non-written instructions	The reading ability of the user needs to be little to none.	Author	Include users that have low reading/writing ability	5	4	

12	The system should reward the user	The user is motivated to keep on walking until the walking session is completed.	Author	Display a reward when the user has reached their goal	5	3	
13	The system should be able to turn off	The user can end the game, and the progress is saved	Author, supervisor	The application can be gracefully shut down	2	3	

4.4 Non-Functional Requirements

As the target user group require special design needs, there are a few non-functional requirements as well:

Appearance

The user interface has to be appealing and welcoming for the users. It has to create a familiarity with what the content of the game is.

Security

The users should be assured that their data is not shared on insecure channels. The data should be anonymized so that researchers and analyzers can't be able to see any characteristics that enable identification of the user.

Safety

The application should be safe to use, from a physical perspective. The use of the game should not put the user in any physical danger. The game should require no dangerous actions from the player.

4.5 Summary

In this chapter requirements, both functional and non-functional are presented. We described a scenario, and based the requirements on that scenario. In Chapter 5 on page 39 we describe how the requirements are answered.

5 Design

In this chapter, the different design points are described in detail. The game content and all design choices made to reach the final version of the game application are addressed.

5.1 Paper Prototype

The idea from the start was that the game should be based around the user walking a certain distance, or going to a specific geographical location, in order to reach a virtual gate (see Figure 5.1 on the following page), that could only be seen by the camera on the mobile device. Inside this virtual space, one could orientate a space, and there would be different activities to do.

So this solution was based around getting a large reward after achieving the daily goal.

It was revealed through discussion with psychologists that such a solution might not be the best because people with intellectual disabilities might need more constant stimuli.

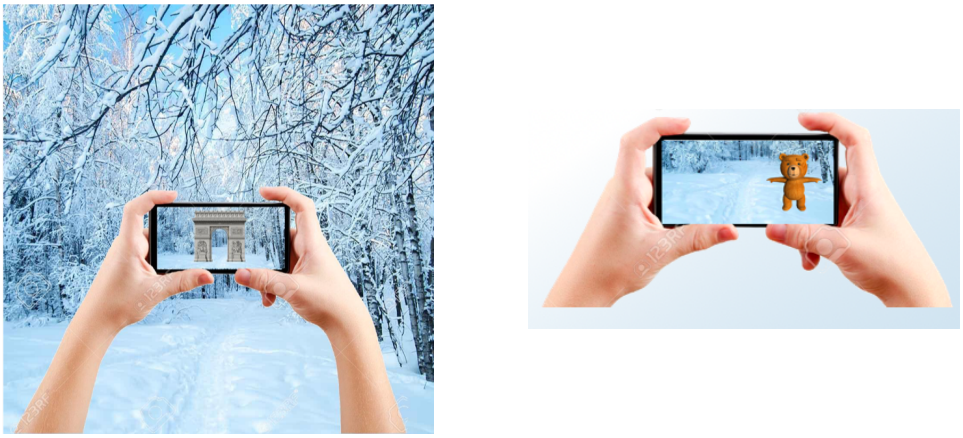

Figure 5.1: The initial design of the game.

5.2 Game Title and Icon

The title of the game is "Dyrejakten" and has come through a discussion with a professional psychologist. Initially, the name of the game was the same as the thesis; CorpOperatio, a contraction of the two Latin words *Corpus* and *Operatio*, which translates to body activity. Another idea for naming was Active IDea, which is a combination of activity, idea, and accounting for intellectual disability.

The name that was agreed upon is neither snappy or particularly clever, but it is simple, understandable, and more in terms with the user group. We want the users to want to use it, rather than have a smart and snappy name that no one utilizes.

The icon of the application is based upon a sheep illustration. It closely resembles the sheep that the user meets in-game and creates a familiarity between the application screen (where the user chooses what applications to use) and the game content itself.

The game title and icon together creates a recognizable and representable outline for what the application offers the user.

5.3 Game Scenario

The game scenario is based upon the user utilizing the camera lens on their mobile phone, orientating around the world. Upon orientating the world, the ground planes detected through the lens is covered in the desired texture,

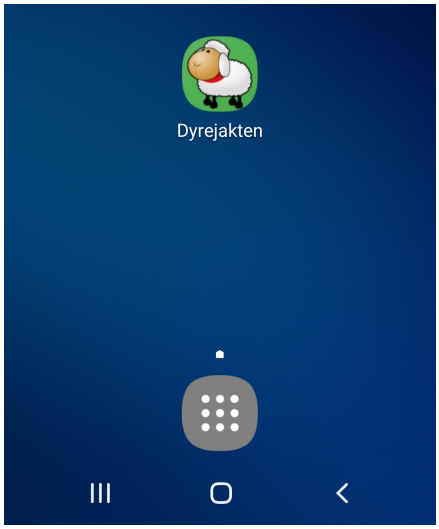

Figure 5.2: The icon and game title as displayed on the phone application selection.

so that when the user looks at the screen, they see the real-life objects that you would typically see through the camera lens, but in addition they see a texture laid over the ground planes detected by the software. Such ground planes can be asphalt, gravel road, indoor floor and all other surfaces that are somewhat level. The visualization of the ground planes through laying texture over the ground planes is a direct answer to requirement #5 from requirement specifications.

The texture laid out is visible while the user is progressing through the game. In addition, the user is prompted with the possibility of placing animals on the texture they have uncovered. Once the objects placed out are visible on the screen, the user can move towards them – to see them more clearly and when close enough; catch them.

This progression is iterative: The user makes ground texture visible in their immediate vicinity and places an animal. Then they move on to catch the animal, and during that physical transmission, they uncover more texture.

As there is always more texture "dressed" on the ground planes while the user is moving, they can use this while walking on trips.

Figure 5.4 on page 43 displays the scenario where the user is looking at "undiscovered" territory – a place not yet walked to. In the second picture, the user is looking backward toward the path already visited. We can imagine that the user started where the pig is located (see Figure 5.4 on page 43 picture 2) and has walked to the position of where the photo is taken. All "discovered"

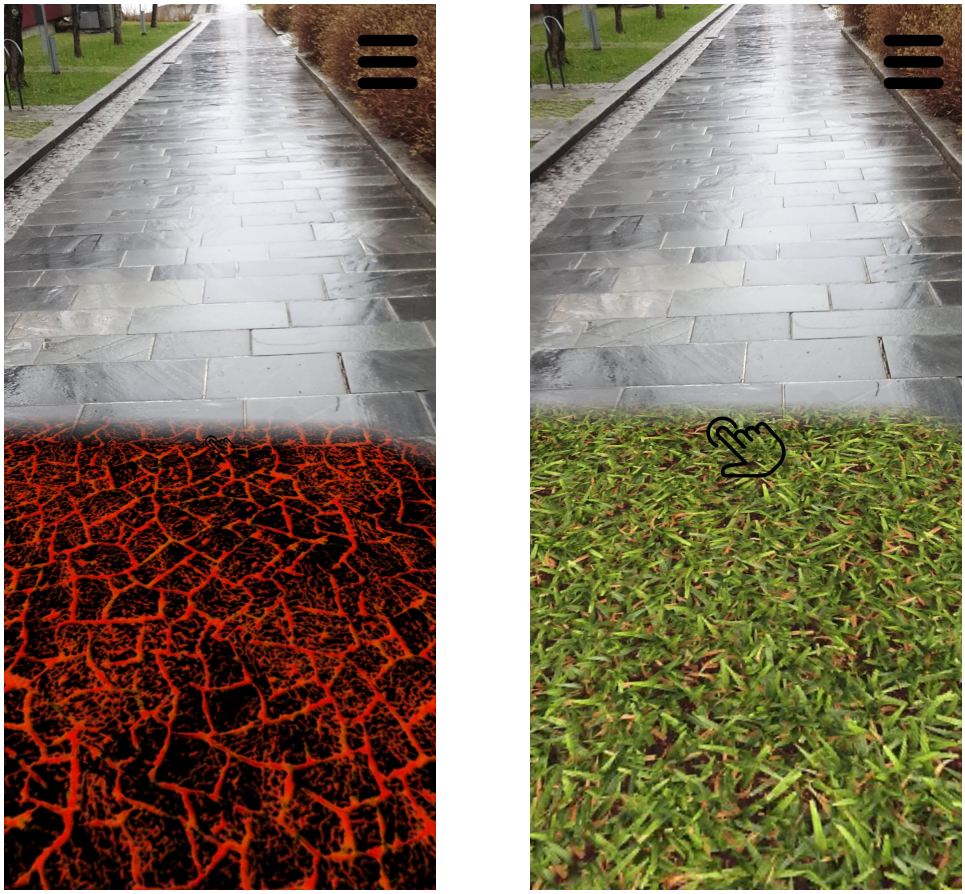

Figure 5.3: The two different textures available to choose from

texture is still visible, and that goes for all other texture the user lays out; it stays there.

5.3.1 Catching Animals

For each "captured" animal, the user is prompted with a text informing about the number of animals caught, as well as the number of animals they have set as their goal.

This functionality in the game fulfills requirement #6 from Section 4.3 on page 32 . The users can place 3D objects in the world-space and are thus forced to move.

When the user comes close enough to the virtual animal with their mobile device, the animal disappears and "confetti" stars appear on the screen. This is

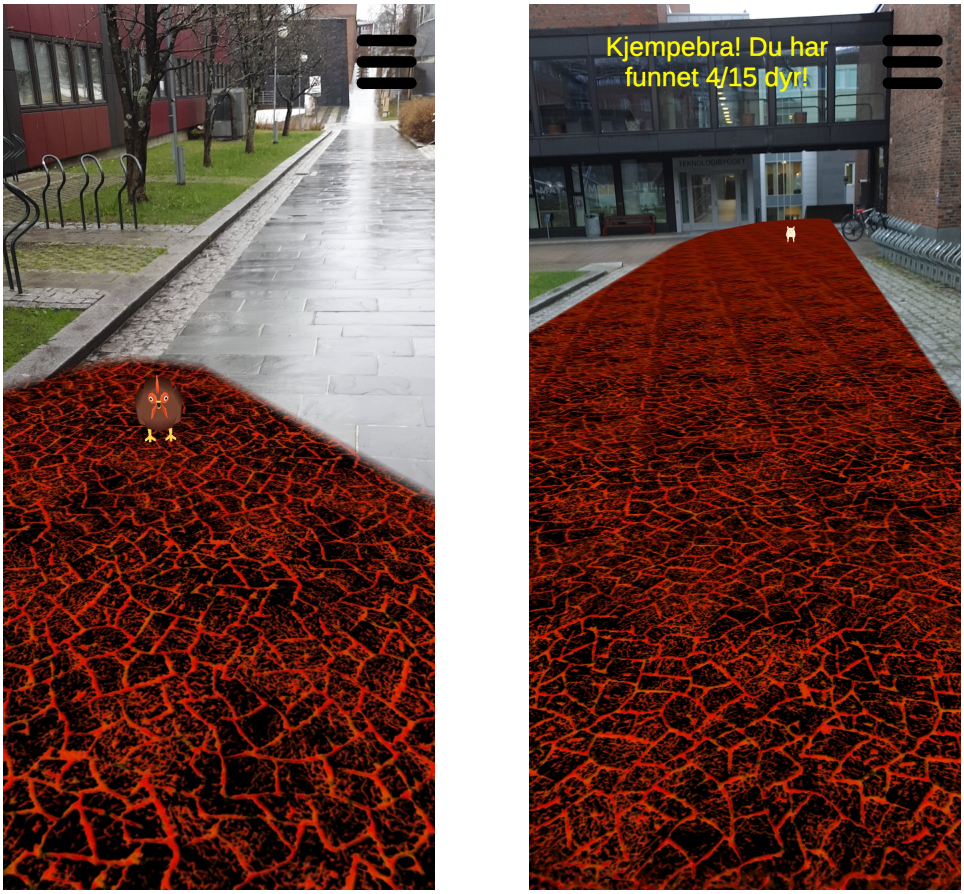

Figure 5.4: In the first picture, the player is looking "forward" to a place not yet traversed physically. In the second picture, the user is looking back at the place at the length already traversed.

done to indicate to the user that the animal is caught and that the animal does not disappear due to a loss of plane detection, or other unfortunate software based mistakes.

5.4 Geographical Binding

The game is not based around any geographical location. This is done to lower the threshold of using the application and allowing the user to go the way they want instead of following a specific route because the game tells them that is where they have to go.

As the main points of interest in the gameplay are the animals displayed on

Figure 5.5: The first picture shows the user coming up close to an animal, and the second picture shows the user coming close enough to "catch" it.

the screen and not some real-life scenery, the design is based around locating any ground planes, instead of specific geographical locations. This means that the user can use them in areas around their residential homes, indoors or even in areas that are far away from home.

This design choice is made to lower the threshold of starting a physical activity session by allowing the user to specify where to go.

5.5 Constant Stimulation

One of the requirements that came through meetings with professional psychologists was that for people with intellectual disabilities, the stimulation from the game has to be more or less constant, or in very short intervals. So even

though an early idea for the game was to base the gameplay around distance traversed or steps made by the user, it was argued that this might be (1) too little stimulus for the users, and (2) not comprehensive enough.

The two points above is where the idea of getting the texture laid on the ground planes came from. By using the phone throughout the whole physical activity, the user can track both where to go (by looking at the screen and seeing the real-life objects), and get constant stimulation from the screen, by laying texture on the ground planes.

The game is designed in such a way that makes the user unable to place an animal so close that they don't have to move to catch them. This way, every time the user is going to catch another animal, they have to physically walk some distance to catch another animal.

5.6 User Interface

In this section, the user interface of the game is described. All user interface objects are statically placed on the screen-space of the mobile device. They are not augmented on the screen like the texture and animals described above and are not dependent on the orientation of the mobile device, contrary to the gameplay objects.

5.6.1 Main Menu

In Figure 5.6 on the following page, we see the main menu that meets the user when starting the game.

There are only three components that the user sees in this frame;

1. The picture of the sheep.
2. The play button.
3. The settings button.

Only item 2. and 3. are interactable, while the picture of the sheep is merely for aesthetic purposes.

The design choice of having few interactable items in the screen at the same time is made with intent, to create a menu as easy as possible, where there are

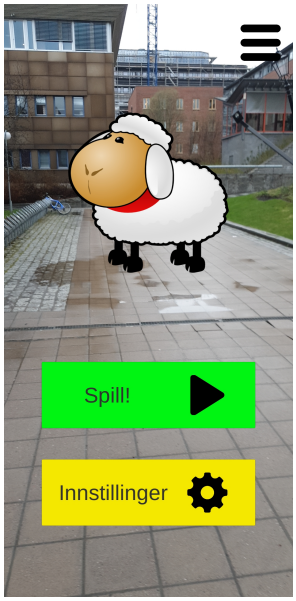

Figure 5.6: The main menu of the game.

few routes to choose.

The button marked play is colored green, while the settings button is colored yellow. This is a design choice, and the choice of color schemes for user interface items are described further down in this section.

The main menu enables the user to start the user interface "journey" towards starting a game session, this reflects requirement #3 from the requirements specification.

5.6.2 Sub Menus

If the user chooses to play, two additional menus have to be traversed to start the game. Both menus are designed in such a way that you are not able to continue without choosing anything from them. This design choice is made to minimize the room for error.

Texture Selection

On the screen for selecting textures, the user is prompted with two different options: Lava texture and grass texture (see Figure 5.7 on the next page).

Figure 5.7: The menu for selecting which texture to display on ground planes.

The layout for these buttons is a little different than the buttons from the main menu because here they do not only contain the name of the texture they represent, but also a visualization of the elements they represent.

This design choice is made to make a visual representation for the user of what effects their choice has on further gameplay, rather than just being text on the screen.

Clicking on one of the textures takes the users to the next menu, as they cannot have two different textures applied in the game at the time.

Animal Selection

As we can see in Figure 5.8 on the following page, the first picture (1) displays the scenario where the user has not chosen any animals. The animals are a crucial part of the gameplay, and therefore the user is not allowed to continue from this screen.

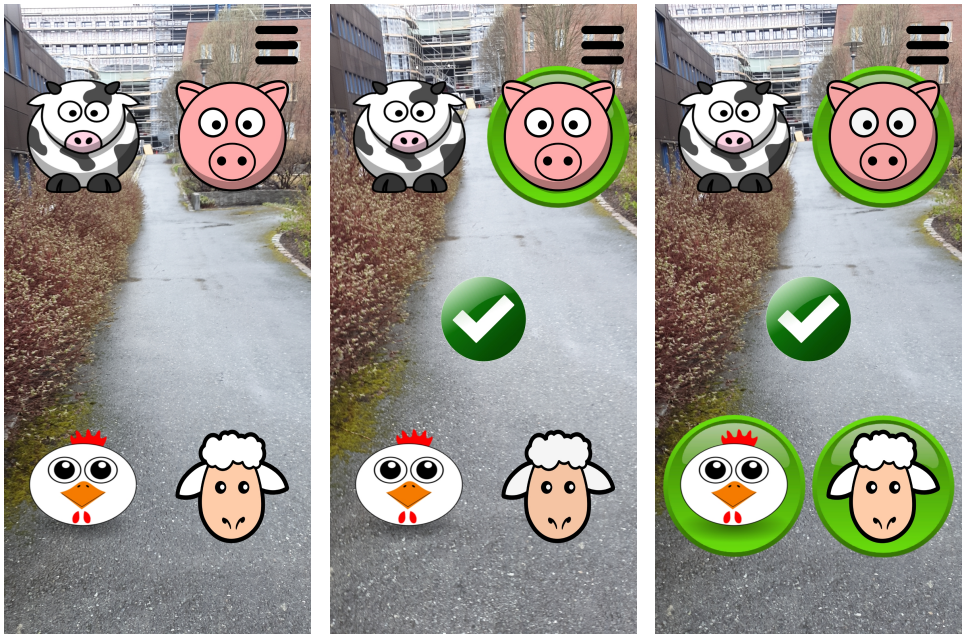

Figure 5.8: 1. The user has chosen no animals.
2. The user has chosen one animal.
3. The user has chosen multiple animals.

The second picture in Figure 5.8 on the next page displays the scenario where the user has chosen one object, and thus the green button in the middle is enabled, and the user can continue, or choose more animals.

Also, the user's selection is marked with a green background to indicate that the animal is a chosen one. In Figure 5.8 picture 2, we can see that the user has chosen the pig, and is now able to continue to the next step in the game.

If the user were to change their mind, and want to de-select their already selected animal, they could do so by tapping the already chosen animal once more, to remove them from their selection, indicated by removing the green background behind that specific animal.

Figure 5.8, picture 3 displays the scenario where the user has not only chosen one animal but three they wish to play with. We can see from the figure that the three selected animals are all marked with a green background to indicate their selected status.

Once the user has chosen their desired animals or left out the ones they don't want, they can press the green button in the middle of the selection panel to continue into the game.

Figure 5.9: The settings menu
1. Settings without making any interaction. The number of animals to catch is set to 50.
2. The numerical keyboard displayed when entering the number of animals to catch.

Both the animal selection menu and the texture selection menu are direct answers to requirement #4 from Section 4.3 on page 32, where the user is supposed to be able to define the contents of the game. This is now achieved through the animal selection menu and the texture selection menu.

5.6.3 Settings Menu

Should the user choose the yellow option from the main menu, they are directed to the settings menu.

Here they meet a menu an entry field indicating the number of animals they

are supposed to catch to complete their goal (see Figure 5.9 on the previous page, picture 1). They are prompted with the possibility of tapping into the input field to change their goal for the next session. In requirement #2 from Section 4.3 on page 32 it is stated that the user should be able to define the number of animals to catch, that requirement is answered through the settings menu.

Figure 5.9 on the previous page, picture two, displays the scenario where the user has tapped into the input field, and the numerical keyboard has been displayed to the user. The numerical keyboard is chosen to minimize the risk of misunderstanding, as the only logical input to the field is numbers.

Once the user has put in their desired number, they can return to the familiar main menu by tapping the back arrow located in the upper-hand left corner of the screen.

5.6.4 Reward Screen

If the player reaches the point where they have caught as many animals as specified beforehand, they are met with a medal. Also, confetti and sparkles are displayed on the screen, and an audio clip is played for the user. This is a direct answer to requirement #12 from Section 4.3 on page 32.

The medal in the screen contains one of the randomly picked animals that the user has encountered through the game, and the animal is the same as the one the user encountered in the animal selection panel.

The user is prompted with the possibility of tapping the medal to return to the main menu.

5.6.5 Other Design Aspects

Audio

Throughout the entire game, an audio voice describes every aspect of the game. This voice describes what each user interface button leads to, as well as what effects the particular choices have on the gameplay, and effectively on the player. This design choice is made in response to requirement #11 from Section 4.3 on page 32, and also it assists requirement #10 as well.

The voice is female and is slowed down to 0.8 of the original speed, to give the user some more time to hear and process the message they are listening to.

Figure 5.10: The screen that is presented to the user when reaching their specified number for caught animals.

The voice is in Norwegian as well, so this is in line with requirement #9 from Section 4.3 on page 32.

Flaws that users do during gameplay is also pointed out by the voice. For instance, if the user tries to place an animal too close to themselves, the voice prompts them with the indication that they should try to place it a little further away.

Also, the animals make sound, so if the player does not recognize the virtual animal right away, the sound makes an audio familiarity.

Color Choices

The three primary colors in the interactable user interface are as mentioned; green, yellow, and red (see Figure 5.11 on the next page).

In both the main menu (see Figure 5.11 on the following page - left), and in

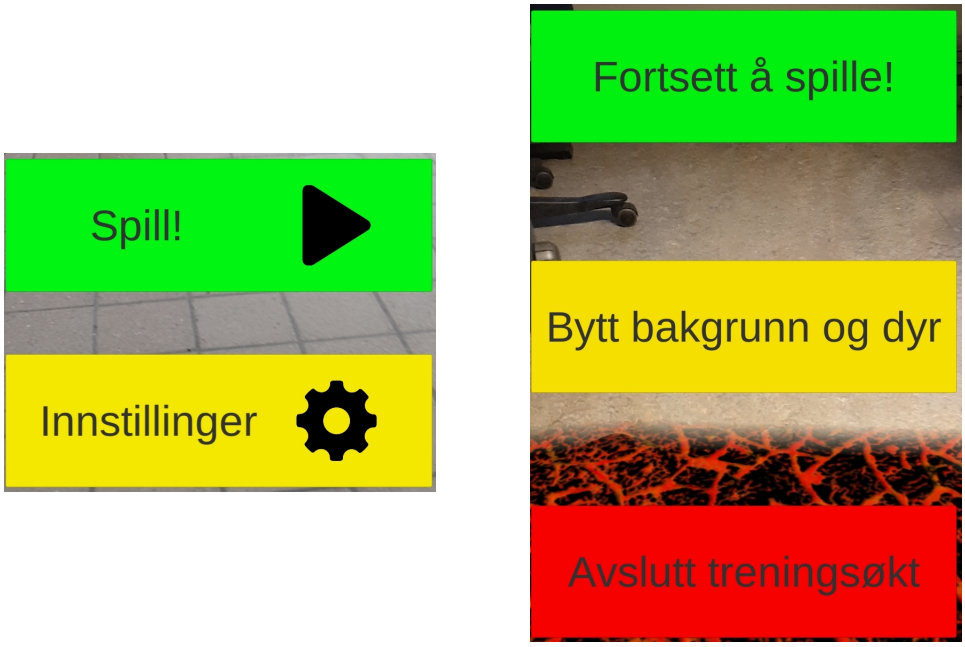

Figure 5.11: The colors used on user interface buttons.

the in-game menu (right), the green button indicates *play*. Green is the most visible of the three primary colors and can be used to indicate *go ahead*[71]. Positive associations made with green are i.e. *nature*, *spring* and *safety*, while negative ones are "decay", *greed* and *inexperience*.

The yellow button in both menus indicates settings. In the main menu, it indicates the settings where the user adjusts the number of animals they want to catch, and in the in-game menu, it indicates the settings for changing texture and animals to display in-game. The use of yellow in this game is to indicate something other than the *go* of the green color and the *stop* of the red color. It brings associations to the traffic light, which is in the middle, between green and red.

The red color, on the other hand, is only used in the in-game menu and effectively ends the game session. Just like in the traffic light, red symbolizes *stop*. Red is an aggressive color, crying out to be noticed, and indicates a warning or danger[71].

In a study on food labeling, it was found that this kind of traffic light labeling had an effect on the consumer's considerations on making healthy choices[72]. So the design of the buttons in the user interface was chosen based on making common color associations familiar in the application as well. This works towards the goal of requirement #11, where the color codes help the user

navigate through the application without reading the text on the buttons directly.

5.7 Summary

In this chapter we have described all the major and minor design choices made in the game. The game scenario, and user interface design choices and their founding requirement are presented.

In Chapter 6 on page 55 we see how the game is implemented.

6 Implementation

In this chapter, the implementation of 'Dyrejakten' is described. Software used, important implementation aspects, and project structure is covered. The implementation is a game for Android mobile devices. The devices have to be supported by ARCore[73].

6.1 Unity Game Engine

To implement the game, the Unity game engine was used. Unity offers cross-platform development for Android, Apple iOS, and Universal Windows Platform (UWP), among others, and Unity can be used to develop both two- and three-dimensional games, as well as virtual reality and augmented reality games. The unity editor is available on Windows, Mac, and Linux.

Large parts of the unity editor revolve around game objects. Every object adding content to the game can be looked upon as a game object. Each game object consists of components, giving them their specialized field of usage. From Figure 6.1 on the following page we can see two game objects. They are nothing alike, but if we removed every component from the two game objects, they would essentially be the same.

The Unity editor enables developers to initialize properties at compilation time. Through scripting, the developer can change variables at runtime. The editor

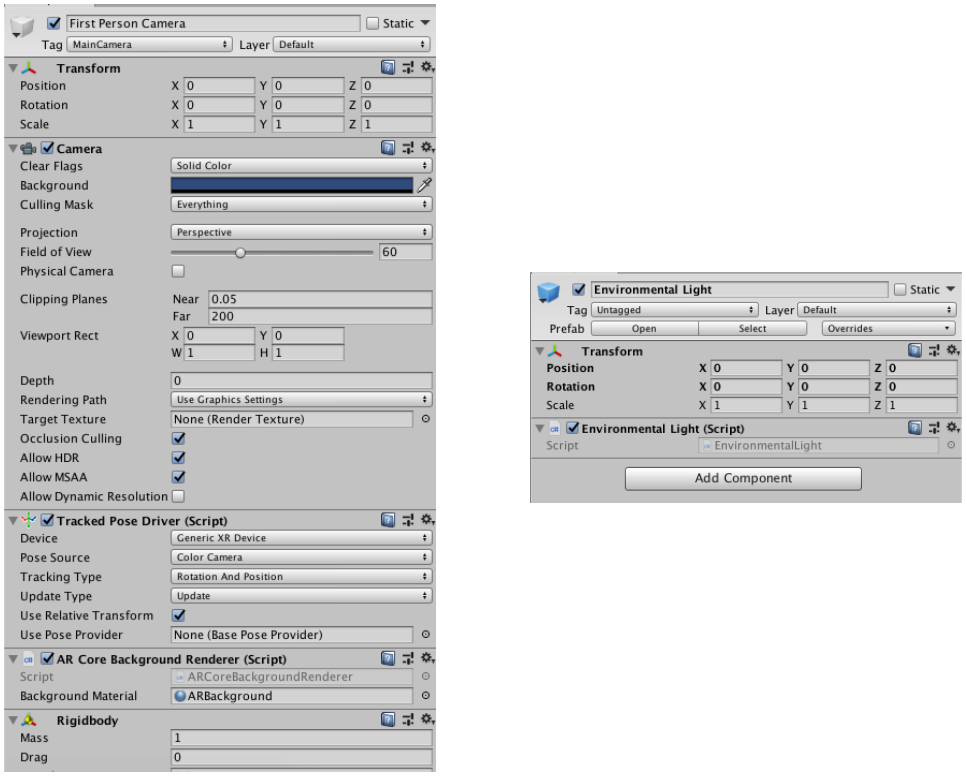

Figure 6.1: Two game objects, where their components make them different.

itself is based around drag-and-drop, where game objects and their properties can be assigned, altered, and initialized at compile time. Functionality that can't be directly accessed through the editor can be accessed through scripts. Scripts are assigned to game objects and give functionality that can't be accessed through the Unity editor itself.

Unity offers an asset store that sells user-created game assets. Such assets can be 3D models, libraries enabling functionality, and other environments that can be useful in game development. From Figure 6.2 on the next page, we see the asset for the farm animals used in the game, and how it is displayed within the game.

6.2 Augmented Reality

Augmented reality describes the technique of bringing three-dimensional virtual objects into a three-dimensional real environment in real time[74].

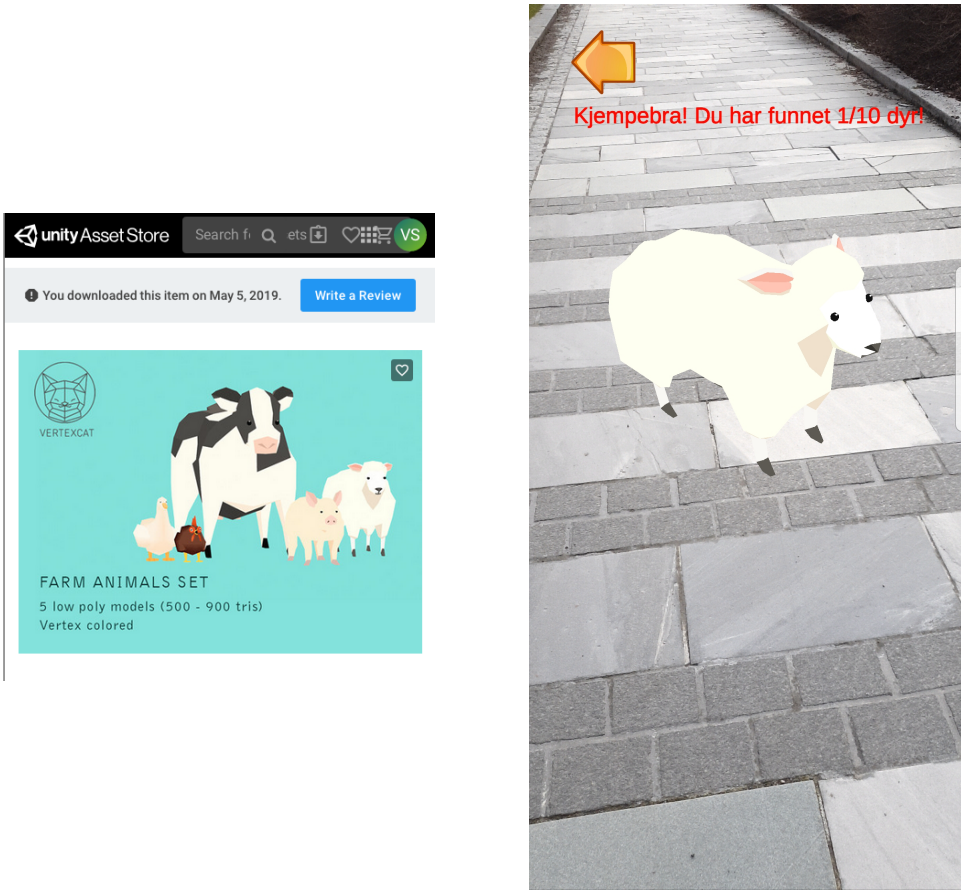

Figure 6.2: The asset used in 'Dyrejakten' comes from the Unity Asset Store. The second picture displays the asset in the game.

In augmented reality, the user is able to sense the real environment around, contrary to virtual reality, where the user is completely encapsulated in the synthetic environment. Ronald Azuma defines augmented reality through three characteristics[74]:

1. Combines real and virtual.
2. Is interactive in real time.
3. Is registered in three dimensions.

6.2.1 Different Technologies Used in Development

Upon starting the project, we were uncertain as to how we would solve the augmented reality aspect. As we were fairly sure we were going to use Unity 3D for building the application, we started looking for AR libraries compatible with Unity. Through a search for resources, the library named *Vuforia*[75] was found. Vuforia seemed to offer the AR functionality that was desired.

Vuforia offers compatibility with both Android, iOS and UWP (Universal Windows Platform), which is great if you're developing cross-platform – so even though we did not need the cross-platform functionality, it was a resource for future work. Both image tracking and ground plane tracking is supported in Vuforia, and therefore it was seen as a safe solution to pick this library, as it seemed it could offer functionality for whatever turn the application would take.

What was later discovered was that the ground plane tracking, which lays the foundation for the development of the application, was not *as* good as earlier assumed. When Vuforia is initialized, it identifies the first ground plane it sees – and after that, the ground plane behavior is bound to that plane. This means that if you move out of or far away from the firstly discovered ground plane, you lose the functionality because Vuforia is still looking for the initial ground plane. For an application intended for the user to move around, potentially (and hopefully) over larger distances this solution was not ideal.

To solve the problem, another considered and evaluated library was utilized instead. The new library was called ARCore[76], and is developed by Google. ARCore complies just as well to the use-case for this project as Vuforia did. To see if it offered the functionality desired, a simple test project was created with some of the functionality required. It passed the test, and the project was rewritten to fit the ARCore project set-up.

6.2.2 ARCore

For 'Dyrejakten' we used ARCore for Unity, which is Google's platform for augmented reality[76].

ARCore keeps track of two things:

- The position and orientation of the mobile device.
- The environment around the device.

Figure 6.3: The first picture shows feature points (blue dots). The second picture shows where ARCore has identified feature points on common horizontal surface.

Through concurrent odometry and mapping[77] ARCore is able to keep track of where the mobile device is relative to the world. By detecting visually distinct features in the camera image, it can map them, and by these mappings, ARCore can track the device's change in location. This visual information or mapping is then combined with the pose and orientation of the device to create a picture of the *world* and the position of the device relative position in that *world*.

By having such a real perspective of the world, ARCore is then able to render virtual three-dimensional on top of that image.

In this project, the augmented reality features revolve around detecting ground planes. By identifying feature points that lie on common horizontal ground, ARCore can detect them and project them to the user.

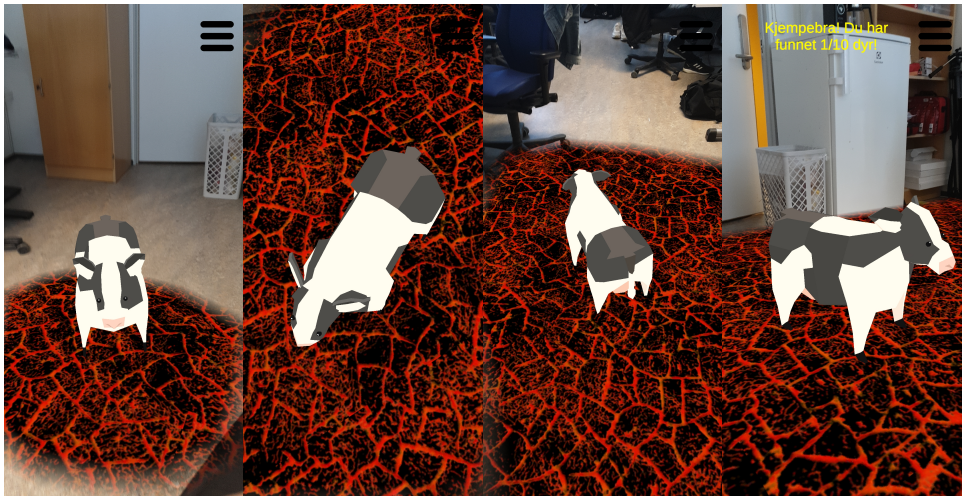

Figure 6.4: Visualization of how ARCore uses feature points to orientate the 'real world'. The cow is placed in the same position, and pictures are taken from different angles.

As we can see from Figure 6.3 on the preceding page, the first image shows the feature points that ARCore maps the entire time it's recording through the back camera. The second picture shows the ground plane it has identified by identifying clusters of feature points it identifies as on the same elevation.

We can see from Figure 6.4 how ARCore navigates and creates an understanding of the real world through the lens of the camera and the orientation of the device.

6.3 Project Structure

Unity enables scene structure for games, where development occurs on one scene at the time. For this project, there is only one scene, where all game objects, UI content, and menus are gathered in one scene.

As we can see from Figure 6.5 on the facing page, the project is structured in such a way that parent objects hold game objects of that specific type.

Figure 6.5 on the next page displays how the game object "MainCanvas" hold all canvas type game object, namely the Menus, the animal selection panel, and user interface items that are not in-game.

Figure 6.6 on the facing page displays all available assets for the project. This

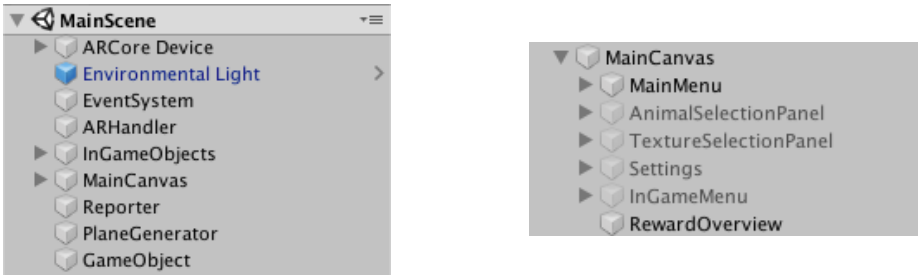

Figure 6.5: Structure of the scene & expansion of menu's

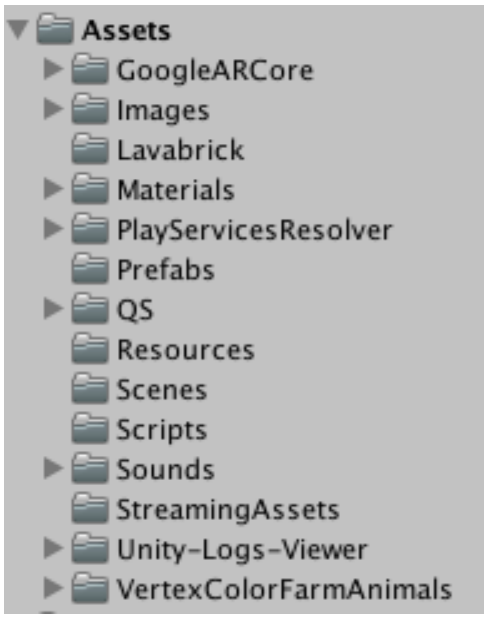

Figure 6.6: The assets folder of the project

means that every available game object, texture, or any other component that is to be displayed in the scene has to be in this folder.

6.3.1 Executing at Runtime

Some things are not contained within the scene at compile time, and they can't be found in the scene window displayed in Figure 6.5.

I.e., the animal figures that the user puts out in the wild, aren't initialized at compile time, they are instantiated at runtime, and thus the only reference to them is through scripts.

As we see in Figure 6.7 on the following page, there is a developer written

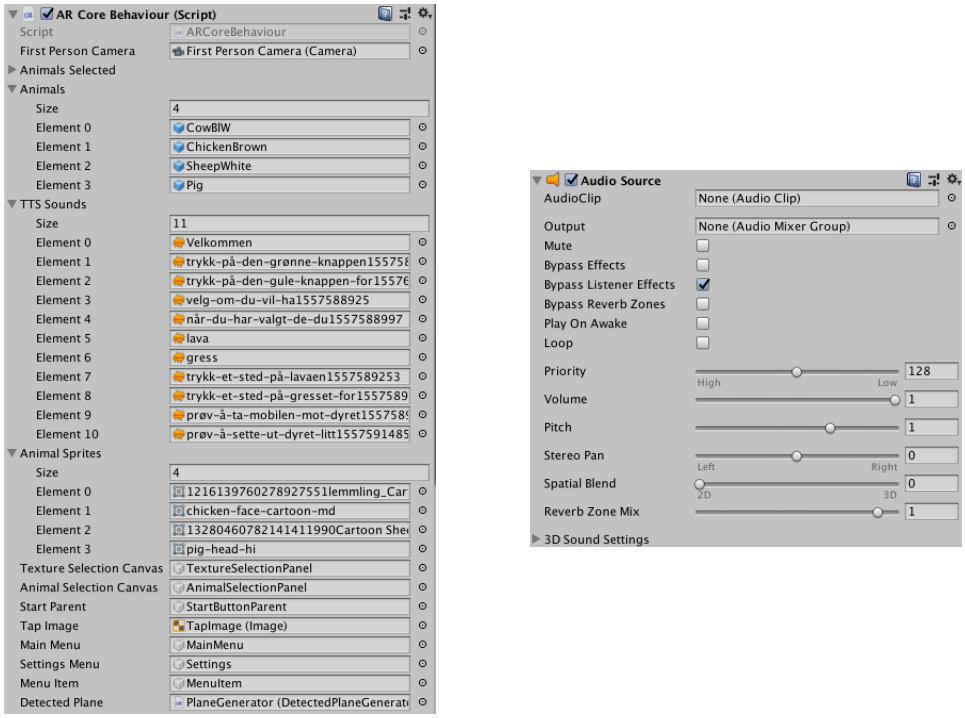

Figure 6.7: A script attached to a game object & an audio source attached to the same game object

script attached to a game object. All the fields that we can see in that script component are made publicly available in the C# script, and can thus be accessed in the unity editor. There are lists, and individual game objects that are used, enabled and altered during runtime, and are not instantiated on compile time.

The script from Figure 6.7 has a list called TTS Sounds, this list contains all the voice instructions that the user hears throughout the game. As they can't be played all at once, they are attached to the Audio Source (see figure Figure 6.7) at runtime, depending on the situation the user is in.

6.4 Storing Data

The application is not storing any other data other than the number of animals the user wishes to catch. This is done so the user does not need to specify the animal count every time the app is started: By default the value for catching animals, is the same as last time they played, meaning that if the user has found an adequate number of animals to catch, they can stick with that number.

Even though there is no user data stored, other than the number of animals, there is a created structure for storing all sorts of data. This means that if in the future, the game is continued, the structure for storing data is there, and can be utilized to store other types of data, i.e., user information, passwords, progress, physical activity data, and such. This can be useful and is discussed in the discussion chapter of this thesis.

6.5 Summary

In this chapter we have described the implementation specifics of the thesis. The core functionalities and technologies used are presented. In addition, the usage of different augmented reality kits and their pros and cons are described.

7

Tests and Results

In this chapter the results from the evaluation described in Chapter 3 on page 23 is presented.

7.1 Preliminary Questions

We were given some background information about the testers who had used the game-application over the test period at the daycare center. Two individuals had tested the game, and they could be described like this:

- Female.
- Little to no experience with smart-phone devices.
- Interested in technology.

As the two testers owned low-technological mobile devices, with little experience with technological devices. From this, we can say that we tested the game on users with minimal prerequisites for using technical solutions.

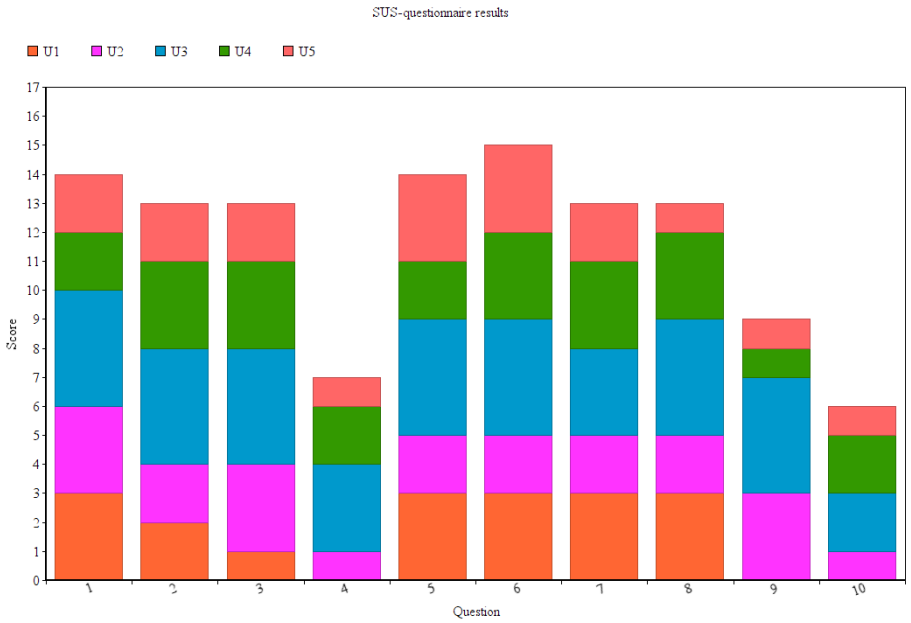

Figure 7.1: The accumulated scores for each of the ten questions. Maximum score for each item is 20, and minimum score for each item is 0.

7.2 Scoring SUS

Following SUS gives a number representing the overall usability of the system under evaluation. Each question on their own are not meaningful, but the composite gives a relevant measure of usability[69].

For every positively weighted statement (see statement 1 in Section 3.4.3 on page 28), the score is calculated by taking the scale position minus 1. For the polarized statement (see statement 2 in Section 3.4.3 on page 28), the score is calculated as 5 minus the scale position.

After the interviewee has answered all the ten questions, and the score of their answers are calculated, all question scores are accumulated, and multiplied by 2.5. This creates a scale from 0-100, where 100 is impeccable usability, and 0 is utterly unusable.

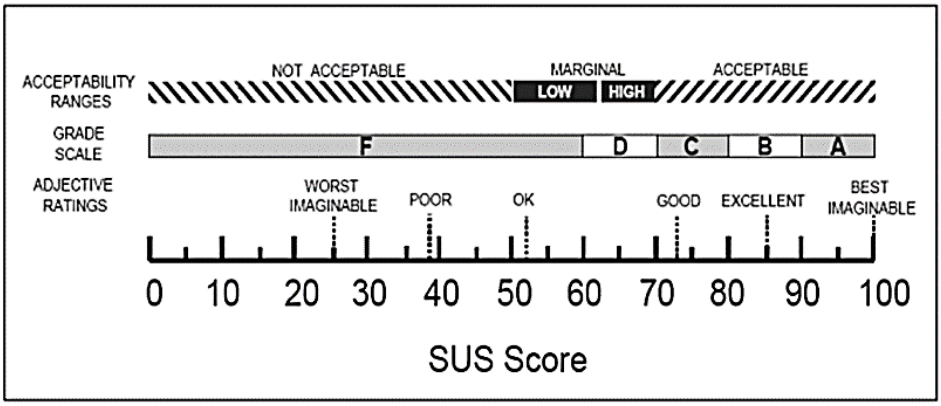

Figure 7.2: The SUS Score grading scale[78].

7.3 Results

From Figure 7.1 on the facing page, we can see the results from the five questionnaires. Each bar in the bar graph represent one question, and the height of the bar is determined by the accumulated score from all five questionnaires. As there are five testers, and each SUS-item can achieve a max-score of 4, we can see that the potential max height of a bar is 20 (5 * 4 = 20). The lowest possible score for each item is 0, and thus, the minimum potential score for each bar is 0. Further, each different color in the graph represents an individual respondent. I.e., the orange color represents the answers from 'respondent 1'.

The direct SUS-score from the respondents were:

[18p, 21p, 24p, 36p, 18p]

This gives a mean score of 23.4p. The 23.4p * 2.5 is equal to a SUS-score of 58.5.

7.4 Interpreting the Results

As we can see from Figure 7.2, the achieved SUS-score of 58.5 gives:

- An acceptability score on the low side of *marginal* between 'Acceptable' and 'Not Acceptable'.
- Grade F on the Grade Scale.

- A score between 'Good' and 'OK' on the Adjective Rating.

This can be interpreted as the system not being particularly satisfactory, but neither utter useless. On the grade scale, the system scores the worst possible grade with an F, but as we can see from Figure 7.2 on the preceding page the F ranges from 0-60, so the threshold for not getting an F is quite high.

The two other categories, on the contrary, show a more optimistic score, not impressive in terms of satisfaction, but nonetheless optimistic.

As we can see from the score, put into Figure 7.2 on the previous page, the system is not very usable in the point of view of the respondents.

7.5 Summary

In this section we have elaborated on the evaluation of this thesis. The scoring method and results are presented.

The results from the evaluation are mediocre. With a mean SUS-score of 58.5, the game is not unusable, but also carry potential for further improvements. In Chapter 8 on the facing page we will discuss the test results and what implications they carry.

8 Discussion

In this chapter, the results from the evaluation performed in this project is discussed, as well as other lessions learned throughout the project. Also, future work is discussed and the research problems are answered.

8.1 Discussion of Results

Even though Brooke states; "*Note that scores for individual items are not meaningful on their own.*"[69] we have to address some issues with the results.

Two questions from the SUS-questionnaire stick out negatively:

> Statement 4: I think that people with an intellectual disability would need the support of a technical person to be able to use this system.

and

> Statement 10: "I think people with an intellectual disability needed to learn a lot of things before they could get going with this system."

These two statements and their replies are pulling down the overall score quite a lot, but are they a problem?

This game-application is targeted towards people with moderate intellectual disabilities. They need constant supervision while they are outside walking, so the help needed is not that far away.

Now if we look at statement 10, there is an indication that the application demands much learning before the system is usable. This user group demands learning in nearly every aspect of self-care, so no matter how easy an application is, it is probably going to require some level of learning.

8.2 Other Revelations from Evaluation

In addition to the standardized statements from the SUS-questionnaire, we discussed with the respondents to get opinions on aspects of the game they felt they hadn't answered through the questionnaire.

8.2.1 Thorough Training Led to Attractive Gameplay

Even though the SUS-questionnaire revealed that the "entry fee" or threshold of learning the application was high, the users enjoyed the game when they learned the basic functionality of augmented reality.

The main problem the users had with the game, was that it was perceived as hard to understand the difference between the virtual space on the screen of the mobile device, and the real space captured by the naked eye. Once the care-staff had given a more extensive introduction to how augmented reality worked, giving real-life examples, the user got a better understanding of how to play the game. This is closely connected to statement 10., from the SUS-questionnaire, where the users need to learn many things before they can use the application.

It was explained that once the users had extensive training in understanding the functionality of augmented reality, they had much fun playing the game.

8.2.2 Not a 'One Size Fits All' Solution

The two users who tested the game at the daycare center had little to no previous experience with neither smartphones or gaming. Once they understood

the gameplay, they found the game fun and challenging, the caretaker told us. The response we got from the reference group was however different; as some of the users they represented had extensive experience with both smart devices and gaming, they would probably feel that this game would pose too little challenge to the users, which would lead to little motivation.

This is one of the main challenges with creating solutions for this user group because in a more considerable degree than in the general population; the motivation has to come externally (through an assistive device or from people around), rather than internally (wanting to improve health to improve quality of life). And again, this differs widely throughout the user group, some users may need challenges to be motivated, and some may need it to be as simple as possible, to have the user perform successfully.

8.3 Augmented Reality as a Motivator

A discussion point is if the augmented reality technology is the best solution for creating a motivational game for people with intellectual disabilities. It might be that adding an advanced concept on top of the difficult task of motivating this user group, isn't the best approach.

Once again, this differs between users; some players will embrace and understand the concept straight away and will need little introduction and training to start using the game in full, while some may never fully understand the concept.

Maybe a solution like this is more applicable in a user group like children and youth without intellectual disability, where the threshold of learning how augmented reality functionality works is lower and perhaps easier to learn.

8.4 Future Work

In this section, we discuss what enhancements we can make on the game.

8.4.1 Requirements Not Fulfilled

In Chapter 4 on page 31 there are several requirements listed. Most of them are clarified and explained in the design chapter of this thesis, but two of them are not fulfilled.

Requirement #7 and #8 are requirements are requirements that refer specifically to recording data and enabling it for analysis. This is something that we wanted to do, so that the solution proposed at the end of the project period was a complete package ready for deployment. However, as the main focus became implementing motivation features for the user, these two requirements were neglected.

As we weren't allowed to store or share any of the data when testing the application at the daycare center, the lack of these two requirements was not that important during the project phase.

If the game is further worked upon, both recording and uploading of data should be implemented, to give the game-package a more wholesome functionality.

8.4.2 Add Social Aspect

One of the things that were revealed through the review of relevant literature and discussions with psychologists and testers was that people playing games, including people with intellectual disabilities, like to share their gaming with friends, family, and competitors. This is the social aspect of gamification.

In 'Dyrejakten' this could be solved in many ways, and here are some propositions:

- Once the user has achieved their goal of the day, they can record a message and leave it for other users that achieve the same thing.

  I.e., 'user 1' catches 50 animals, is prompted with leaving a message, "leaves" it for the next person to come. Once 'user 2' collects 50 animals, they would see the message left by 'user1', and they are also prompted with leaving a message. This way, the players would share a semi-communication through these messages, and they could be motivated by knowing that their friends or other users are doing the same things as them.

  This solution could be made geographically independent, meaning that players could interact with people not living near their institutions or geographical area; it would only be based on the progress and goals of the users.

- Geographically bind the users to a specific route, by having staff design a route to follow when outside walking.

If the care staff could put out checkpoints, in the form of QR codes or equal, the user could reach a checkpoint, leave a message stating that they were there, and at the same time see other users that had visited that checkpoint.

This solution would narrow the sociality by adding the geographical aspect, but at the same time, the users are more likely to know the other users.

This is just two of many ways of adding a social aspect to the game. Generally, people with intellectual disabilities like to be social, but as in any other case, the functionality has to designed in such a way that those who don't like the social or competitive aspect can play on their own.

8.4.3 Thorough Introduction

As mentioned in the discussion of the evaluation, the threshold for learning the functionality of the game is quite high. To prevent the need for direct help from care-staff, one could argue that a thorough walk-through of the application could be used to introduce the user to the gameplay.

Such a walk-through could consist of a video, displaying a user playing the game, showing every aspect of the game and giving the user an example of how to do it. By using video, instructions are translated, from interpretive to exemplified.

Such an approach would minimize the room for interpretation, and the users would get a clear example of how to play the game. In addition, this would enable the care-staff to focus on other things than training the users in playing the game.

8.4.4 Expanded Customization and Additional Content

A point that is important in every game is the point of having enough content. As the user may get tired of playing with the same content over and over again, it might be an idea to expand the catalog of available game content, i.e., expanded selection of animals and textures.

The game requires no back-end service, as all the game content is loaded on install. So a viable option would be to create a back-end containing multiple 3D-models to catch, and more textures to lay over the ground planes.

Another solution is to change the appearances of the existing models to create the illusion of having different animals. Three different materials for the 3D animal models would effectively create an illusion of having twelve different animals.

One partaker in the reference group mentioned the collection mentality of many people with an intellectual disability. Many collectible items, i.e., Pokémon cards, have special cards that are more rare and collectible than standard cards, something like that could be implemented, to make the game more motivating.

8.5 Research Problems

In Section 1.2 on page 3 we defined sub-problems that made up a main research problem. In this section, the research problems are discussed and answered.

8.5.1 Sub-Problems

In Section 1.2 on page 3, we listed the research problems of this project. Moreover, in this section, we will discuss them.

Sub-Problem 1

The first sub-problem was worded as follows:

> *RP1: What what motivational theory do we have to use when designing a mobile game for people with intellectual disabilities?*

As Dyrejakten is a motivational exergame, we have utilized persuasive design in the game to try and motivate physical exercise for people with intellectual disability.

The main focus has been to create a game with content in such a way, that it is not apparent to the user that they are in physical activity.. If the user is so engrossed in the gameplay that they are not thinking about the physical activity they are doing, or that the physical activity performed is enlightened by the gameplay, then something right has been done. The game is designed

in such a way that the content outweighs the 'cost' of exercising.

During the test phase, it became apparent that there is no definite answer to the problem of motivating intellectually disabled people. Some things work for some users, and will not work for others.

The responses and discussions after the evaluation phase made the problem of differences between users very apparent. The testers at the daycare center thought that the way the game was designed could help encourage and motivate physical activity, while a parent in the reference group thought that it would be too dull with such an easy challenge.

A possible solution to this problem is the obvious answer of adding an abundance of content and differentiate the level of challenge so that those individuals that need the most manageable level of gameplay can play in "easy" mode, while those of the users that need more challenge can adjust the difficulty to make it more appealing. A Utopian solution is to allow every player to customize the game so it fits the user in every aspect.

Sub-Problem 2

> *RP2: How do we encourage the user to continue the physical activity until the end of the session?*

In Dyrejakten, the main focus for the user has been to reach the reward of the session. If the user does not collect the animals that have been agreed to, they will not receive their reward for that session.

Through the psychologists and researchers, it was found that one of the main motivators of physical activity for people with intellectual disability was good dialog between the intellectually disabled, the care-staff and the relatives of the intellectually disabled. Clear dialog and plans, had a positive effect on the intellectually disabled.

Dyrejakten can be used as a tool to help that dialog. The game is used as baseline, to communicate what the physical activity goal is, and it creates a visualization of what the user is supposed to achieve.

A way to do this is by having the intellectually disabled agree to a weekly goal, and use the game to record their progress. If the players reach their decided upon goal, they can have a bigger reward, in the form of movie tickets or

something else that they desire.

Sub-Problem 3

> *RP3: What special techniques do we have to use, when designing a game-application for people with intellectual disabilities?*

Through the meetings with professionals of psychology, it was uncovered that the main objective was to make the gameplay as simple as possible, without much room for the user to interpret things. The user interface had to be intuitive, and as simplified as possible.

Design choices, like having few interactable items in the screen simultaneously, and giving the user feedback on their actions, are essential aspects.

It was revealed through testing that using audio instead of text to inform the user was a helpful feature. Also, the introduction to the application has to be more thorough than that for the general population. Another critical feature is allowing the user to choose which content to include and exclude in gameplay as the users both have things they like, but more importantly, they have things they loathe.

The baseline is:

- Create a simplified user interface.
- Do not rely on text-based feedback.
- Create more extensive introduction routines than for the general population.
- Allow the user to include the game content they like and exclude what they don't like.

8.5.2 Main Research Problem

The main research problem was formulated as follows:

RP: How can we design and implement a mobile game to encourage physical activity for people with intellectual disability?

The main goal of the project was to create a mobile-based exergame to encourage and motivate physical activity for people with moderate intellectual disabilities. The solution provided through this project is the mobile exergame Dyrejaken, which uses augmented reality as its central technology to improve the physical activity levels of its users.

The design choices made throughout the development of the game is based on relevant literature and discussions with professionals in the field of intellectual disability.

The main drive behind the implementation of such an exergame is to make the 'cost' of using the game, lower than that of doing idle activities, leading to a sedentary lifestyle. In other words, the usage of Dyrejakten should be more fun and encouraging than doing idle activities. The physical activity performed in the game is not an outspoken part, but in order to play the game, the user is required to perform physically.

The testing phase of the project revealed that the use of augmented reality in games can be a challenge to understand for the user group addressed, but it proved to be a fun and new way to play once the threshold of learning the functionality was surpassed.

Also, the use of simplistic design, audio instructions, and reward had a positive effect on the users' mentality towards the game.

8.6 Miscellaneous

8.6.1 Challenges

Over the project period, there were many challenges. The main challenge may have been the process of designing a product for a user group consisting of unavailable users. In addition, it's hard to put yourself in the position of the user, and see wants and needs from their perspective.

The diversity within the user group was overwhelming. When working on requirements and specifications for the design of the application, one scenario tailored for one subset of the user group proved to be non-functional for another

subset of the user group. This was at times frustrating and challenging.

Thankfully, the author had good resources in literature, but most importantly the resource of people who work in this area of study over a more substantial period. Good discussions and conversations with professionals of the field were essential to the end product of this thesis.

8.6.2 Paper Submitted for Review

During the project period, the three projects contributing to *Effects of Physical Activity with e-health support in Individuals with Intellectual Disabilities.* were named co-authors on a paper submitted. The paper can be seen in Chapter A on page 91.

The paper was accepted for publication at the 1st International Workshop on Digital Transformation for Inclusive Society (DTIS) 2019, held in conjunction with The 18th IFIP Conference on e-Business, e-Services and e-Society (I3E) (Trondheim, Norway, 18-20 September 2019). The proceedings will be published by Springer Verlag.

8.7 Summary

In this chapter we have discussed the results from the evaluation of the project. Both the direct score from the SUS-questionnaire and other revelations from the testing phase.

The game shows promise, and with some further work on important aspects, it can provide a solution for increasing physical activity in people with intellectual disabilities.

The research problems from Section 1.2 on page 3 are answered, in addition to a miscellaneous discussion.

9

Concluding Remarks

Throughout the project we have revealed a lot about design and system development for intellectually disabled. The literature review, the conversations and discussions, the implementation and the evaluation lays the foundation for further work towards a viable solution for people with intellectual disability to improve their self-management in terms of physical activity.

Even though the work performed in this project is designed for and targeted at intellectually disabled, the results from this project do not contradict a similar solution for people who aren't intellectually disabled. The research from this project may assist future projects that work on similar technology.

The author feels that in a society where the knowledge about technical solutions is growing, we may see a more extensive use of augmented reality, not only for gamification, but possibly for more daily use-cases as well as reaching a bigger age spectrum.

Augmented reality pose a possibility of use cases in learning and education, where the combination of real world and virtual world can be a good solution for school children learning new concepts.

9.1 Contribution

The contribution of this project is a game application for people with intellectual disabilities. Design principles of the game are founded in relevant literature and discussions with professionals in the field of intellectual disability.

The game has been tested by intellectually disabled users in a randomized controlled study. The results showed that the game is not ready for deployment and that further improvements on the concept can improve the applicability of the game in a real-world situation.

The test results were ambiguous: On one hand, it showed that the core functionality and features of the game were hard to comprehend for the users, and was a threshold to overcome, while on the other hand it proved that augmented reality was fun and challenging once the core functionality was understood.

A critical contribution from this project are the reusable project results. Large parts of the design, implementation and technical foundation can be reused in future projects, both for the specific user group of people with intellectual disabilities, but also for other user groups, as mentioned in the discussion of this thesis. It may be an idea to re-target this sort of game towards a more "intellectually mature" audience, with more focus on learning and use the combination of the real world and the virtual world from augmented reality in a more meaningful way.

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Appendices

A

Paper Describing the Three Sub-Projects

eHealth Approach for Motivating Physical Activities of People with Intellectual Disabilities

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Abstract. Compared with the general population, persons with intellectual disabilities have worse health, lower levels of activity, and greater barriers to participating in fitness activities. As low physical activity is a determinant of health, and as increasing activity has positive effects on cardiovascular and psychosocial health, identifying effective interventions for use in everyday settings is exceedingly important. In this position paper we present the design and development of prototypes of game-based eHealth solutions for behaviour change and health promotion by influencing physical activity. Participatory design and agile development have been applied in this project to deliver a system based on three solutions to promote, motivate and maintain physical activity in people with intellectual disabilities: Guided in-door bicycle exercise, guided out-door exercise and guided mild workouts. All the solutions provide virtual environments and motivation features adapted to people with intellectual disabilities for better engagement.

Keywords: Intellectual Disability, eHealth, mHealth, Physical Activity, Gamification.

1 Introduction

1.1 A Subsection Sample

Intellectual disabilities (IDs) are intellectual and functional impairments caused by a neurodevelopment disorder [1]. The prevalence of IDs ranges from 2 to more than 30 per 1,000 children [2], and the classification of IDs depends on the severity of the deficits in the adaptive behaviour (measured by the Intelligence Quotient –IQ). Peo-

ple with IDs are on an increased risk of health-related problems and their health needs are often unrecognized or unmet.

Among the comorbidities of people with IDs, metabolic related diseases are the most prevalent [3], caused mainly by a significant lower physical activity and higher weight decompensations [4,5]. Approximately 50% of persons with IDs perform a sedentary life style and 40% has been found to do low physical activity [6]. A recent review found that only 9% of people with IDs worldwide achieved the WHO´s minimum physical activity guidelines [7], despite meeting the physical activity guidelines was positively correlated with male gender, younger age, milder IDs, and living without supervised care. In the general population, a more sedentary lifestyle has be-come a pronounced problem in younger people [8], and it is a greater problem in youth with ID [9]. Low levels of physical activity could be due to barriers, such as scarcity of available resources and opportunities or a lack of motivation [10].

Physical activity is a modifiable risk factor for chronic diseases and an important way to improve health and prevent diseases [11]. Several studies have reported on the effects of physical activity interventions for people with ID on physical fit-ness indicators, such as balance, muscle strength, and quality of life [12]. Further-more, a review found a moderate level of evidence that sport-related activities seem to contribute to well-being and perception of social competence [13]. A multi-component intervention in Sweden to improve diet and physical activity in individuals with ID in community residences showed positive effects on levels of physical activity and work routines [14]. However, only adults with mild to moderate IDs were included, and effect sizes were small. A recent theory-based randomised con-trolled study of adults with all types of ID did not find any significant increases in levels of physical activity (steps per day) [15]. Furthermore, the results of a recent cluster-randomised study of older adults in the Netherlands showed marginal effects and substantial missing data, despite being well-prepared with a published protocol and using day-activity centres for the intervention [16].

Studies often include people with mild to moderate ID only, but the benefits for people with severe ID tend to be at least as good [14]. Motivational issues have been challenging, particularly for approaches oriented to sustain the effect after the intervention [13]. The main objective of the project *"Effects of physical activity with e-health support in people with intellectual disabilities"* is to enhance physical activity in youths and adults with IDs by means of motivational technology-based tools. As low physical activity is a determinant of health, and as increasing activity has positive effects on cardiovascular and psychosocial health, identifying effective interventions for use in everyday settings is of utmost importance. Studies conducted to increase physical activity in people with IDs are often non-randomised, in non-natural settings, and not theory-based and often exclude people with more severe IDs. Recent well-designed studies in this field have failed to demonstrate improved levels of physical activity in intervention groups. This paper describes the rationale and characteristics of three prototypes to support and motivate persons with IDs to increase their physical activity.

2 Materials and methods

The study will involve persons with all types of ID who perform low activity levels, as this target group has been previously identified to have the greatest chances of improving the fitness condition [16]. A person-centred physical activity (PA) programme is expected to increase level of fitness, mental well-being and social support, and improve health conditions such as blood pressure and functional strength.

Although previous studies have been theory-based, the person-centred focus could improve with the use of individual goalsetting [18] and we have designed the intervention in a natural setting to enhance the effect [19]. Staff involvement will be central. We also expect the systematic use of e-health with rewards and gamification to be beneficial [20]. In Norway, many persons with IDs have a smartphone they can use for tailored physical activity games, which has not been tested previously. Accelerometers have been used to examine physical activity and sedentary time patterns in related populations [21].

The project to which this position paper belongs defines three sub-objectives. First: to integrate theory with users´ needs to design a motivational e-health support in natural settings. Second: to investigate the effects of this physical activity programme in youth and adults with ID in a randomised controlled trial. Third: to increase research activity and national and international cooperation in this little investigated field.

2.1 Technology-based motivation

The technical contribution of the research project *"Effects of physical activity with e-health support in people with intellectual disabilities"* shall be the development of tools that can contribute to increased physical activity. Given the user-centred approach, we aim to take advantages of that many people with IDs enjoy the use of new technologies and multimedia and thus give them access to virtual and real environment through recorded physical activity. We plan to develop several applications that are able to record physical activity and provide real-time motivational feedback. Recorded activity will then be swapped into time to watch movies and TV. We aim at studying different reward and motivation mechanisms from computer games and tailor them to people with IDs.

2.2 User involvement from early stages

Users and user-organisations are involved in all parts of the project. To understand the users´ needs and to design effective health behavioural support tools, we will gather data from focus groups and individual interviews. Participants will be selected strategically.

Two focus groups will consist of six to nine participants who will be asked to discuss their opinion regarding the role of technology and behaviour change support. Users, relatives, staff and professionals will be involved to design an optimal enjoyable programme for increasing physical activity [19]. We will use thematic analysis to summarize the results and extract user needs and perceptions.

We wish in the current project to go a step further than just gather user input at the start of the project, and use Participatory design (PD). More specifically, we will use workshops and think-aloud-protocols in our lab and out in the participants daily environment. We will conduct individual interviews with participants after the focus group discussion. Later, these participants will be invited to think aloud while interacting with our prototypes and reflecting its ability to meet their needs.

2.3 Mobile technologies and gamification for motivating behaviour change

Despite the promise of mobile health (mHealth) and the explosion of fitness-related apps in markets, the vast majority of solutions are yet focused to a routine care basis and to record health and fitness-related data. Several studies have evaluated the effectiveness of mHealth interventions in specific clinical endpoints related to health promotion and disease worsening preventing [22]. Gamification and coaching techniques are also a promising feature of mobile health apps Sannino et al. [23] introduced the concept of a constant follow-up of the patient's performance along with continuous feedback and reward system according to the user behaviour and disease control.

In the scientific literature, there is a lack of work to create a rigorous process for design of mobile-based solutions for persons with IDs targeting a behavioural shift. Giunti proposed a model based on User-Centred Design (UCD) [24] for the design of mHealth solutions for chronic patients using a compromise between medical knowledge, Behaviour Change Technologies and gamification. Schnall et al. explored the use of Information Systems Research (ISR) framework as guide for the design of mHealth apps [25] as a way to promote a change in the users. Jia et al. defined a design framework for self-management mHealth solutions employing the quantitative Fogg Behaviour Model to enhance user's execution ability [26]. Those work used several participatory researching techniques but both including adults and children. Although authors identified the participatory techniques used in their work, no information regarding what type of technology was determinant for promoting a behaviour change, which limits its reproducibility in the context of IDs. To the best of our knowledge, no study has proposed a methodological framework to design context-aware and personalised mHealth solutions to support and motivate persons with IDs to increase physical activity habits.

3 Results

This innovative project results in a system composed of three different solutions which can co-exist and motivate people with IDs to increase physical activity on daily basis with the use of mobile phones, wearables and gamification strategies.

3.1 Used-centred design requirements

The thematic workshops with experts, parents and institution staff leaded us to define the baseline requirements of the system. This information was exchanged on meet-

ings and contact through emails in the start phase of the project, but also during implementation to discuss features and decisions. This cooperation has provided valuable information on how to develop a system for this kind of users when it comes to design, content, and layout. At the meeting, the ideas for this project were presented through illustrations of the design and explanations from the authors. The attendants of the meeting were then allowed to give their opinion on what they thought about the ideas. The meeting resulted in constructive input to the project and new features that could be included in the application. It was also motivating to see that the user representants were positive and interested in the project.

Table 1. Summary of the system requirements based on experts opinions.

Scope Area	Requirement
Physical activity in persons with ID	Critical factors for being physically active are the support from parents and care-takers, to be able to show someone what is achieved, predictability, coping ability of activity, amusing and fun, medals and rewards. It is necessary with a clear correlation between reward and activity.
Intervention studies in persons with ID	Few intervention studies with ID and E-health and struggles with dropouts and missing data in studies. However, the presenter is favourable to that mobile health apps interventions can provide a significant effect on improving PA levels.
Motivation in persons with ID	Inner (joyful, meaningful, coping, etc.) should be preferred over external motivation (praise, money, threats, etc.) to get a long-term effect. To achieve a behavioural change takes a structured plan, support from caregivers and much effort.
User-friendly environment	It is important to achieve predictability and how the application should be able to express what is about to happen for an individual with ID or at least be helpful to do so. Use figures and icons to explain different activities and support audio.

Table 1 summarizes the main requirements of the system based on the opinions of experts. Some of the critical remarks were that e-health should provide amusement, be a tool that can show others the achievements performed and provide rewards that are related to the performance in an activity. An e-health tool should be easy to use, but not childish as it can appear stereotypical and insult some users.

3.2 eHealth based proposed solutions to increase physical activity

Physical activity will be measured using the mobile phones in-built accelerometers, wristbands and a bike-roller for in-door static physical activity. This input will be the

basis for the game. Our approach provides primary rewards mechanisms including fun and achievement elements. Social interaction has been identified as a powerful reward, so opportunities for collaborative missions are included.

The game needs to offer progressive mastery experiences, which again means that it will have to be tailored to the user. Care workers involved in the project helped to tailor the physical activity game to the individual´ goals and resources and specifics of the intervention will be developed iteratively in close collaboration with users.

The system provides three main solutions: Guided in-door bicycle exercise for aerobic mild intensity exercise, which makes use of a tricycle and a bike-roller connected through Bluetooth to a tablet; an augmented-reality based game for out-door moderate exercising and a coaching app for promoting in-door workouts for moderate to hard exercises.

Proposed solution #1: Guided in-door bicycle exercise. The first solution comprises hardware and software modules to track and record the amount (intensity and time) of physical activity on indoor bikes. To this end, the solution can use two different bikes: (1) an outdoor bike mounted on a Tacx roller, and (2) an indoor, stationary exercise bicycle / ergometer bike. The goal is to detect the activity performed on the bike and transfer the activity measurement to a tablet- based entertainment system, which will react to the performance of the user in the bike and will show different multimedia records (real routes, virtual routes or media).

This solution will provide continuous feedback during realization of the physical activity. Therefore, the designed setup will monitor parameters such as speed, cadence and power. The setup is capable of transmitting data wirelessly (in the current prototype is Bluetooth LE) and in a real-time to a control unit (e.g. smartphone/ tablet). The user is rewarded when selecting heavy load on the bike and for cycling for longer periods of time, proportionally. The graphical user interface contains computer game features connected to the hardware of the bicycle, so for example, by cycling through a landscape with computer game elements, receiving rewards in the form of symbols, animations, sounds, etc., during the exercise.

The first prototype uses a Tacx Flow Smart trainer (Upside left corner in Fig. 1) that support Bluetooth Low Energy and Ant+ connection. This trainer measures speed, cadence, and resistance; and it is possible to adjust the resistance on the power wheel. A cadence is a standard unit of measurement for bike trainers, and it means the frequency of the pedal turns when cycling. This trainer suits most type of bikes with a power wheel with a size between 26” and 30”. For testing of the first solution during development, we borrowed a three-wheel bike from NAV, a welfare institution in Norway among other services provide equipment for those who have special needs (https://nav.no). Using a three-wheel bike is that it will appear steady and stable to ride.

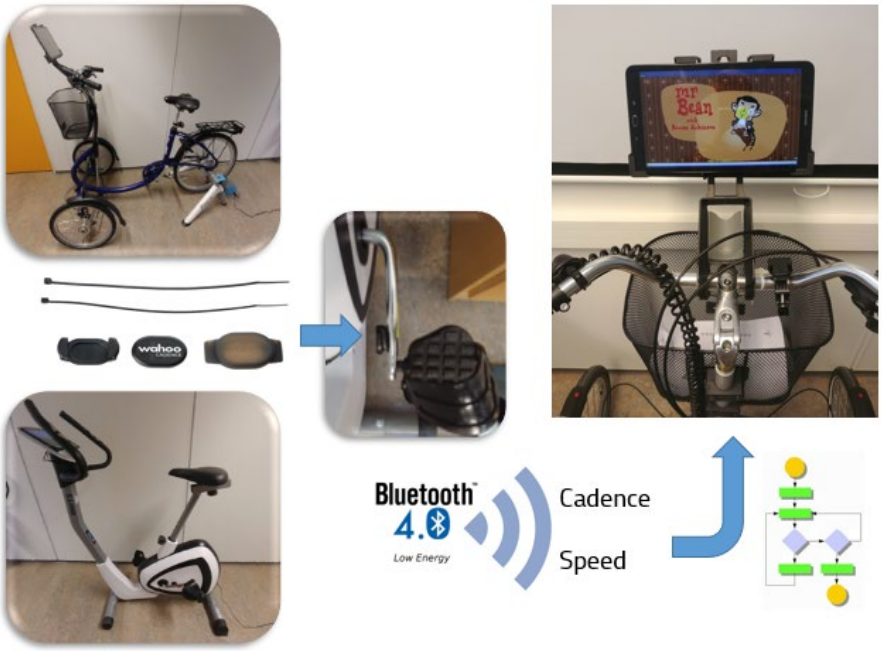

Fig. 1. Set up of the in-door bycycle based activity monitor.

The second prototype is mounted on an U.N.O. Fitness ET1000 (https://www.fitshop.no) ergometer bike (Down-left corner in Fig. 1). The bike comes with an embed computer that measures speed, resistance, and distance during a training session. To make the setup of the system more straightforward and scalable we decided to use a separate Wahoo cadence sensor which supports Bluetooth Low Energy (BLE) connectivity (central part in Fig. 1). The Wahoo sensor uses the FTMS protocol through BLE, the same as the Tacx Smart Flow trainer which makes the connection implementation simpler as it can be used in both solutions.

When the application starts (Upside-right corner in Fig. 1), a display showing the status of the current week activity time performed. From the start page, there is a navigation option to settings, video mode, game mode and history of activity. Video mode and game mode are the two options for activity sessions this system provides. After an activity session is finished, the activity time is added to the total activity time of the current week.

Proposed solution #2: Guided out-door exercise. The second solution provides a tool for people with intellectual disability to make them more physically active in mild to moderate intensities (walking and hiking). The technical solution is a mobile application that can be used anywhere and is tailored for a user group that previously have had no specially tailored solution with the same objective.

The app tacks the amount of physical activity in outdoor walking, hiking, etc. by means of step counters and GPS-tracking. This information is then transmitted to the entertainment system, which adapts the environment and reacts according to the pre-set preferences.

The gamification technique is based on augmented reality and proposes the user to chase virtual animals into a real environment (recorded with the mobile phone built-in camera). The user can select four different farm animals displayed through user-friendly avatars (Fig. 2), which will be distributed into the user surroundings, so they can walk towards the animal to 'collect' it.

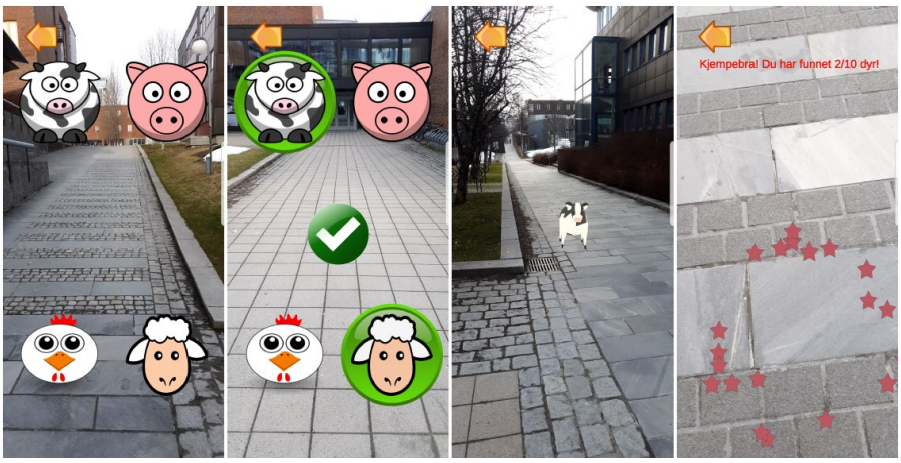

Fig. 2. Graphical user interface of the guided out-door exercise app.

Once the animal is collected, they will be prompted with a supportive message on the screen, and a voice recording encouraging and recognizing success. In addition, the screen has confetti bouncing on it, and a medal will be displayed containing the animal they reached. The setup is able to monitor parameters such as intensity, type of activity and time, and in future extensions it will transmit recorded data to a control unit / cloud-based application.

Proposed solution #3: Guided mild workouts. The third solution provides a coach-based mobile application to promote physical activity in people with ID by means of a three-dimension avatar. This virtual character is customizable so that each user can make it look like he/she wants, so that connection between the user and the character may lead to higher levels of engagement and them wanting to use and interact with it. Once the avatar is created and customized, the app provides a set of basic workouts and pre-set combinations of them, so the user can choose to perform specific or complete routines.

When selecting an activity, the user interface shows the activity animation to make it clear to the user what it entails (Fig. 3). This is because it can be difficult to explain

an exercise activity without any type of movement. Text To Speech features are also included in the app, to help the users understand context and functionality of the app which can otherwise be hard to convey using only the visual user interface. The app includes reminders by means of notifications to sustain the adherence to work out routines in case of periods of inactivity.

Fig. 3. Screenshots of the guided workouts app and the avatar.

4 Discussion

E-health provides a wide range of possibilities for monitoring and motivating people in the self-management of chronic illnesses. In this position paper we present the design and development of prototypes of game-based eHealth solutions for behaviour change and health promotion by influencing physical activity. Motion sensor games have been explored and found to be promising in people with ID.

Our approach to move out of the lab and into actual use included a first stage for meeting user's needs. Participatory design and agile development have been applied in this project to deliver a system based on three solutions to promote, motivate and maintain physical activity in people with IDs. These solutions may contribute to the physical activity of the user group of persons with intellectual disability and also act as ring effect their physical and mental health, as well as improving their health and lifestyle situation.

Once these applications have been assessed and improved in beta-tests, they will be used into a randomized-control trial to assess the effect of eHealth in direct physical activity indicators and secondary health endpoints.

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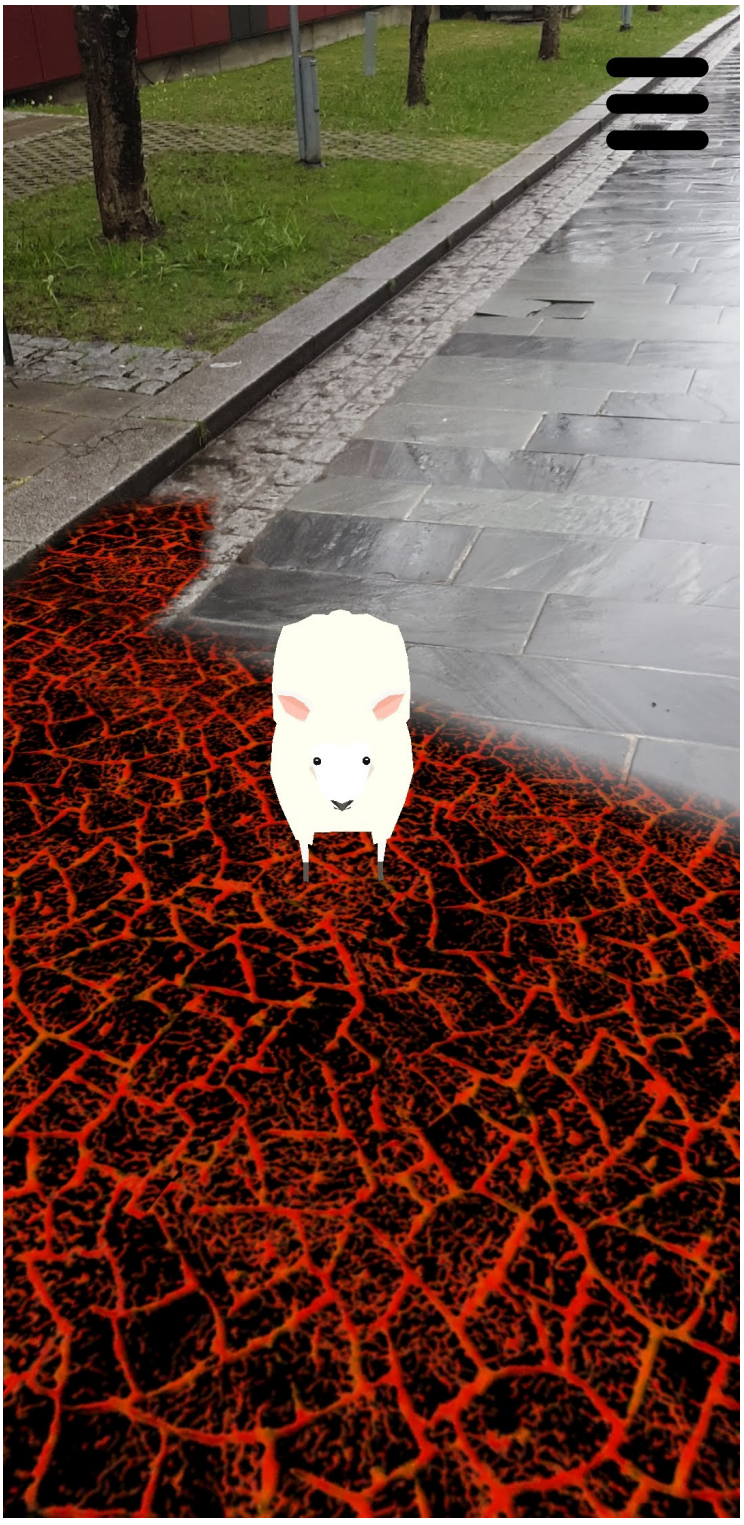
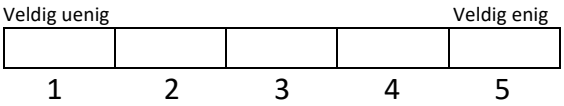
B

SUS Questionnaire (Norwegian Only)

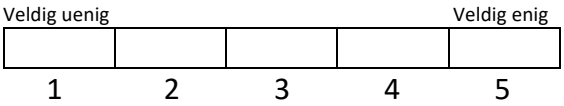
Spørreskjema - Dyrejakten



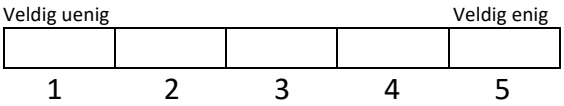
1. Jeg tror vi kunne brukt denne appen jevnlig.



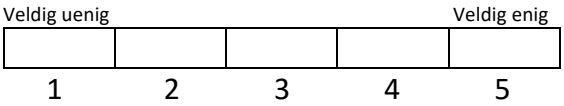
2. Jeg tror appen blir for komplisert for psykisk utviklingshemmede å bruke på tur.



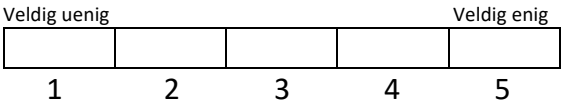
3. Jeg tror det er lett for psykisk utviklingshemmede å bruke appen på tur.



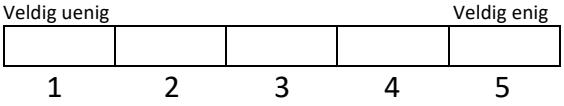
4. Jeg tror brukeren vil trenge mye støtte til å bruke appen på tur.



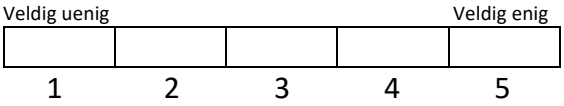
5. Jeg syntes at de forskjellige delene av systemet hang godt sammen.



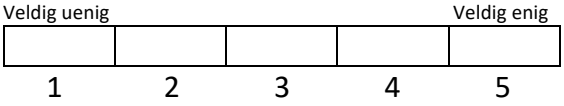
6. Jeg syntes det var for mye inkonsistens i systemet. (Det virket "ulogisk")



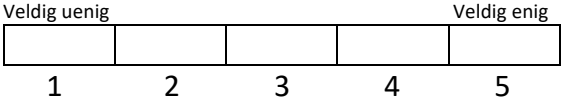
7. Jeg ser for meg at de fleste med psykisk utviklingshemming kunne lært seg å bruke denne appen.



8. Jeg tror det vil være tungvint for brukerne å bruke appen.



9. Jeg tror brukerne var komfortabel med å bruke appen alene.



10.
Jeg tror brukerne trenger omfattende opplæring for å kunne bruke appen.