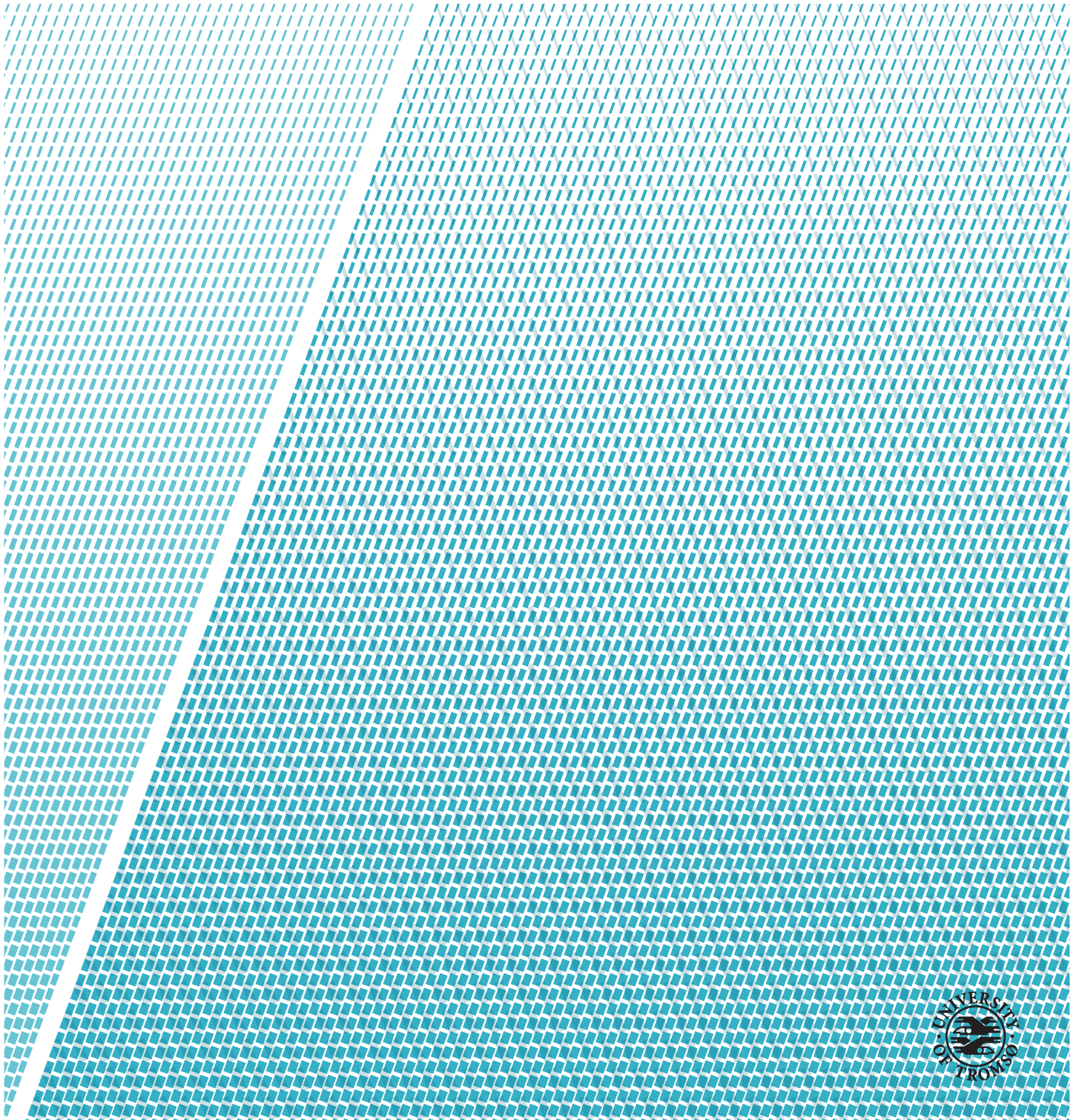# AGA: A Game-Inspired Mobile Application for Promoting Physical Activity in People With Intellectual Disabilities

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Marius Wiik
INF-3981 Master's Thesis in Computer Science - June 2019

To Ria, my girlfriend, companion, best friend and partner in crime the last 11 years. I love you.

Will you marry me?

"The people who are crazy enough to think they can change the world are the
ones who do"
–Steve Jobs

"When something is important enough, you do it even if the odds are not in
your favor."
–Elon Musk

"There's nothing wrong with having a tree as a friend."
–Bob Ross

"We don't make mistakes. We just have happy accidents."
–Bob Ross

"Writing a master's thesis is hard"
–Marius Wiik

Preface

Going into this project earlier this year, I was excited to get my first big front end oriented project during my studies, as most previous assignments had no or small amounts of work involving user interfaces. I was shortly after that overrun with fear when realizing that not having worked with any 3D manipulation previous to this was going to be a considerable part of the learning experience for me. It became apparent that it was not going to be a walk in the park. The challenge did not get any less intimidating when I started digging deeper into what it means to create an application, in terms of user interface design, making it accessible and so forth, for people who do not have the same cognitive capabilities and most people. It was tough to imagine what it would be like for them using the application, and I had to rely on what I found through research and experiences told by experts in the field. However, I am not one to shy away from challenges, and this aspect only made the project even more exciting by introducing that interdisciplinary aspect.

Buying my first house with all that entails while writing a master thesis was also not, in hindsight, the best of ideas. However, now as I'm here at the end of the semester, I would say it was still worth it even though I have had periods of unevenly divided attention. My mindset has also wandered between a state of motivation and discouragement, but I would think that is pretty normal. While its good to be able to put behind me the past five years and have something to show for it, it is making me ambivalent. On the one hand, I am excited to start my new job as a software developer, but on the other hand, this does mean my entire class splits up and will rarely see each other going forward.

I have many people to thank for getting me here. Hopefully, I don't forget anyone. First I want to thank my primary supervisor Gunnar Hartvigsen for guiding me through the jungle that is research and thesis writing, for giving me tips I couldn't possibly dream up myself, the insight in the medical field and the weekly follow up meetings. I want to thank Audny Anke and Henriette Michalsen for facilitating and arranging for me to conduct real-world testing of my application as well as Elisabeth Andresen for receiving us with open arms and her enthusiasm in application testing. Also, especially Henriette who has been very helpful in answering every single little stupid question

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I have asked with thorough and constructive answers. I also want to thank Santiago Martinez, Javier Gomez, Mirek Muzny, and Audny Anke for accepting to be my co-supervisors and giving valuable feedback and guidance in both the computer science and medical research fields. I want to direct special recognition to Antonio Martinez Millana who wasn't my co-supervisor but came in clutch at the end of the project and provided invaluable feedback from a fresh perspective both in regards to the application but also for the thesis itself. To my co-students of five years; thank you! Especially those I shared an office with this semester. Sverre, Vebjørn, Tobias, Valter. You made it fun to get up in the morning and go to university. Thanks for all the laughs, the discussions, the banter, the coffee overdoses, and the motivation. Also, thanks to my co-student and colleague Jørgen Lund for reading through my entire thesis and giving exceptionally good feedback.

Last but not least, I want to thank my family: Mom, dad, Kurt-Ove, and my brother Joakim for always rooting for me during these years. And of course an unbelievably huge thanks to the love of my life Ria for standing by my side and believing in me in periods where I didn't.

So, enough chit chat. Let's get on with it.

Marius Wiik — Tromsø, Norway, May 2019

Abstract

Obesity and other health problems have a high prevalence in people with intellectual disabilities. Many lead a sedentary lifestyle and often have low scores on fitness indicators such as muscle strength and cardiovascular fitness. The purpose of this research is to identify design techniques and features of a mobile application that can help promote physical activity in people with intellectual disabilities.

We review literature found in a literature review, consider mobile applications from a doing a state of the art review and through other research. We also receive input from experts in the field and inspiration from other applications and use the information to identify features of a mobile application which can promote physical activity by being fun, engaging and motivating. We identify techniques and factors to consider when designing a mobile application accessible to people with intellectual disabilities. Lastly, we conduct a real-world usability test where people with intellectual disabilities and their support staff use the application and give feedback.

We create AGA (Activity Gaming Avatar), a 3D training partner presented in a mobile application which can demonstrate physical activity exercises and dances with music to people with intellectual disabilities and users can earn points through completing workouts. The application is set up with longevity in mind where adding new exercises and clothing items is made easy. Results from the usability tests show potential to help and motivate people with intellectual disabilities to become more physically active. Both users and staff reported enjoying using the application and users were able to navigate and exercise with it without much assistance, and upon trying to retrieve the testing gear, we were compelled to leave it there as they had too much fun with it.

The resulting 3D avatar application is shown to be a facilitator of physical activity in people with intellectual disabilities. We achieve this through introducing fun and motivation using praise and giving the user contingent rewards. The long term effects remain to be measured, but according to preliminary tests, the application can have a significant impact on the physical fitness of people with intellectual disabilities as well as encouraging positive attitudes towards

being physically active. In the long run, making this group of people healthier can lead to them being better integrated into society, better mental health and reduced government expenses incurred by reduced productivity and treatment of medical problems caused by obesity or poor mental health.

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List of Abbreviations

BCT Behavioural Change Techniques

FDD Feature Driven Development

GAC General Adaptive Composite

GCP Google Cloud Platform

ID Intellectual Disabilities

REK Regional Committees For Medical and Health Research Ethics

SUS System Usability Scale

TTS Text To Speech

UI User Interface

UMA Unity Multipurpose Avatar

VR Virtual Reality

WHO World Health Organization

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Introduction

1.1   Background

> "*A condition of arrested or incomplete development of the mind,
> which is especially characterized by impairment of skills manifested
> during the developmental period, which contribute to the overall level
> of intelligence, i.e., cognitive, language, motor, and social abilities.*"

This is how the World Health Organization (WHO) defines Intellectual Disabilities (ID) [1]. Prevalence of ID varies widely across the different regions of the world due to different criteria in identifying ID [2][3, p. 8-10], but is thought of as being in the neighbourhood of 1% of the worlds population [4]. Common characteristics of people with ID are deficits in adaptive and cognitive functions [2] and the IQ of the person often determines the severity ranging from a mild case which is between 50-70 IQ to a profound case with below 20 IQ [3, p. 6]. There are several disorders and conditions frequently found in people with ID. The most common include epilepsy, cerebral palsy (20-30% of people with ID), sensory impairments as well as mental health problems due to the difficulty in identifying them [3, p. 12] as a result of them having difficulties expressing themselves.

Causes of ID are many and can happen in different parts of a person life from prenatal up to adulthood. Prenatal can be chromosome disorders like Down syndrome which represents 20-40% of people born with severe ID [5] and 4-10% for mild cases [6]. Another prenatal cause is environmental factors like

maternal diseases and malnutrition [3, p. 15]. In the perinatal stages of a pregnancy[1], causes of ID can be lack of oxygen and premature birth [5]. Lastly postnatally, causes of ID include infections, degenerative disorders and child abuse [7, ch. 3].

People diagnosed with ID has been found to have worse health than the general population [8, 9], with low scores when it comes to fitness indicators such as muscle strength, cardiovascular fitness as well as lower performance when running and high blood pressure [10, 11, 12, 13]. Cases of obesity or being overweight is also more prevalent in people with ID [14] and is considered to be a significant health threat to this group of people [15, 16]. Obesity, being considered an epidemic in many populations [17], is a real challenge to society in terms of reduced productivity, medical expenses and higher rates of disabilities leading to billions of dollars being spent to mitigate the impact [18]. The identified reasons for poor physical fitness in people with ID are lack of healthy eating habits in addition to getting far less physical activity [19, 20, 21, 22] as these people often end up having sedentary lifestyles [23, 24] whether it is involuntary or by choice. One study shows that as many as 60% is reported to have low levels of physical activity across the ages 19-65+ with under 10% saying they do any recreational activity such as sports, jogging or gardening [24]. As low as 9% of the population of the world with ID has been known to meet the minimum physical activity guidelines put in place by the WHO [25]. Being physically active is potentially an essential way of improving health in people with ID [26] and studies show that physical activity interventions can have a positive effect on these peoples fitness indicators [27, 28, 29]. This part of the population also often suffers from mental illnesses, where physical activity has shown to be one way to reduce anxiety and improve mental health [30, 31].

While people with ID do understand and appreciate the importance of a healthy lifestyle and physical activity, and typically know what is good and what is terrible for them [32], they describe not having fun while exercising as a barrier for motivation to being physically active [33] while expressing being healthy and staying fit as facilitators towards physical activity [34].

This project is part of the research project "Effects of physical activity with e-health support in individuals with intellectual disabilities" [35] funded by Helse Nord whose goal is to enhance physical activity in youth and adults with ID using motivational e-health support, investigate the effects of these and to increase research activity on the topic both nationally and internationally.

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1. The perinatal stage stretches from 22 weeks pregnant to 7 days after the child is born

1.2 Scope and Research Problem

This project was conceived by the idea of using mobile devices to promote physical activity. Nearly 74% of people with ID aged 15-64 owns a mobile device which opens up to many potential users [36]. The project aims to create an avatar running in a mobile application which shows users exercises to perform as well as tracking the physical activity and giving praise when completing tasks. One key goal is to incorporate fun and play into activities otherwise thought of as dull and mundane by gamifying said activities.

The main research problem of the project is:

> *How can a 3D avatar running in a mobile application help people with intellectual disabilities become and stay more physically active?*

We further divide the main problem into these subproblems:

> *Sub-Problem 1: What makes a mobile application accessible for people with intellectual disabilities?*

This sub-problem is in regards to design, accessibility, and functionality. It is vital that the target group can understand features and interact with the application without too much intervention from support staff.

> *Sub-Problem 2: Which features and characteristics of a mobile application can help motivate people with intellectual disabilities to be more physically active?*

Here we want to explore what functionalities are most suitable for people with ID. It can not be too complicated to follow and should introduce levels of fun to keep the user engaged and should not force specific exercises on the user if they are not interested, i.e., give them choices. It is necessary to keep it person-centered and make it tailor-made for the specific user who is expected to increase the level of physical activity and mental well-being. [2]

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2. Stated in the original project "*Effects of physical activity with e-health support in individuals with intellectual disabilities*" [35]

> *Sub-Problem 3: How can a mobile application retain users with intellectual disabilities over a period of time?*

When the user starts using the application, it is important to keep them motivated to continue using it over time as physical benefits from activities come after prolonged use [37].

1.3   Assumption and Limitations

Ideally, we would want to develop an application that works for all levels of ID, but it can be quite hard as differences in cognitive and physical capability are severe. Since the target group has to be able to use a mobile device, this application is trying to target people with moderate to mild levels of ID where the cognitive age ranges from 6-12 years [38]. This group also counts for 85%+ of all cases of people with ID and are capable of learning communication, can participate in activities and perform tasks [39]. People with severe ID have a mental age of 3-6 and it is possible to design an application for people of this age, but they often have poor motor skills [38] which does not go well with the use of a mobile application.

Only the client portion of the application is considered and implemented in this project. Some features might need a back end for data processing and storing, which is not a part of this design. Additionally, although the tools used are capable of creating cross-platform applications, some native libraries are platform specific. We decided to create an Android application as Android is the most popular mobile platform as of now, with over 75% of the market [40].

When testing an application aimed at promoting physical activity, measuring fitness indicators over time is vital to assess the effects it has on the target population. In studies, the effects of interventions are often measured over 15+ weeks, and even longer when measuring the maintenance of physical fitness. Since this is a relatively short project, implementing an application, deploying and measuring is hard to achieve, and we are therefore limiting it to usability testing.

1.4 Methods

We conduct a systematic review to identify previous attempts at using software to promote physical activity in people with ID, the measurement variables used, and techniques applied. We then perform a state of the art review where we look at other mobile applications available in marketplaces on popular platforms in addition to performing searches for non-published applications. We analyze the results to see if there are any overlap in what we are trying to achieve and to learn from them in terms of design and functionality. Afterward, we research behavioral change and mobile design techniques to determine which aspects and features of our application are essential to focus on to accommodate people with ID. Lastly, we iteratively develop an application, then test it on users from our target group before we gather feedback from staff and attendees in a reference group meeting containing staff who works with the target group, researchers in the field and parents of people with ID.

1.5 Contributions

The main contribution of the project is the first known implementation of a 3D-avatar in a mobile application to promote physical activity in people with ID. The application implement features based on previous studies on what kind of interventions the user group responds to before conducting a usability test to see how well users can interact with the application. To make the application accessible to people with ID, we research, present and apply techniques in mobile design to achieve accessibility. We also identify and implement features and characteristics of mobile applications to facilitate physical activity such as fun and praise. To try and retain users over time, we notify the users to use the application after a period of inactivity, while trying to engage support staff by introducing a competitive element using a leaderboard. From the usability tests, we get positive results where users both can and want to interact with the application to the point that it was difficult to get back from them as the testing phase ended. The avatar could also be incorporated in other applications in the future, and be a familiar face for the user in many different settings such as educational games and software. The results contribute to insight into the feasibility of using mobile 3D avatars as a means of facilitating physical activity in people with ID.

1.6   Organization

The rest of the thesis is structured as follows:

Chapter 2 Theoretical Framework goes through the theory that led to many of the design decisions. The systematic review summarizes literature before performing a state of the art analysis to see what applications exist in this domain. Then we talk about behavioral change and how to design an application for people with intellectual disabilities.

Chapter 3 Methods and Materials describes the research paradigm applied in addition to how we conducted the usability test.

Chapter 4 Application Requirements goes through the requirements of the application and how they were identified. It also talks briefly about the software engineering methods applied to the project.

Chapter 5 Design walks through the applications features and shows how they work.

Chapter 6 Implementation talks about some of the implementation details and how we worked with 3D models.

Chapter 7 Tests and Results presents the results of the usability test.

Chapter 8 Discussion reviews the findings and application shortcomings. We address the research limitations and recommend further improvements to the application with new features and changes.

Lastly, **Chapter 9 Conclusion** summarizes the thesis and its findings before presenting concluding remarks.

/2

Theoretical Framework

To establish a theoretical foundation for our solution, we conduct a systematic review before talking about mobile applications currently in the market. We then proceed to talk about behavioral change in people with ID and also, important aspects of how to design an application for this user group.

2.1   Systematic Review

The objective of conducting a systematic review in this project was to find previous technological efforts to get people with ID to be more physically active. We aimed to find studies that successfully implemented software or hardware with a gamification aspect to attempt to improve motivation in the target group. We wanted to use the results to potentially see what has previously been done, what works and what doesn't, but also see what evaluation criteria has previously been assessed to identify evaluation criteria for our project.

We conducted a literature search early in the project, and the databases used were:

- IEEE Explore [1]
- ACM Digital Library [2]
- Pubmed/Medline [3]
- Scopus [4]
- Science Direct [5]
- Embase [6]
- PsycInfo [7]
- CINAHL [8]
- Games for Health Journal [9]

The Games for Health Journal was especially considered due to its potential relevance as it focuses on advancements of game research on human health and well-being. In the Science Direct database, we only included review and research articles in the search. The search terms used were chosen to try and capture any variation of words used to describe gaming, applications and mobile, in conjunction with intellectual disabilities and physical activity and combining them using boolean operators such as *AND / OR*. We did not put any restriction on publication dates, believing that relevant publications for this kind of application would probably be of recent date. The challenge was finding search terms that weren't too broad, but not so narrow that they would exclude essential publications. We contacted the University Library, and they assisted by both suggesting some of the mentioned databases and identifying essential keywords. The complete list of databases and search terms are found in appendix A.[10] In addition to the database searches, two papers were provided by Henriette Michalsen, a Ph.D. student working on the main research project [35], which we also considered in the total pool of results.

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1. `https://ieeexplore.ieee.org/Xplore/home.jsp`
2. `https://dl.acm.org/`
3. `https://www.ncbi.nlm.nih.gov/pubmed/`
4. `https://www.scopus.com`
5. `https://www.sciencedirect.com/`
6. `https://www.embase.com`
7. `https://www.apa.org/pubs/databases/psycinfo/`
8. `https://web.b.ebscohost.com/ehost/search/advanced?vid=0&sid=5838eb23-b2e4-4286-b408-542df5ec84a3%40pdc-v-sessmgr03`
9. `https://home.liebertpub.com/publications/games-for-health-journal/588/overview`
10. Note that the search terms include the word "*mental retardation*" in addition to "*intellectual disabilities*", which we included due to historical reasons where this was the term used in the medical field. Intellectual disability is now the preferred term. [41][42, p. 12]

To be included in the review, each publication had to satisfy three criteria:

- The subjects of the study had to be people with ID.
- The goal of the study had to be to motivate to an active lifestyle or increase levels physical activity.
- Reaching the goal should be done using software, either on desktop or mobile devices.

Using these inclusion criteria, we got 267 results, and then we did an initial screening where we removed duplicates and ended up with 236 unique results. After that, we removed papers which, based on the title, abstract, and introduction did not match the inclusion criteria. The initial screening eliminated many potential papers, some of which were not in English when opening the paper, even though it contained keywords in English, but mostly they were excluded for not ticking all three inclusion criteria boxes. After this stage, we had 19 preliminary papers. We read these studies in full, and we eliminated six before being left with 13 eligible studies. The reasons for eliminating the last six studies were that some of them focused more on motor skills improvements than physical activity, and some did not have the full text available with the accesses given by the university.

The PRISMA [43] flow diagram of the process of sifting through the results is seen in figure 2.1.

Amongst the resulting studies, the technology used to improve physical activity in people with ID varied. Some used Virtual Reality (VR) as a way of gamifying exercise [44, 45, 46, 47] while others used a sensor mat to record user input [48, 49, 50, 51]. A couple of studies [52, 53] used the Nintendo™Wii Balance Board while one study used phone notifications [54] and one used praise delivered through an iPod [55]. The last study explored using a group conference call to deliver physical activity interventions remotely [56].
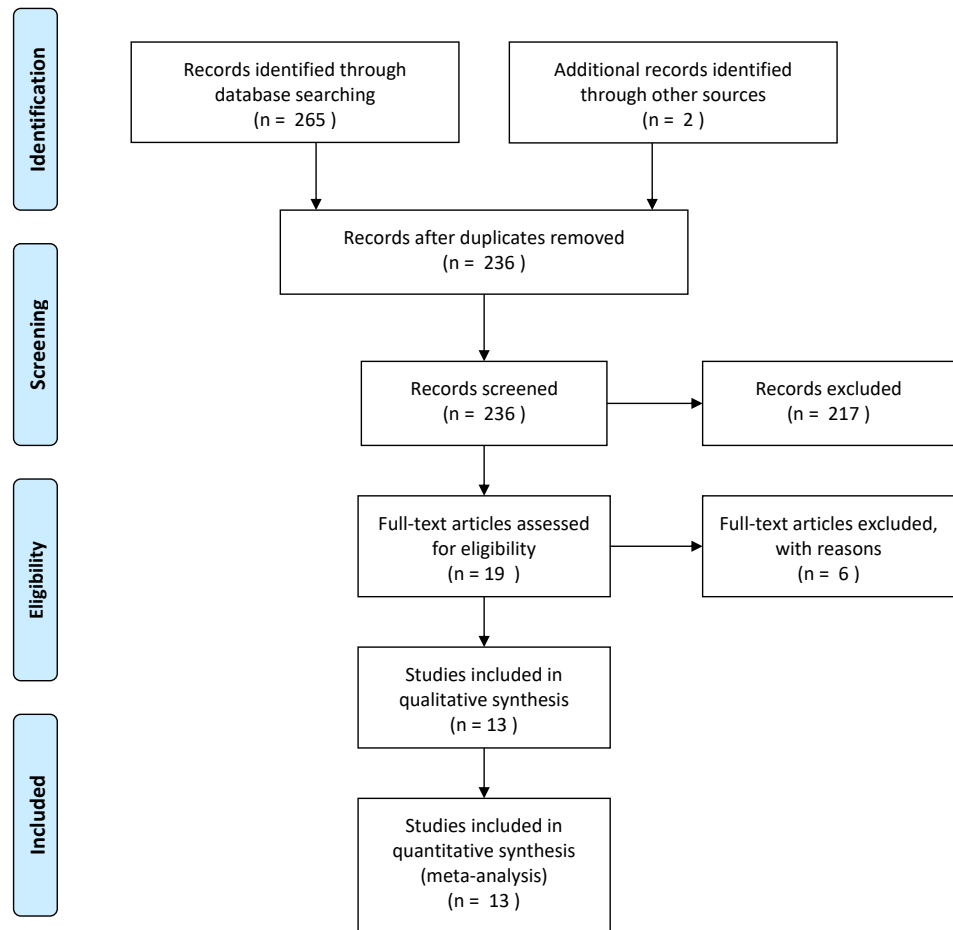
Figure 2.1: The PRISMA Flow Chart
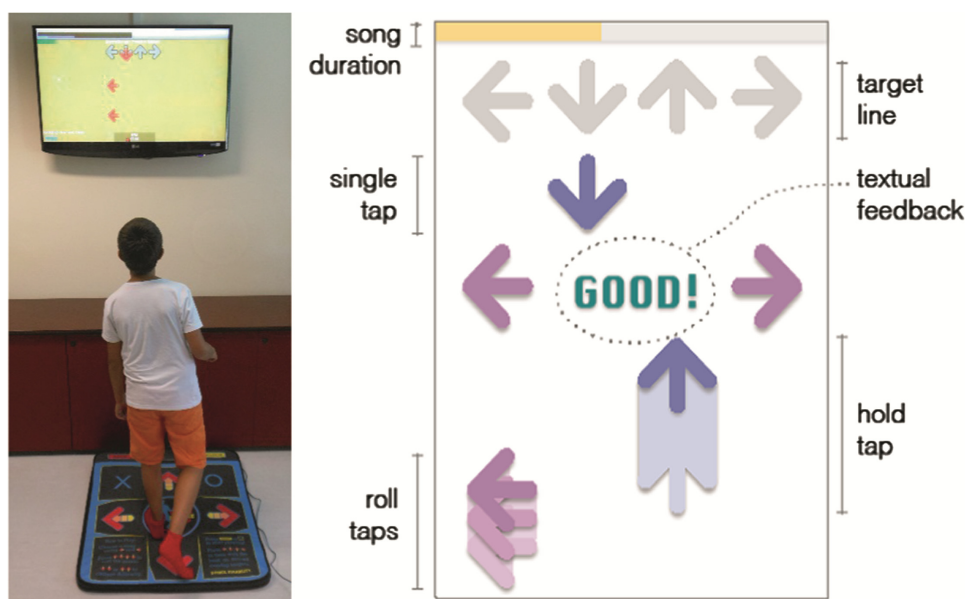
Figure 2.2: One of the studies using a sensor mat. [50]

Most of the studies main measured result is the changes in physical fitness or physical activity before and after the intervention, but engagement is also a key point of interest. If someone can engage a person with ID and make them want to come back and use the device or application more, it could lead to higher levels of physical activity in the long term. The results in large were positive for all the studies, meaning an increase in physical fitness, activity, or engagement. However, the results seemed to vary greatly depending on the level of ID the user had. One study was conducted twice, once on people with moderate levels of ID [45] and once on people with a severe level of ID [46]. While the first one demonstrated significant improvement in physical fitness, the second showed that even though the users were motivated to participate, their physical fitness was only slightly enhanced. These observations tell us that it is crucial to cater to a specific target audience when developing these kinds of applications, and not try to find a silver bullet that works for everyone. The study that delivered praise through technology [55] showed mixed results amongst the relatively small test group (n = 3). Two of the three participants largely favored that the praise was delivered using technology. The one that favored in-person praise was interestingly the one with the lowest General Adaptive Composite (GAC) score, which is a score that indicates a persons ability to adapt to common demands in life [57]. The study that notified users on their mobile phones to be physically active, showed that the users with the application installed had a more significant level of maintenance of physical activity than those who did not use the app.
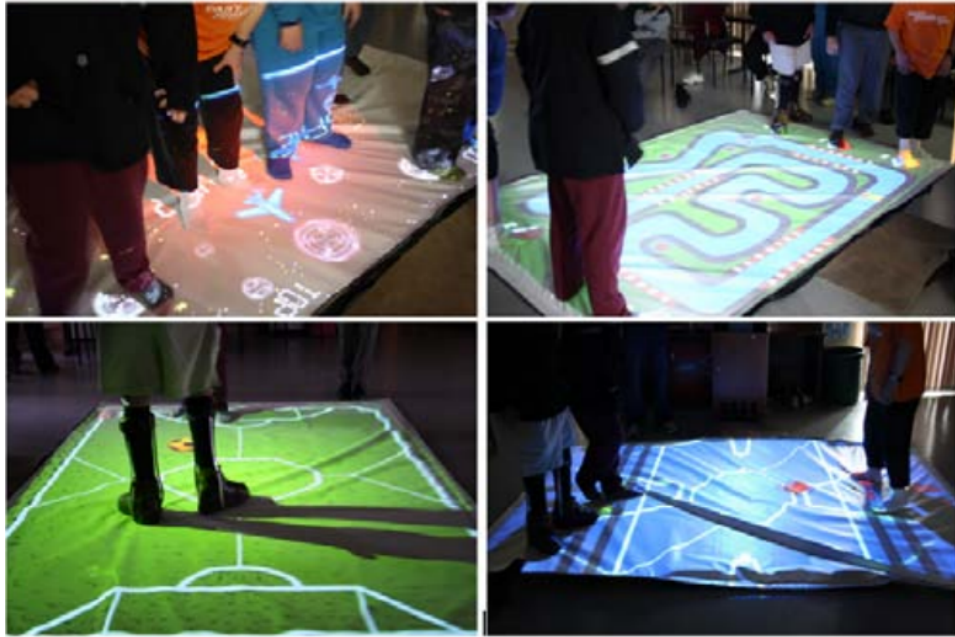
Figure 2.3: The STOMP sensory mat [58]

The majority of the studies used some existing technology to engage users in physical activity (e.g., VR and Nintendo™ Wii balance boards), but one study [48] created an entire platform called STOMP which aims to encourage playful interactive experiences to enhance cognitive, social and physical play by having a sensory mat where the game is projected directly onto the mat. They point out the importance that the experience should not heavily rely on a person's social skills, and that interaction between people should be present without the need for collaboration or teamwork.

Tables 2.1 and 2.2 summarizes all evaluated articles in terms of goals, methods, target group and results.

Table 2.1: Systematic Review Articles Summarized

Article	Goals	Method	Target group	Results
[44]	Promote participation in leisure activities	Using VR based activities	Adults with moderate ID and cerebral palsy (n = 17)	Participants found it enjoyable. High level of interest maintained
[45]	Improve physical fitness	Using VR-based exercise program	Adults with moderate ID (n = 30) + control group	Significant improvements in physical fitness
[46]	Improving physical fitness	Using VR-based exercise program	Adults with severe ID (n = 20) + control group	Significant improvement in heart rate, but not strong enough to claim improved physical fitness
[47]	Improving sensory functions	Using Nintendo Wii and VR technology	Children with Down syndrome (n = 105) + control group	Improved motor proficiency and sensory functioning.
[48]	Improve cognitive, social and physical activity	Custom mat to control games and make users use their whole body	Children with ID (n = 13)	Effectively supports cognitive and physical activity
[49]	Introduce physical activity into daily lives	Custom edutainment system with padded floor mat with sensors	Children with mild (n = 6), moderate (n = 6) and severe (n = 5) ID.	Good results, but more interest from people with mild to moderate levels of ID
[50]	Encourage physical activity	Rhythm game with dance pads and video screens	Children with mild to moderate ID (n = 6)	Encouraging results, mostly got feedback on possible improvements

Table 2.2: Systematic Review Articles Summarized (continued)

Article	Goals	Method	Target group	Results
[51]	Enhanced and enjoyable learning process while addressing the need for physical activity	Multimedia technology based games	Children with mild (n = 36), moderate (n = 34) and severe (n = 7) ID	High motivation levels in all groups but best results in children with mild levels of ID
[52]	Promote physical activity	Using Nintendo Wii Balance Board and custom software	Children with ID. One test subject with moderate levels and one with profound	Increased stimuli compared to what they started off with
[53]	Promote physical activity	Nintendo Wii Balance Board	Children with ID	Similar results as above. Some increased physical activity and good response to the system
[54]	Increase level of physical activity	Using smartphone reminders	Children with mild ID (n = 8)	Significant increase in physical activity
[55]	Increase physical activity	Deliver praise using technology and in person	Children with ID (Autism) - Moderate (n = 2) and mild (n = 1)	Good response on praise, sometimes better with using technology
[56]	Increase physical activity	Deliver physical activity sessions using video conferencing	Adolescents with mild to moderate ID (n = 31)	Group video conferencing may be a feasible alternative to on-site programs

2.2   State of the Art

When developing an application, it is essential to explore what others have done previously and what exists in the market. This knowledge is vital for two reasons; to avoid doing work that has already been done and to get inspiration for features to include in our application. We searched the most popular application repositories, namely the Android Google Play Store and iOS AppStore as they count for 97% of the market share combined as of April 2019 [40]. We also used the Google search engine to look for applications and used it mainly to identify applications not necessarily released yet but also because the search functions in the app stores were not very good. For example; searching the word "exercise" on the Google Play store yielded 230 results, but this seemed to be the limit on how many results they could show. Using another service called AppCrawlr[11] yielded many more (600+) results in the exercise category for Android. Another challenge with searching directly in the Google Play Store and AppCrawlr was that the search terms did not support boolean operators such as AND and OR. It seemed to default to OR, so a search for "*Intellectual Disabilities*" *AND* "*exercise*" gave many results not containing any reference to intellectual disabilities. Using the iOS AppStore did not provide more precise results as their search engine do not return applications based on anything in the description. They might base the results on some keyword mechanism that is not visible to the user. However, searching for terms that we knew was present in the description of applications like "utviklingshemmede" (developmentally disabled in Norwegian) gave zero results. The last challenge is the number of applications. Google Play and AppStore has a combined number of apps of almost 4 million [59] which is a daunting library to search through without advanced search capabilities.

The results were much better using Google, which gave results leading to curated lists of relevant applications for children, exercise, intellectual disabilities, and avatars. To try and find applications not released to the public, we also searched some journal databases like IEEE Explore, ACM Digital Library, Games for Health, Pubmed and Science Direct. The search words were a combination of "*Intellectual disabilities*"*,* "*avatar*"*,* "*exercise*"*,* "*app*"*,* "*application*"*,* "*mobile*"*,* "*serious games*"*,* "*fitness*"*,* "*character*"*,* "*mental retardation*" and "*game*".

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11. `https://appcrawlr.com/`

2.2.1   Application Evaluation

From the results, we reviewed 13 applications for mobile or tablet. Most of the applications were downloaded and tested, but some were too expensive, and the creators' description and screenshots were the sources of evaluation. Many of the included results were not directed to people with ID but rather kids, while some were mostly for adults but had some other aspect similar to what we are trying to make. We looked at things like the UI design, how exercises were demonstrated (if applicable), the target population of the app, and if it had an avatar, how it helped with physical activity.

The following sub-sections give a brief description of each application along with some pros and cons compared to what we are trying to create while showing images which are all taken from the listing in their corresponding application stores or websites. A quick evaluation summary can be found in Tables 2.4 and 2.5 in section 2.2.2, while table 2.3 show the mapping from the numbers in the first column of tables 2.4 and 2.5 to the application names and supported platforms.

Boo - 3D Avatar & AR Chat

Description
The application offers customizable creation of a 3D avatar with facial features and outfits. You can also create a home and visit other players' homes. The purpose of the application is to chat with friends.

Pros

- Simple and clean UI in terms of colors and good use of icons.
- Has a 3D avatar.
- Playful expression.

Cons

- No physical activity.
- Not targeting people with ID.
- Many small buttons which can be hard to reach.
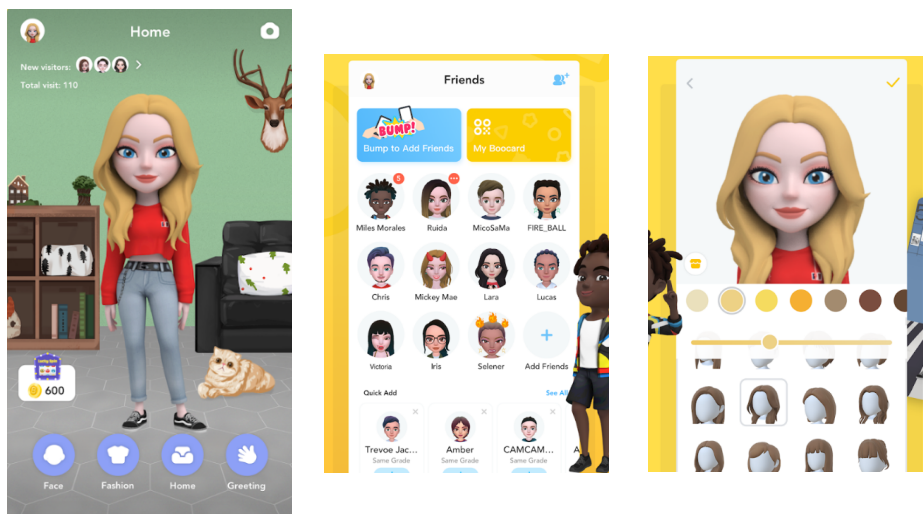
Figure 2.4: The "Boo - 3D Avatar & AR Chat" application

Burn Your Fat With Me

Description
This application is a romance adventure fitness application and dating simulator which exists for girls and boys in two different versions. The idea is to give people motivation to work out to gain popularity with the other (or same) sex and date them.

Pros

- Has an element of physical activity.
- Demonstration of exercises using static images.
- Can choose between several avatars.
- Has a gamifying aspect by having to hit fitness goals within time limits and a storyline.

Cons

- Very messy user interface.
- No customizable avatar.
- Not targeted at people with ID.

Figure 2.5: The "Burn Your Fat With Me " application

HealthyHeroes

Description

The application tries to motivate the user to be active. It is supposed to be fun, social, and engaging. You can unlock rewards which you can share with friends and level up a character.

Pros

- Earn points which you can use to upgrade your character.
- Mostly simple UI.
- Offers physical activity.
- Social aspect through competing with friends.

Cons

- Some clutter in the UI with small icons.
- Character not directly customizable.
- Not targeted at people with ID.
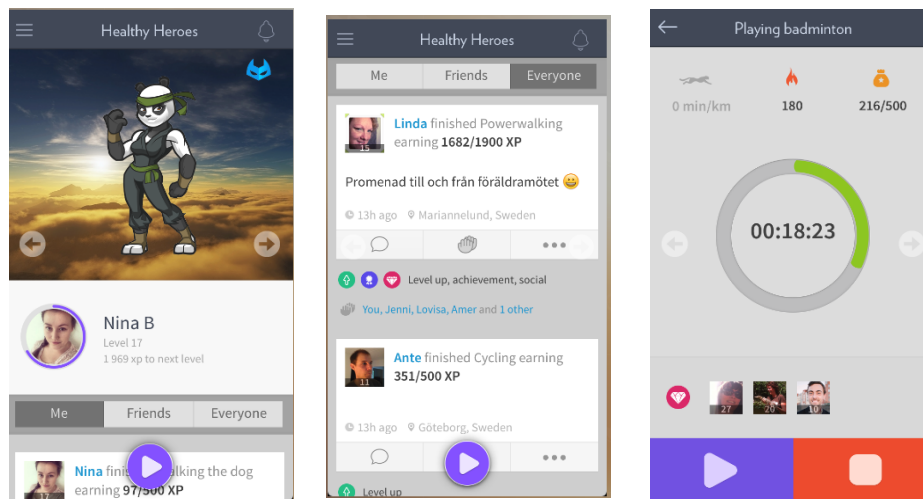
Figure 2.6: The "HealthyHeroes" application

Female Workout - Lose Weight in 30 Days

Description
Designed to lose weight in a fast and safe way, this application provides systematic workouts, diet plans, and synchronization to Androids Google Fit. The user can track progress and provides animations and video guidance with a variety of workouts.

Pros

- Good use of colors in the UI.
- Mostly big clickable areas and clear font used.
- Animations, videos, and static images provided as guidance.
- Has progress tracking.

Cons

- Not targeted at people with ID.
- Does not have any avatar, customizable or otherwise.
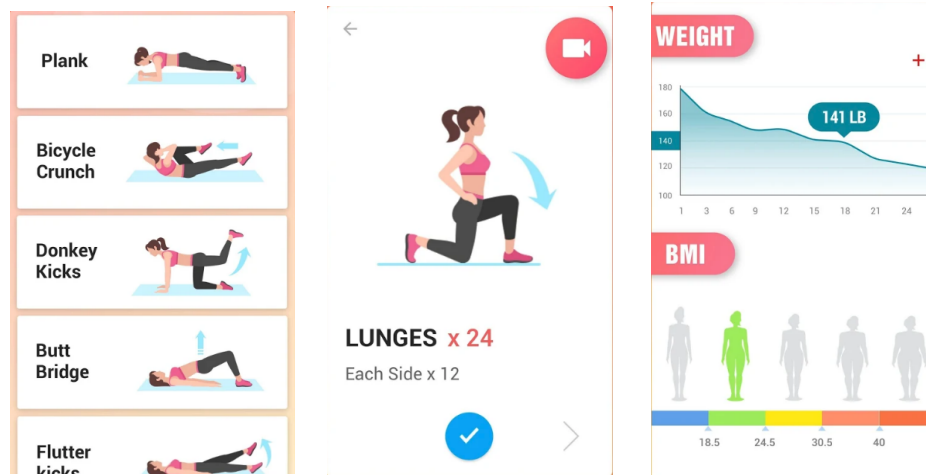
Figure 2.7: The "Female Workout - Lose Weight in 30 Days" application

UFit App

Description
The application is created to help instructors and support staff to adapt exercises for people with disabilities. It provides resources and tips to make the users' fitness services available for everyone and serves as an educational platform to promote inclusion.

Pros

- Targets people with disabilities (included ID) for inclusion and accessibility

Cons

- Hard to get started with, might not be completed according to reviews.
- Author was not able to even log in.
- Requires pricy subscription.
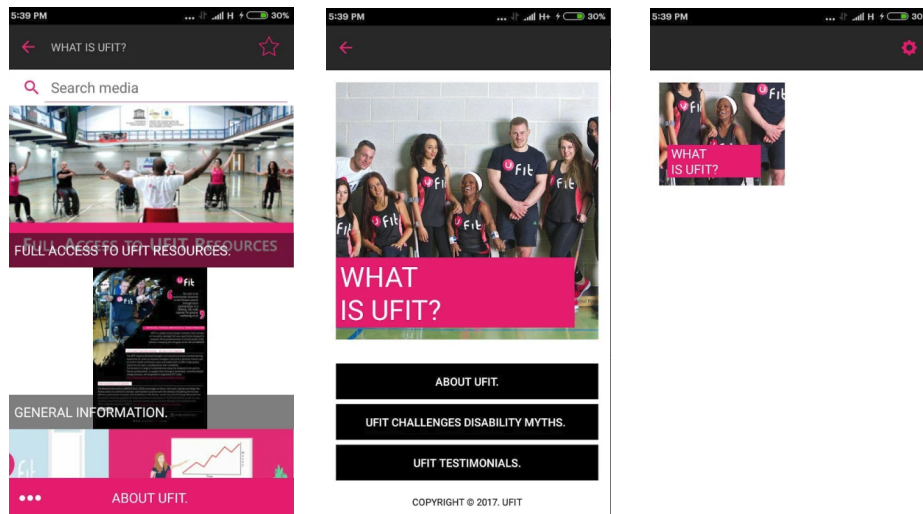
Figure 2.8: The "UFit App" application

Just Dance Now

Description
This application enables the user to dance choreographed dances to over 400 different songs. The user can earn points through following the choreography.

Pros

- Heavy emphasis on fun physical activity through dancing.
- Has an avatar as a dance partner.
- Has a social aspect where you can play with friends.
- Has a demonstration through the dance partner showing which moves to do.

Cons

- Very complicated UI. We had problems using it ourselves.
- Not targeted at people with ID in terms of requiring specific, complicated motion and the complicated UI.
- Unlimited playing requires a subscription.

Figure 2.9: The "Just Dance" application

UNICEF Kid Power

Description

UNICEF Kid Power enables users to turn an everyday activity into lifesaving food for children around the world. It is primarily based on gathering steps and complete daily challenges

Pros

- Does target children which has many similarities in design principles and therefore simple UI.
- Incorporates physical activity and challenges.
- Offers a social aspect by creating teams.
- Has praise when you do good.

Cons

- No customizable avatar.
- No demonstration of activity.
- Even though it targets children, there is no special care taken for people with ID.
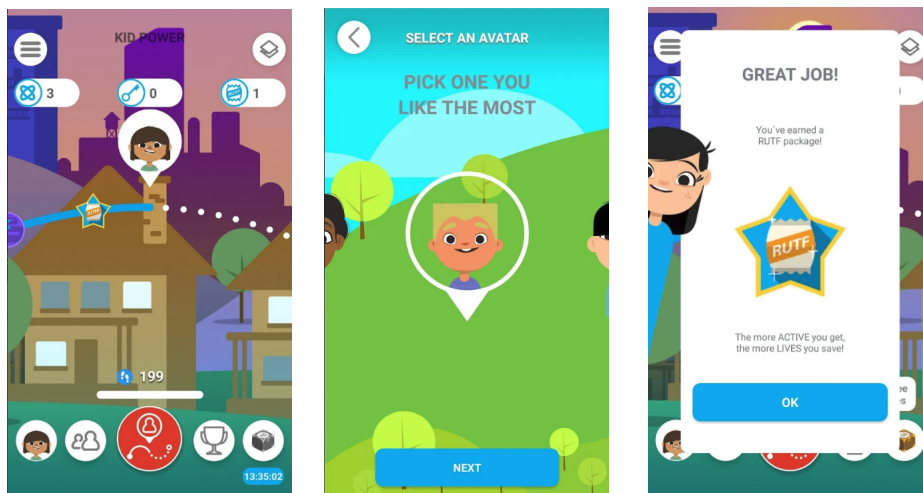
Figure 2.10: The "UNICEF Kid Power" application

GoNoodle - Kid Movement & Mindfulness Videos

Description
This application provides dance-along, activities, yoga, and otherwise fun ways
to be physically active.

Pros

- Demonstrations using videos.
- Fun component with dancing.
- Created for children which might be appealing for people with ID.
- Large clickable areas.

Cons

- Many sub-par design decisions such as hard to read fonts and capitalized
  letters.
- No avatar.
- No special accessibility choices for people with ID.
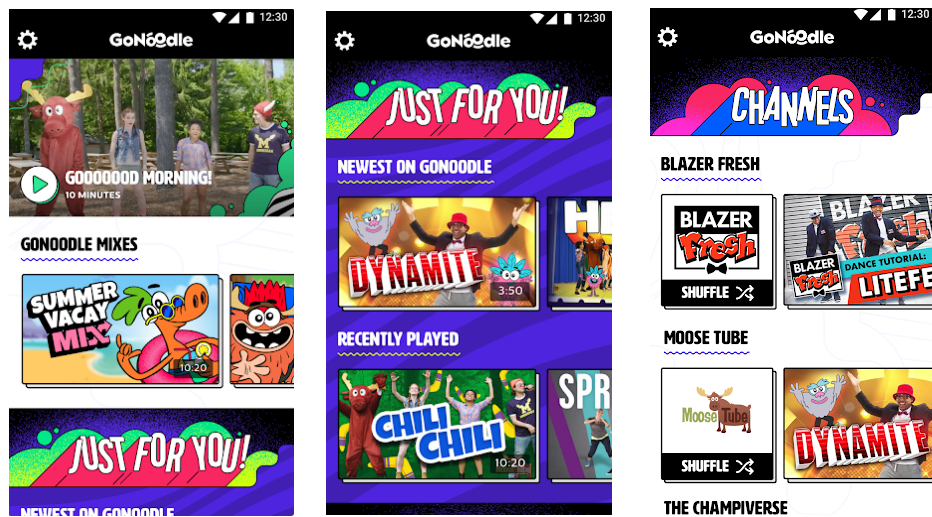
Figure 2.11: The "GoNoodle - Kid Movement & Mindfulness Videos" application

Sworkit Kids - Fitness Meets Fun

Description
This application aims to gamify fitness for kids using customizable workouts. Exactly what the gamification aspect they are claiming to have is, is not well documented in the description. It reminds us of a regular fitness application with children as demonstrators instead of adults.

Pros

- Good video demonstrations of exercises using kids.
- Simple UI where we only used two clicks to start an exercise.
- Can create custom exercise routines consisting of different exercises.

Cons

- No avatar at all.
- Some text can get too small.
- Not directly aimed at people with ID.
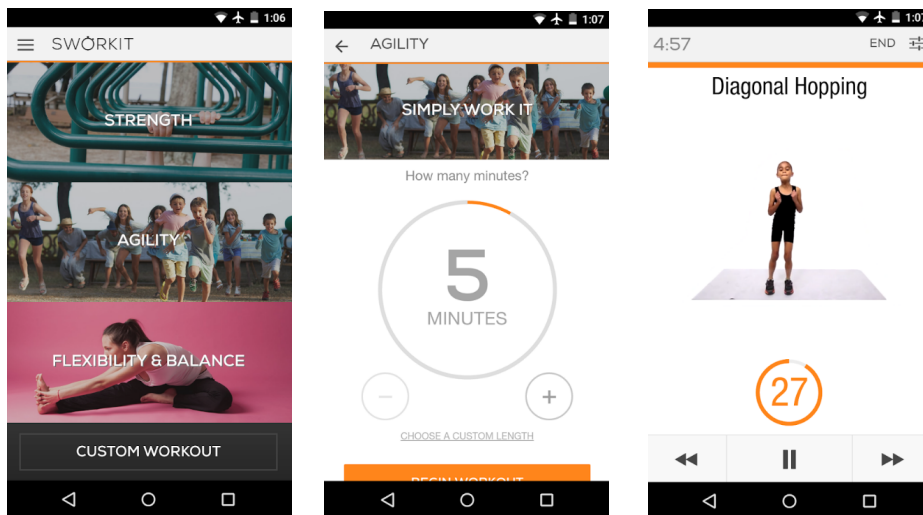
Figure 2.12: The "Sworkit Kids - Fitness Meets Fun" application

Choiceworks

Description

Choiceworks is a learning tool to help improve independence for people with ID. It uses symbols in, among other things, creation of schedule boards which can help users understand a schedule and a feelings board to help users express and understand emotions.

Pros

- Straightforward UI, good use of colors (not too many different ones).
- Uses symbols to communicate
- Created for people with ID or other developmental disabilities.

Cons

- No physical activity component (but this can be created through custom symbols).
- No avatar.
- Is not free, but one-time purchase

Figure 2.13: The "Choiceworks" application

Proloquo2Go

Description
Much like the previous application, Proloquo2Go is a symbol-based communication app for increasing communication skills and helping people with ID express themselves.

Pros

- Created for people with ID.
- Uses symbols.
- Can be personalized for any individual.

Cons

- The user interface looks complicated (not tried by us), might have to be used with support staff.
- Very expensive ($250).
- No component of physical activity or avatar.
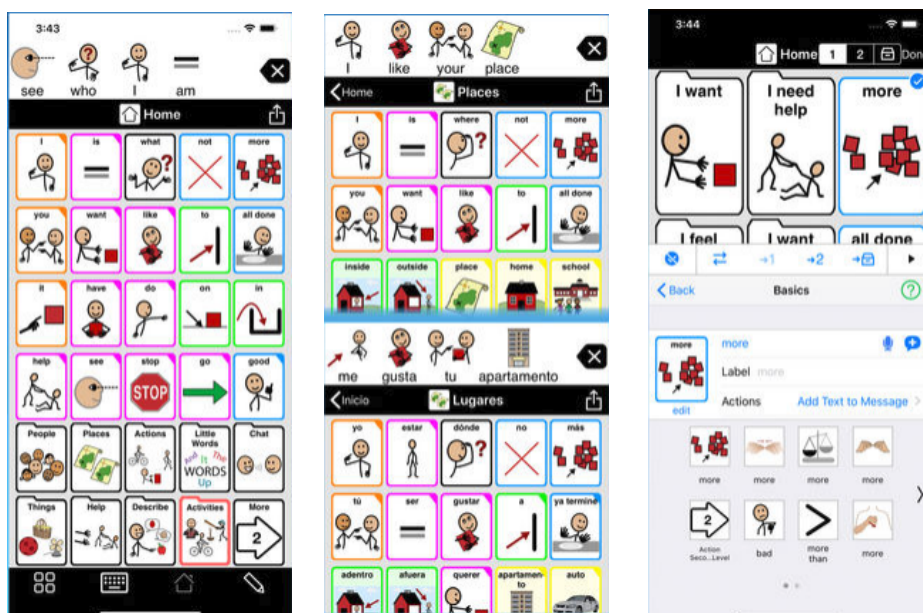
Figure 2.14: The "Proloquo2Go" application

FTU

Description
This domestic application has as a goal to get more people out hiking or on field trips with a focus on including people with ID. The application acts as a calendar which can be used by people with ID where they can get information about the trips available.

Pros

- Mostly good UI.
- Created with people with ID in mind.
- They include Text-to-Speech for people that have trouble reading.
- They use symbols and images to emphasize meaning.

Cons

- No demonstration, other than telling about the field trips.
- No avatar.
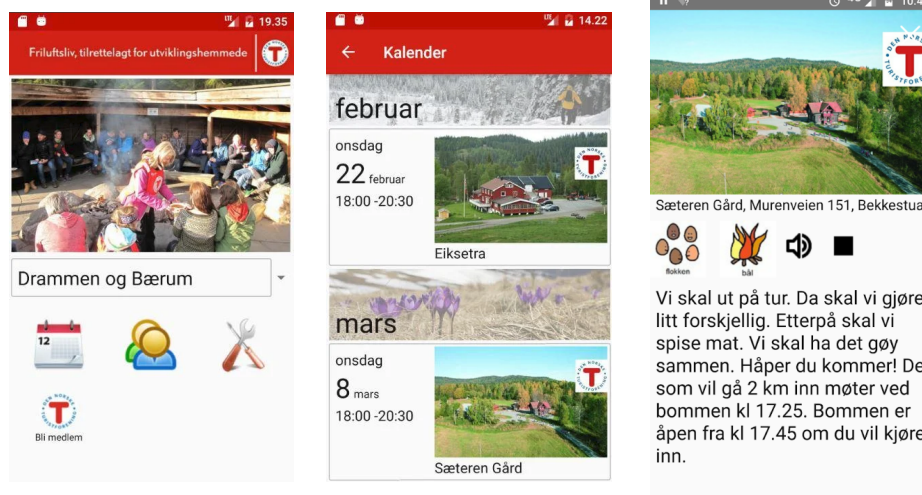
Figure 2.15: The "FTU" application

FunDoRoo

Description
This application is developed to improve motor skills and physical activity of
people with developmental disabilities. They provide activities which include
images, written descriptions, and demo videos of activities.

Pros

- People with and without developmental disabilities demonstrate Exercises.
- Can create custom exercise plans.
- The premade exercise routines follow a progression and increase in difficulty.
- Big main buttons in the UI.

Cons

- No avatar.
- Tiny text, colors that blend into each other (same color for button and background), a lot of buttons and menu options which can be confusing.

Figure 2.16: The "FunDoRoo" application

2.2.2   Results Summary

From the applications evaluated, we can see that none of them checks all the boxes. Only one uses a customizable 3D avatar, and few had customizable 2D ones. Most of the exercise-related applications had demonstrations one way or the other by either using instructional videos or static images. What was worrying is that none of the applications for people with ID was directed at physical activity except for number 12 and 13. Number 12 presents activities in a manner easy to use for people with ID through using symbols, text to speech, and straightforward sentences. The UI for getting to activities could probably improve as the clickable areas were not necessarily apparent and take as much space as something much less important like the settings menu.

There were no difficulties finding exercise applications, but from what we can see there are few to none that can be considered to be accessible for people with ID due to complicated menus, many clicks required to start an exercise and was complicated to setup and get started with. In our search, there were no applications that combine the use of a 3D-avatar to demonstrate physical activity, not to mention doing that while still designing the application with our target group in mind. The results show that there is a gap to be filled in the mobile application market.

Table 2.3: Mapping from app number in table 2.4 to application name and platform

App #	App Name
1	Boo - 3D Avatar & AR Chat (Android / iOS)
2	Burn Your Fat With Me (Android / iOS)
3	HealthyHeroes (iOS)
4	Female Workout - Lose Weight in 30 Days (Android / iOS)
5	UFit App (Android / iOS)
6	Just Dance Now (Android / iOS / Playstation)
7	UNICEF Kid Power (Android / iOS)
8	GoNoodle - Kid Movement & Mindfulness Videos! (Android / iOS)
9	Sworkit Kids - Fitness Meets Fun (Android / iOS)
10	Choiceworks (iOS)
11	Proloquo2Go (iOS)
12	FTU (Android / iOS)
13	FunDoRoo (Android / iOS)

Table 2.4: Evaluation of current applications

App #	UI Design	Demonstration	Target population	Avatar?	Physical Activity
1	Clean / simple, Icons, small buttons	None	Youth to adults	Yes, customizable	None
2	Messy UI	Static images	Adults	Yes, not customizable	Yes, exercise routines
3	Mostly simple, small icons, some clutter, Simple UI when exercising	None	Not sure	yes, not customizable, upgradable	Yes, different activities
4	Simple design, good colors, small buttons	Yes, videos and static images	Adults	No	Yes, Exercise routines
5	Not sure, seems incomplete, not tried, requires subscription	Dont know	Instructors and support staff for people with ID	No	Yes

Table 2.5: Evaluation of current applications (continued)

App #	UI Design	Demonstration	Target population	Avatar?	Physical Activity
6	Complicated UI	Embedded video	Kids, adults	Yes, not customizable	Dancing
7	Simple	No	Kids	2D character not customizable	Encourages physical activity
8	Cluttered, many different colors	Yes, through videos	Kids	No	Yes, dancing
9	Simple	Videos	Kids	No	Yes, exercise routines
10	Clean, symbols	Shows pictures	People with ID	No	No, but can be created
11	Cluttered	No	People with ID.	No	No
12	Simple text, symbols, TTS	Explains activity	People with ID	No	Through activities
13	Clean design, capitalized letters	Still images and videos	Kids / Youth with developmental disabilities	No	Yes, exercise routines.

2.3   Behavior Change

Behavioural Change Techniques (BCT) are theory based methods for influencing people to change their psychological determinants, which are personal characteristics such as beliefs and motivation [60]. The effects of using BCT to increase motivation and positively affect the ability to be physically active have been widely researched, and their effects reviewed [61, 62, 63]. One complication in research on this topic is that there are no standardized definitions of these techniques, along with the fact that the interventions described in research often are brief and unprecise. As an example, one article can describe a technique called *behavioral counseling* as educating patients on the importance of physical activity while another uses it as terminology for giving users feedback on self-monitoring. The different interpretations of terminology make it hard for researchers to find previous work and results. Efforts have been made to standardize the vocabulary used by researchers to define BCT's intervention components and to differentiate between intervention content [64, 65]. Having a standardized vocabulary helps in discerning which techniques and combination of techniques enhance effectiveness, which is crucial for behavior change [64].

Table 2.6 shows an excerpt from the complete CALO-RE table of definitions [64, 65] which are selected based on feedback after conferring with an expert in the field [1] as to which of the techniques people with ID might be susceptible to as well what we discovered through our research.

In her[1] experience people with ID responds well to the two BCT's relating to information about the links between their behavior and their health in addition to consequences if the behavior does not change for the better [33, 34]. She also viewed the encouragement of personal goals to be a viable option [37]. It is crucial when assessing BCT's concerning people with ID to think about which of them are accessible for the target group. People with ID can have trouble interpreting knowledge, which can indicate that the more complex BCT's might not fit into the capabilities of these people [66]. As an example, one study found that even with help from support staff, many users were not able to use pedometers for self-monitoring [67] which lines up with studies that found that equipment ease of use is critical not to make this a barrier to exercise [68, 69].

Providing contingent rewards or general encouragement through praising or rewarding the user has been reported to be a powerful tool where users have positively responded to these techniques used as facilitators. Studies show that users are more likely to take part in a physical activity where they are praised

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1. From conversations with Henriette Michalsen 03.05.2019

[70], rewarded [71, 34] or got awards [72, 68]. Rewards and awards include an activity they like (watch a DVD, having coffee with friends) or material things like trophies and medals [73, 34].

Demonstrating the desired behavior and providing instructions to things like exercise routines have also shown to be an important technique as the lack thereof can lead to frustration in people with ID and consequently the lack of interest and abandonment of the activity [70]. Support from caretakers has also been found to be a facilitator to physical activity alongside with the familiarity with the activity [32]. The contingency is the most uncertain aspect of praising and rewarding as the reward is not guaranteed, but instead, is earned through hard work.

Lastly, there is the set graded tasks technique where a task starts as easy before ramping it up to the desired difficulty level. We were unable to find sources on whether this type of interventions is effective on people with ID, but it can also be seen as an extension of the intention formation technique which entails setting goals. It is a natural evolution that when a goal is met, setting a new one is important to stay motivated. A person with ID has an easier time understanding small incremental tasks to reach their goals than big goals set far into the future. As an example, its more comfortable to think about wanting to lose 0.5KG of weight the next week or so, than thinking about the 20KG you want to lose over the next two years.

Table 2.6: CALO-RE [65, 64] Taxonomy Definitions of behavioral change techniques
and their accompanying theoretical framework.

Technique (Framework¹²)	Definition
Provide information about behaviour-health link (IMB)	General information about behavioral risk, for example, susceptibility to poor health outcomes or mortality risk in relation to the behavior
Provide information on consequences. (TRA, TPB, SCogT, IMB)	Information about the benefits and costs of action or inaction, focusing on what will happen if the person does or does not perform the behavior
Prompt intention formation. (TRA,TPB, SCogT, IMB)	Encouraging the person to decide to act or set a general goal, for example, to make a behavioral resolution such as "*I will take more exercise next week*"
Provide general encouragement.(SCogT)	Praising or rewarding the person for effort or performance without this being contingent on specified behaviors or standards of performance
Set graded tasks. (SCogT)	Set easy tasks, and increase difficulty until target behavior is performed.
Provide instruction. (SCogT)	Telling the person how to perform a behavior and/or preparatory behaviors
Model or demonstrate the behavior. (SCogT)	An expert shows the person how to correctly perform a behavior, for example, in class or on video
Provide contingent rewards. (OC)	Praise, encouragement, or material rewards that are explicitly linked to the achievement of specified behaviors

12. IMB = information-motivation-behavioral skills model; TRA = theory of reasoned action;
    TPB = theory of planned behavior; SCogT = social-cognitive theory; CT = control theory;
    OC = operant conditioning

2.4   Mobile Application Usability

Usability not only includes how a product works but also how the users interact with the product and its features. User Interface (UI) design is a vital aspect of creating any software for people with ID as an ever increasing number of services live online, and it becomes apparent that not everyone possesses the skills to use all these services and is at risk of being excluded from society [74]. Whether it's mobile or desktop, all such applications should follow a Universal Design or Design-for-All philosophy to be accessible to as many people as possible [75].

We have identified some fundamental techniques and best practices in mobile UI design for people with ID, which we want to apply to our application.

2.4.1   Navigation and Graphic Design

First and foremost, the UI must have a consistent and straightforward menu with a simple structure [76] where menu options are few and easy to both understand and find, which means using clear labels and signs for UI elements [77]. By extension, having few menu options limits the number of features which is recommended to stay between 2-5 with the possibility of sub menus if needed [78]. The controls should also include an image or symbol to help users identify their function [77] and increase the size of clickable areas like buttons while eliminating redundant images [36]. Most of the attention given to research on mobile applications for people with ID aims at the users cognitive function. However, it is not uncommon that they have an impairment in their motor skills [79, 48, 80], which also should be taken into consideration. People with ID often show poor reading comprehension skills [81] even though it is possible that it can radically improve if given a chance and their abilities are often underestimated [82]. Enlarged clickable areas can make the application more accessible both to those who have mobility challenges and those who have problems reading or even poor eyesight [76]. Figure 2.17 shows an example of what to do and not to do. The mobile application on the left has small buttons with small font and clickable area. The right mobile application has a larger clickable area with larger fonts in addition to showing the meaning behind the button using an icon.

It can be a powerful tool to provide demonstration and audible descriptions when possible. Demonstrations can help with perception, processing, problem-solving, and staying attentive for people with ID [83, 76] while also making the application usable for people with reduced vision [36].
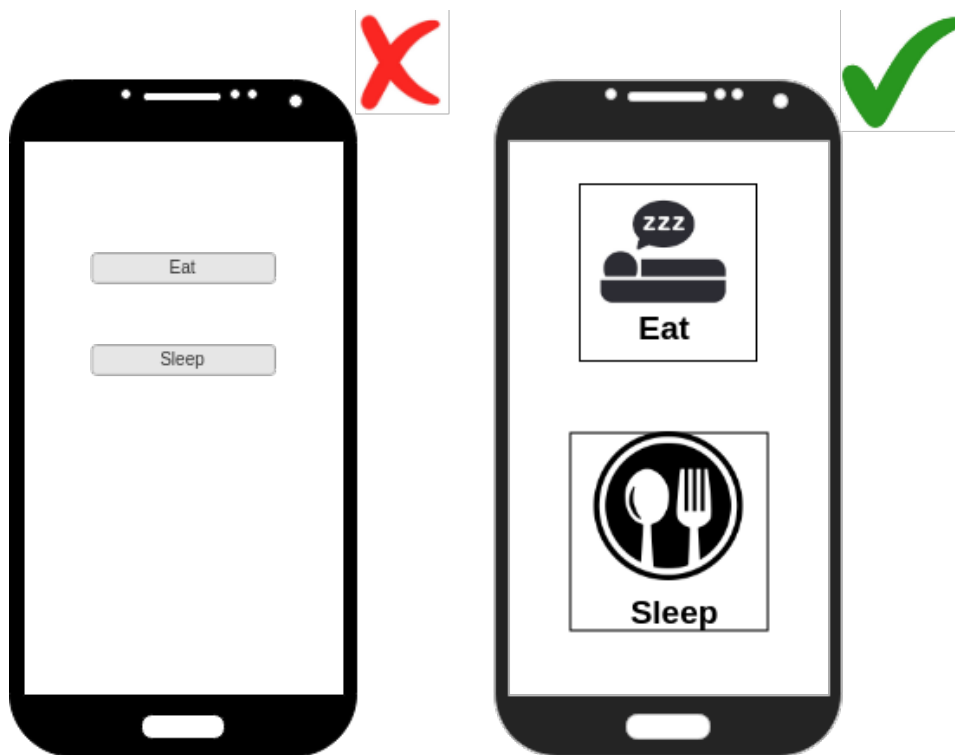
Figure 2.17: An example of do's and don'ts in application design

2.4.2 Text Requirements

When composing a text for somebody with ID there are many considerations to be made to create an experience that is easy to understand. It is recommended to use related images and icons to reduce cognitive load and give a better understanding of the meaning behind the text [83], as shown in figure 2.17. The language used should be brief and concise [77, 83] with short, simple sentences, clear instructions while long sentences of explanation should be avoided [84]. Titles or headings should also be short and simple but should avoid italic writing as it makes the text look like it is running together. Bold with a larger font size is the preferred style, but designers should not use text in capital letters as it is harder to read [76, 84]. In places where there is much text, its essential to facilitate ease of reading by avoiding narrow columns, having lines being too long, dense paragraphs and starting sentences at the end of a line [84]. It is recommended to use an evenly spaced font with high contrast between text and background by for example using a dark-colored text on a light (but not white) background [84, 77]. It can also be a good idea to provide text alternatives to content which are usually only audible [77].

2.5 Summary

In this chapter, we have reviewed the current literature on the topic of promoting physical activity in people with ID and identified which interventions have previously been tried using software and games. We have looked at some of the available mobile applications in the market and reviewed them in terms of how they compare to our idea. From what we could find, there is no application currently in the market that contains the same features as ours. Using the systematic review, state of the art, and what we've learned about BCT's, from the CALO-RE taxonomy table 2.6 and about mobile application design for people with ID in section 2.4 we can later extrapolate requirements for our application.

3

Methods and Materials

In this chapter we the talk about the research paradigm applied to this project, the tools used throughout the project, how we collected data and present our testing methodology.

3.1   Research Paradigm

When talking about computing as a discipline, there are three significant paradigms rooted in mathematics, the experimental scientific method and engineering, respectively [85]. This project mainly focuses on applying an engineering approach which consists of four steps in the development of a system:

- **State the requirements:** By stating the requirements, we can get an overview of features and aspects of the system which are required for it to live up to its purpose.
- **State the specifications:** The specifications job is to specify how to achieve and realize the requirements.
- **Design and implement the system:** The system is first designed according to requirements and implemented according to specifications.
- **Test the system:** To test a system after implementation is crucial to uncover any shortcomings.

These steps should be repeated or iterated several times until the system meets
the requirements satisfactorily, and requirements can change over time as
the need for new essential features are uncovered. The engineering approach
has design as its primary focus where a system is designed, evaluated, and
redesigned until it shapes up to something that solves the requirements. A
project is rarely only using one of the mentioned paradigms and often uses
aspects from each of the other paradigms [85]. We can also see this project in
regards to the experimental scientific method where the steps are to form a
hypothesis, construct a model and make a prediction, design an experiment
and collect data, and analyze the results. Our less formal hypothesis is that we
believe mobile applications including a 3D avatar can lead to higher levels of
physical activity in people with ID while our model is our application features
where each of them is predicted to contribute to our end goal in some way. We
also design an experiment in the form of an interview (more in section 3.3.2)
and analyze the results.

3.2   Tools

During the development of the application Unity3D version 2019.1.1[1] was used,
which is a free real-time 3D development platform and was accompanied by Mi-
crosoft Visual Studio 2017 for the scripting. There are other popular alternative
game engines to Unity3D like Epics' Unreal Engine [2] and Crytek's CryEngine[3].
While Unreal Engine does support cross-platform mobile development, they
use a lower level programming language (C++) and is thought to have a
steeper learning curve for new users. Crytek, on the other hand, does currently
not offer any Android development support and does not fit what we need.
Unity3D markets itself as an easy entry to cross-platform mobile development,
which in addition to knowing people who have used Unity3D before was the
reason we chose this platform.

We focus on developing for Android, even though Unity3D is capable of building
for other platforms, and despite most of the code and assets being compatible
with several platforms, all use of native libraries are platform specific and
will, therefore, need specific implementations. As the Android ecosystem is
fragmented [86], we aimed to use the lowest possible API level so it would
work on as many different devices as possible. An Android API level says
something about the API revision the developer wants to target. Choosing a
lower API level might limit some functionality, but can make the application

1. http://unity3d.com
2. https://www.unrealengine.com/
3. https://www.cryengine.com/

compatible with more devices. We landed on API level 16 which translates to Android version 4.1 "Jelly Bean" released in July of 2012. This API level should be supported by 99.5% of the Android devices in use today [87], given that the phones are otherwise powerful enough to run 3D applications. For on device testing, the university provided us with a Samsung Galaxy S9 where we could install and test our application. We performed debugging by utilizing wireless process attachment using Android Debug Bridge[4] over WiFi and Visual Studio to attach. Using the Android Debug Bridge enabled us to step through the code running on a device.

Mixamo [5] provided most of the animations and is a service run by Adobe that provides free customizable animations that can be imported in Unity and rigged to a 3D model.

3.3 Research and Experiment Methods

3.3.1 Data Collection

We first collected data by doing a literature review as described in section 2.1 which gave an insight into what others had done on the topic, what they looked for in terms of measurements, what worked and what did not. We also conducted a state of the art review to get an overview of what other applications existed that incorporated what we were trying to accomplish. After that, research was conducted on the topics of behavioral change and designing mobile applications for people with ID. Another source of information was seminars held with the research group where valuable input came from experts on the topic. The experts could give information on essential things like how to communicate with people with ID, likes/dislikes they have and how they use mobile devices and what they do on them.

All this information formed the basis of the requirements specifications for the application.

3.3.2 Testing Methodology

We tested the application by running it through a usability test where we let two people with ID at an institution which provides day time activities try it for four days under the supervision of support staff. In preparation for the tests,

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4. ADB: `https://developer.android.com/studio/command-line/adb`
5. Mixamo: `https://www.mixamo.com/`

consent forms were sent out to the institution so that the users themselves or their legal guardian could sign off on them participating. The full consent form and study protocol can be found in appendix C. We provided two devices; A Samsung Galaxy S9 mobile phone and a Huawei MediaPad M5 Lite tablet for them to try with the users along with stands so that the users and support staff would not need to hold the devices up while using them. Figure 3.1 shows the setup which was provided by us and figure 3.2 shows the tablet placed and ready in their exercise room. When the testing period ended, we conducted an interview which can be found in its full form in appendix D. The interview is a mix between structured and semi-structured which means it contains both predefined and open-ended questions where the interviewee can use their own words. We based the interview on a three-step approach to measuring usability, which uses metrics from Organization for Standardization (ISO) 9241-11. The purpose of a usability test is to determine obstacles in the application that hinders effectiveness and efficiency while lowering the level of satisfaction [88].

During the late stages of the project, we attended a reference group meeting where we showcased the application and let four of the attendees fill out the System Usability Scale (SUS) questionnaire described later. The reference group consisted of researchers from the field, people who work with people with ID daily and parents of people with ID. Initially, we only had one SUS questionnaire filled out by staff at the institution, but the reference group meeting gave us the numbers needed to get a more significant result.
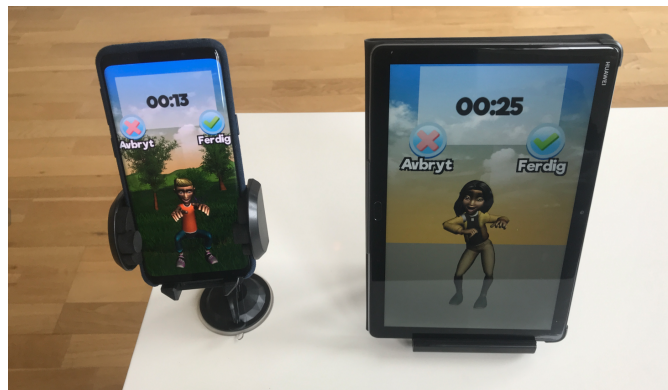
Figure 3.1: The testing setup given to the institution.

First, we wanted to measure the effectiveness of the application. Effectiveness is measured by seeing how many of some predefined tasks they can complete and how many errors they make during the attempts. The next thing to measure is efficiency, which is the level of effort from the user is needed to complete tasks. Measuring efficiency is usually done by timing the tasks to see how long the

user takes to perform it. The two first steps are hard to measure without being present during testing and we can not expect support staff to count errors from users and take the time they spend on each task. Since we were not there to monitor, we tried to make the interview subject estimate these variables.

Figure 3.2: The tablet set up in the training area.

Finally, we want to measure satisfaction in using the application. Measuring satisfaction is done by using a SUS which is a 10 item Likert scale [89] that contains a set of predefined statements which we translated to Norwegian and slightly modified to fit our situation. As we do not have direct access to the users, the support staff had to answer the questions on their behalf with what they thought about the application in regards to people with ID. The interviewee answers by giving a score between 1 and 5 on 10 statements where 1 means "*strongly disagree*" and 5 means "*strongly agree*". The statements in a SUS are designed to cover a variety of aspects of the application like the need for support, training, and complexity and often contains overlap in the form of asking questions with both a positive and negative connotation. You could, for example, find both statements "*I am satisfied*" and "*I am dissatisfied*" in the same SUS. To get a clear picture of the usability and to identify 80-85% of usability problems, there should be 5-8 test subjects [88], which we are within when combining the results from the institution and the reference group meeting.

The results were then evaluated to determine the usability of the application and what barriers need to be addressed to further improve upon it.

3.4   Summary

In this chapter, we have seen that we have an engineering approach to our project. An engineering approach enables us to get an overview of requirements and their specifications to work more efficiently in the development process. Testing and iterating help us get continuous feedback, making the project more agile when it comes to changes. We have talked about why we chose Unity3D as our developmental platform, and which considerations we made when developing for Android. Unity3D is an easy entry to cross-platform application development while we chose Android due to them having a considerably higher market share than their competitors [40]. Finally, we looked at how we collected data and identified our requirements as well as how we conducted real-world usability testing by using a SUS questionnaire along with questions regarding efficiency and effectiveness.

/4

Application Requirements

This chapter talks about which software development method we used in the project and the process of identifying requirements for our mobile applications by taking what we've learned in chapter 2, from conversations with experts and through further research. We later talk about the functional and non-functional requirements before assessing the importance and rationale behind each task and show how we organized them in a task board.

4.1   Software Development Process

The development process applied to the project is a light version of Feature Driven Development (FDD) which classifies as an agile methodology. In FDD the primary focus is the features and how they address customer requirements. In the real world iterations last about two weeks, but in this project, the iterations were varying in length, as attention was divided between research and development. The focus of an iteration is to perform a client walk-through of the current application to get a sense of scope and context. A client usually refers to stakeholders in the project, and ideally, this would be the end users, but without access to them, supervisors were the source of feedback. After that, we develop a feature list, and features are specified and implemented before being reviewed, and the process starts over again [90, ch. 3]. It is crucial to keep the features small so that implementation can fit within the time of an iteration. Longer implementation time might lead to splitting features into

smaller ones. For example, one feature could be a full sign-in functionality
for a system which can be a huge undertaking and not easy to specify in
terms of acceptance criteria. We could later split this feature into smaller, more
manageable features like validating password, encryption, and the front end,
which are easier to reason about.

4.2   Identifying Requirements

We created the requirements from what we learned from experts in the field
(Henriette Michalsen, PhD student, Gunnar Hartvigsen, Professor & Audny
Anke, Professor) and relevant literature both in regards to what the goal of
the application was and how to achieve them. All requirements were then
documented using the Volere requirements specification template [91, ch. 8]
before being broken into smaller, more manageable tasks to make it easier to
understand the specifics of the feature. Each entry of the specification template
consists of several key points:

- **Requirement type**: We use a subset of the types which includes 9:
  functional requirement, 10: look and feel, 11: Usability
- **Description**: The intent of the requirement.
- **Rationale**: The reason behind the existence of the requirement. Why
  the requirement is important and the contribution to the purpose of the
  product
- **Source**: Who raised the requirement in the first instance
- **Fit Criteria**: When a requirement is perceived as fulfilled, like an accep-
  tance criteria
- **Customer Satisfaction and Dissatisfaction**: A ranking between 1-5.
  How happy is the client if the feature is implemented and how unhappy is
  the client if the feature is missing. Ranking features help with prioritizing
  features.
- **Dependencies**: What other requirements (if any) have to be imple-
  mented before this one?

The complete overview of these requirements are found in appendix B. Sec-
tions 4.3 and 4.4 talks more about the rationale behind the features and we
present them in the category, either functional or non-functional requirement,
that they belong in. Requirement #3 does not have a dedicated section as
earning points span over multiple requirements (#2, #8 & #5).

4.3   Functional Requirements

Functional requirements are absolute requirements to the functionality of the application, i.e., what the application must do. They define the functionality that is required to satisfy the reasons for its existence and is derived from the purpose of the product [91, ch. 6]. The following sections describe some of the rationales behind the features of the application.

4.3.1   Requirement #1 & #13 - Character Customization

One of the main goals from the start was to make the application engaging to the users. Early on, there was a seminar with people from different disciplines that all works on the project. In this seminar, one tip was to make the application in our projects more individualized. We thought about how that would apply to this application that would, in some form, contain an avatar. The answer we landed on was to make the characters/avatars customizable so that each user can make it look like they wanted and, by doing that, wanted the character to appear more relatable to the user. We wanted to give the characters personality through animations so that in the long run, the user could see the character as a "friend" it wants to spend time with much like a Tamagotchi [92]. The idea is that the connection between the user and the character would lead to higher levels of engagement and them wanting to use and interact with it. Studies show that having a fun component in applications for health can be a significant motivating factor for people with ID to be physically active [93, 94, 34]. As an extension, a user should be able to unlock new items by spending points or earning them through exercises which tie into the target demographics desire to be awarded for their efforts [72, 68].

4.3.2   Requirement #2 & #8 - Exercise

Exercise, which is the overall goal of the entire project, also makes it a core features of the application. The way we want to deliver exercise is by building on the BCT's that refers to providing instruction and demonstrating the behavior. One study shows that a facilitator for people with ID to engage in physical activity is for them to learn new activities [94] and we want the character to teach them and demonstrate exercise routines for them to mimic at their own pace. We also want to deliver on their desires of shorter activity duration [73] by allowing them to exercise for however long they want while being able to select an activity that they find appealing by providing options.

In addition to demonstrating exercises using the character, we want to enable them to go outside hiking while using the application as being outside is

another previously identified facilitator [95]. We want them to go on hunts for QR codes hanging in the wild and have them take pictures of them using the application to get points. Having this feature enables the support staff to have a personalized hiking trip to each user by strategically hanging QR codes where they can get higher rewards the farther they go on a trip.

4.3.3   Requirement #5 - Engaging Support Staff

Another essential point taken from the seminar was the need and importance to incorporate the support staff in some way. The support staff plays a crucial role in promoting physical activity in people with ID [96, 97, 73] which means that support staffs involvement in, attitudes towards and excitement over using the application is vital to maintain usage over time whether it's employees of an institution or the parents [98, 32]. We also found out that when carers perceived more benefit of exercising with a user, he or she was more likely to exercise [69]. To achieve this, we want to add a competitive/collaborative element in the form of a leaderboard where users can collect points by doing exercises (requirement #3) which adds to the teams' total score. The team can either be only themselves, a group of friends, or their department if they live in an institution. Being part of a team has been reported as being a facilitator for people with ID to become more physically active [68]. Using the function as mentioned above, caretakers can create tournaments and events with prizes either for winning or even just attending. One example could be a mini-competition where the first ones to a thousand points win and can act as a social aspect of the application. The goal is for the leaderboard to make staff competitive in wanting to beat other institutions or departments, leading to more elaborate use of the application.

4.3.4   Requirement #7 - Notifications

An application to help with physical activity is of little use if the user tries it once and then puts it away only to never open it again. We want to use notifications in the application to try to make the user come back in case they have been inactive for some time. One study [54] showed excellent results in making people with ID maintain their physical activity by being reminded to do so using smartphone notifications, and we hope that being reminded can lead to a positive change in behavior in the long term.

4.3.5 Requirement #9 & #10 - Dance And Music

One key point in the first seminar as the project started was that we should build as much fun around the activity as possible. It is crucial to identify the type of activity that leads to higher levels of acceptance and adherence, and dancing exhibits to be a very positive stimulus. Dancing has also shown to give significant positive changes in BMI, weight and cardiovascular fitness [99] as well as one study reporting it as being one of the most enjoyable forms of physical activity for people with ID [100]. In addition to more traditional exercises, the application should be able to offer dances paired with music where the character shows the dance for the user to mimic. Dances can help alleviate the often tedious component of physical activity with it feeling like a chore and instead start to be fun and engaging to the point of being something the users hopefully wants to do at their initiative.

4.3.6 Requirement #12 - Achievement Sharing

Even though using the internet and social media services can be challenging for people with ID due to often poor reading skills and communication challenges, a 2014 survey [101] reports that most participating users that fit in this category said that they used Facebook at least once a day. After sending messages, one of the most popular activities were sharing photos. Experts informed us that people with ID likes to show and share prizes they have achieved, for example, trophies and medals. They also informed that a big motivator for people with ID to be physically active was a social aspect. To cater to this, we want to allow sharing of pictures when the user achieves something in the application. This way the user can "brag" about their accomplishment to people they know on the internet, or show the picture in person from their phone. Being able to share achievements also opens up to an opportunity for social interaction, which has shown to be a facilitator for physical activity [70, 73, 102].

4.4 Non-Functional Requirements

Non-functional requirements are the qualities of the application that makes it attractive, usable, and reliable and includes aspects like accessibility, extensibility, and maintainability. These requirements relate to how an application looks and do not alter the core functionality [91, ch. 7]. The following subsections talk about some of the most important non-functional requirements for this project.

4.4.1 Requirement #4 - Celebration

Coming back to the introductory seminar kicking off the project, one of the essential takeaways were the use of audiovisual stimulation over text. In addition to delivering music through dancing, we should also celebrate the user when they achieve something in the application. This celebration can include the character cheering, applauding or giving the user a thumbs up while music plays in the background and fireworks-looking effects in many colors fly over the screen to emphasize what a good job they are doing. This requirement builds on the BCT of providing encouragement.

4.4.2 Requirement #6 - Text To Speech

In the same seminar, experts informed and advised us to use more visual and audio than text. One study on designing mobile applications for people with ID suggests to add voice output for those with reduced vision [36] and those who have trouble reading. Having Text To Speech (TTS) can be a powerful tool to help the users understand the context and functionality of the application, which can otherwise be hard to convey using only the visual user interface. We want to add TTS as a supplement to icons and text, which in turn can help users read by hearing the text while reading. TTS can also be used to deliver praise in an audible manner, and one study [55] showed that delivering praise using technology can have the same or even better effect than delivering it in person. These studies, in conjunction with what we found during our research on BCT's, suggest that TTS is an important feature and can be utilized in the application to deliver praise at strategic points to motivate the user.

4.4.3 Requirement #11 - User Interface Design & Usability

Having a UI design that fits the capabilities of people with ID is crucial for the usability of the application. During the development, techniques and design guidelines uncovered in section 2.4 and 2.4.2 should be kept in mind. Some of these techniques include few and big buttons that are easy to hit, using icons to convey the meaning of buttons and appropriate font sizes and color combinations. When selecting an activity to do, the user interface should show the activity animation to make it clear to the user what it involves. The preview is vital because it can be difficult to explain an exercise activity without any movement, and demonstration is a behavior change technique known to be effective. For example, to demonstrate situps in a still image can be difficult because it could look like someone laying on their back or sitting up when no motion is involved.

4.4.4   Requirement #14 - Speech Bubble

To further build on giving the characters personalities as described in section 4.3.1 and to adhere to recommendations on text usage in applications for people with ID, speech bubbles should be added to the application, which paired with TTS described in section 4.4.2 can give the impression of the character talking directly to the user. Speech bubbles are also the only way of communicating with the user if TTS or the volume is switched off, along with side icons and images. Speech bubbles are of course not a feature all users can benefit from as their cognitive abilities vary greatly.

4.5   Organizing Tasks

After developing the requirements, we organized them in tasks in a trello board to see progress, what was left to do and with a color code to represent the prioritization of features as depicted in figure 4.1. [1] We base the prioritization on the score from the requirement specifications where green is not very important features, yellow is considerably important, and red ones are core features essential for the application. Each task had its requirements specified in the description field, so it was easier to implement without forgetting vital aspects of that feature. An example of such a description can be seen in figure 4.2.

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1. Note: The trello board was not followed rigorously throughout the project, so some features/aspects of the application were never on the board and were implemented more ad-hoc. Doing this is the blessing and the curse of working alone on a project.

Figure 4.1: Trello task board for the project showing the color coding according to importance. **Green:** Not important - **Yellow:** Pretty important - **Red:** Core features
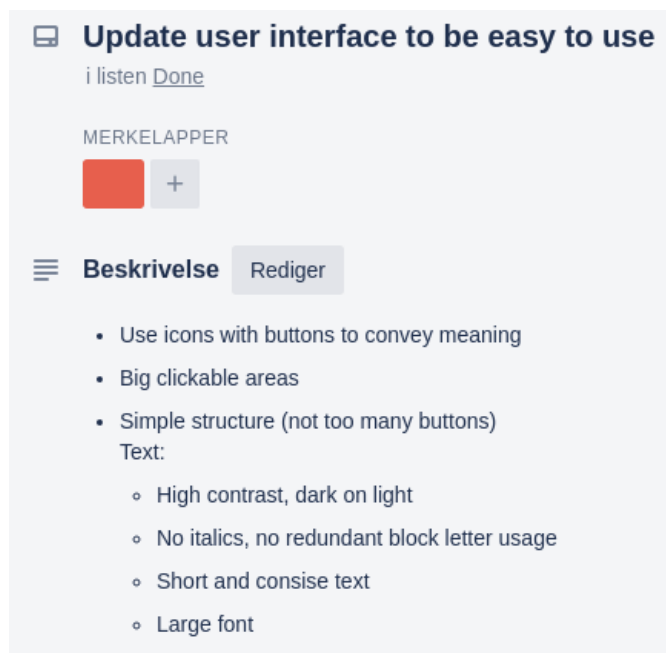
Figure 4.2: An example of the details on a task from the board shown in figure 4.1

4.6 Summary

In this chapter, we have identified key requirements for the application and justified each requirement in terms of which need it caters to based on our research. Other than the core features such as character creation and exercises, we identified several non-essential features which were still crucial to the user experience such as accessible UI design, TTS and speech bubbles to name a few. We have also seen how our requirements were organized in tasks and prioritized according to importance where we decide the level of importance by their contributions towards our goals of accessibility and physical activity.

5

Design

This chapter talks about the design of the application and how we integrated the features previously discussed. We go through the application step by step while providing ample amounts of screenshots to showcase the features and different scenarios.

5.1   Character Customization

When first starting the application, the user is prompted to make their character that eventually becomes their training buddy. The 3D models include many different pieces of clothing like jackets, T-shirts, glasses, hats in addition to hairstyles and hair/skin colors. In the interest of both implementation time and to not make it too complicated for the users, the selection is limited to gender, characters within the gender, hair, shirt, pants, and shoes. Within each of the genders, there are several different models, and within each piece of clothing and hair, there are several styles where each style has several colors. Having these options results in thousands of possible unique characters to create. Even though many of the clothing types are currently not in use, some of the characters come pre-equipped with jackets, hats, and glasses to showcase what they look like despite the user not being able to equip, unequip and change colors of these items. While the user is configuring their character, it cycles through different poses as if they were at a photo shoot, to give them life. The user can fill out their name at the top, which is the name used in their profile

and when the character is talking to the user through TTS. Some of these poses
with different character configurations can be seen in figs. 5.1 to 5.3 with some
female characters in fig. 5.4. This satisfies application requirement #1.

Figure 5.1: Character Creation Screen - Character Poses

Figure 5.2: Character Creation Screen - Character Poses

Figure 5.3: Character Creation Screen - Character Poses
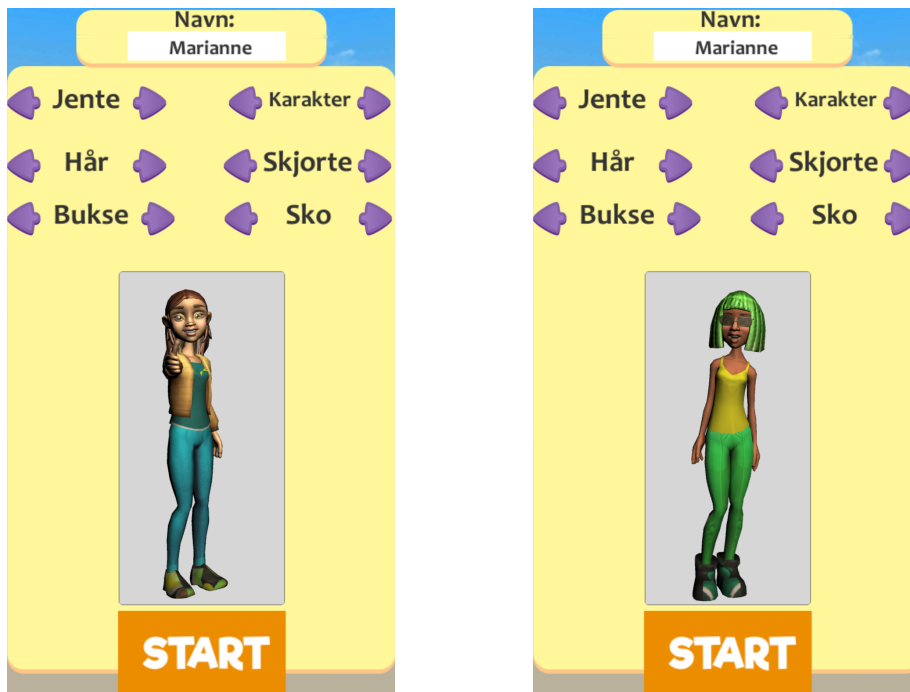
Figure 5.4: Character Creation Screen - Character Poses

5.2   Idle Screen

When the user has configured his or her character, the application transitions to the idle screen. It starts by the users newly customized character greeting the user and asking it to join the character for some exercise as shown in figure 5.5 with a talking animation playing and a speech bubble containing the text which is read out loud in the background by TTS (requirement #6). We present the user with two large buttons. The left button displays the exercise selection menu, and the right button enables the user to scan a QR code. More information on these features can be found in sections 5.5 and 5.7. The top right button is to mute or unmute the TTS functionality while the top left one opens the settings screen. The bottom left button starts the tutorial further explained in section 5.3 while the bottom right opens the leaderboard described in 5.6. In the middle of the two main buttons, there is a circular progress bar that fills up when the user gains points. When the circle is full, the user is awarded a star, and the progress resets so that the user can work towards the next one. The big clickable areas with icons and large fonts help with achieving requirement #11.

While the user waits to make a decision, the character mostly looks right in the camera with small changes to facial expression and breathing to make it look alive. However, once in a while, they transition into looking around, seeming excited, or scratch their cheek. Figure 5.6 shows two of the idle animations. The same figure also shows the three stars at the top. The goal is for the user to fill these stars by completing exercises and earning points. After achieving three stars, the user gets to take a photo showcasing their accomplishment and send it to friends and family, which we discuss further in section 5.5.4.

Figure 5.5: The character greeting the user.

Figure 5.6: Idle screen character poses

5.3 Tutorial

When the user hits the bottom left button, the tutorial screen pops up, which quickly explains the core features of the application and how to use them using three different screens. The first two screens show the two main buttons of the user interface while the third explains that the user can long press many UI components and have their meaning read up to them. In each page of the tutorial, the TTS reads up an explanation as well as displaying it in text. Figure 5.7 shows the tutorial screens.
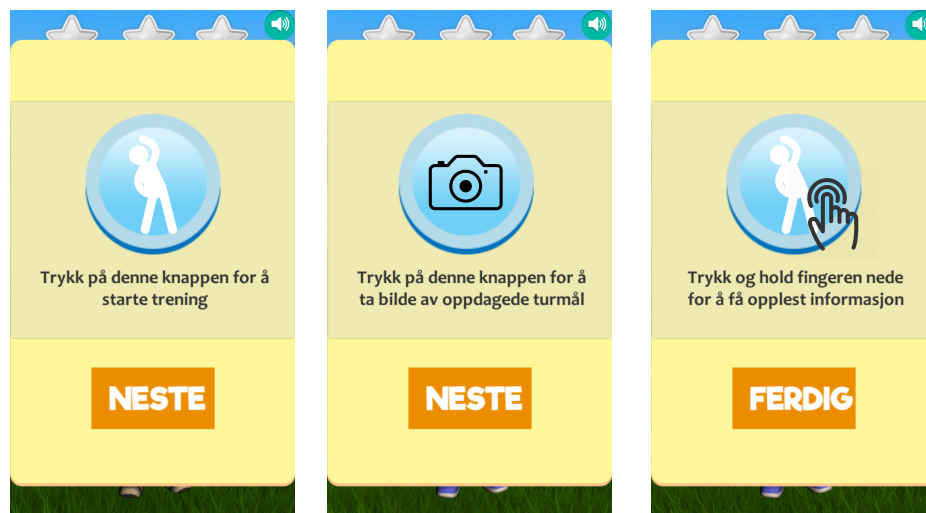
Figure 5.7: Tutorial Screen

5.4 Settings Screen

The settings screen is one of the late additions and enables the support staff to do some light configuration to the application. Three things are currently available in the settings screen; changing the users' name, setting the point target for the user (i.e., how many points are needed to get a star) and the animation speed. The animation speed relates to how fast the animation plays during exercises. Some users with reduced cognitive capabilities can have a hard time registering what is happening on the screen, so for them, the animation speed can be lowered down to a minimum of 30%. Figure 5.8 shows what the settings screen looks like with the slider to set the animation speed.

Figure 5.8: The settings screen.

5.5   Exercise

The exercises are an essential feature of the application and involve three steps; choosing which exercise to do, performing, and finally finishing it. The following subsections go through each step in detail.

5.5.1   Selecting an Exercise

When the user presses the exercise button from the idle screen, the screen presents a horizontally scrollable area where they can browse available exercises. Each of the listed exercises is represented by the name of the exercise in addition to a mini version of the users' character demonstrating the exercise to make it easier to understand what they are selecting while highlighting the currently selected exercise in green. A long press of any of the entries reads

the exercise name out loud using TTS while selecting one and clicking start starts the exercise. Figure 5.9 shows the exercise selection screen and how it helps us fulfill requirement #2 and #10.
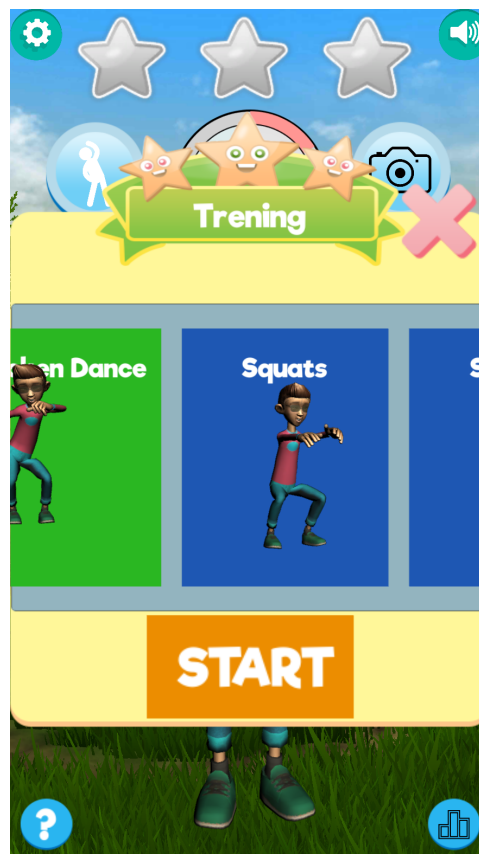
Figure 5.9: Exercise selection screen.

5.5.2 Exercising

When the user starts an exercise, the user interface turns minimalistic where a counter and two buttons replace everything displayed previously. One button is to cancel the workout, and one is to finish it while the counter in the middle shows for how long the user has had the workout active. The character demonstrates how they do the workout repetitively so that the user can mimic the movements as shown in Figures 5.10 to 5.12, while music plays in the background which implements requirement #9.

Figure 5.10: The character doing the chicken dance[1]

Figure 5.11: The character performing burpees

Figure 5.12: The character performing situps

5.5.3   Finishing an Exercise

When the user finishes working out, a speech bubble pops up (requirement #14) praising the user and tells how many points they have earned from that workout while the progress bar increments to show the progress status towards the next star. The praise message is also read out loud using TTS (requirement #6). In the background, we log the exercise for the user with exercise name, duration, and the number of points earned (requirement #3). Figure 5.13 shows how the praise after a workout gets delivered to the user (requirement #4). The points are also added to the total in the departments leaderboard[2]. If the amount of points from the exercise makes the progress bar pass 100%, the user gets a star, and a panel opens on the screen congratulating the user as seen in figure 5.14. When closing this window, the character proceeds to celebrate the users' accomplishment by applauding and giving a thumbs up while up-tempo music plays in the background and firework-like colors fly across the screen. Figures 5.15 and 5.16 demonstrates the celebration.

If the user cancels the exercise, nothing of the above happens, and the application returns to the idle screen.

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1. Video of the chicken dance in action: `https://youtu.be/l5sIspLfmXM`
2. See section 5.6 for more information

Figure 5.13: The user receives praise and the earned score is presented.

Figure 5.14: The praise when the user earns a star.

Figure 5.15: The character celebrating the user by applauding.

Figure 5.16: The character celebrating the user by giving a thumbs up.

5.5.4   Getting All Three Stars

If the user completes the progress bar three times and gets three stars, the praise window from figure 5.13 looks a little bit different. The green close button is replaced by a blue camera button, as shown in figure 5.17. When pressing this button, the front camera opens, and the user can take a selfie with a filter applied on top showing the three stars they achieved along with a trophy and a medal. If the user chooses to take a selfie, they get the option to share it through any channel the mobile device supports such as Facebook or using the messaging app. Figures 5.18 to 5.21 shows the process from taking a selfie to sharing it to either Facebook or messages (requirement #12).

Figure 5.17: The camera button appearing where the close button used to be.

Figure 5.18: The selfie camera with the filter overlay
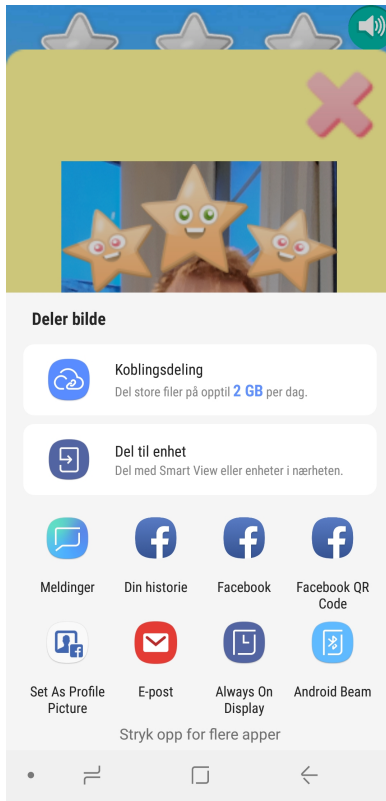
Figure 5.19: After selfie is taken: Showing sharing options
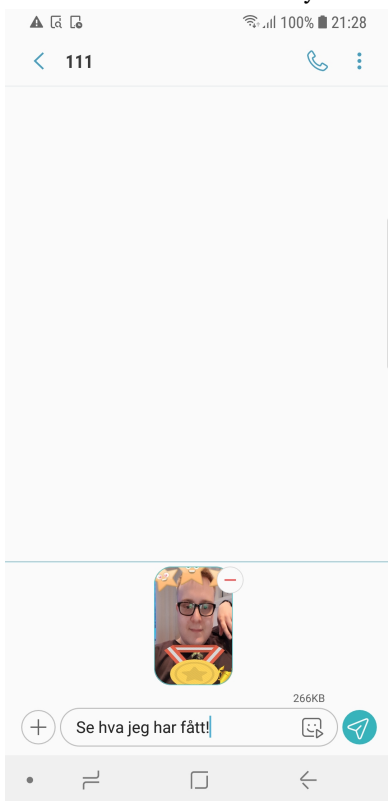
Figure 5.20: Sharing to messages with a predefined text along with it

Figure 5.21: Sharing to Facebook

5.6   Leaderboard

All users are a part of a team where they can cooperate on collecting points. The team can consist of friends or the department they belong to, and everyone using the application can check their current standing by pressing the leaderboard button, which presents the scores in a vertically scrolling panel. Each entry on the leaderboard consists of their ranking along with the name of their team/department and how many points they have. The three top placements also have a trophy next to it to emphasize further the three leading teams and long pressing any of the entries reads the placement and team name out loud using TTS. The leaderboard satisfies requirement #5 and figure 5.22 shows what the leaderboard looks like with some seeded entries.

Figure 5.22: The applications leaderboard

5.7 QR Code Scanning

In addition to selecting exercises and having the character demonstrate them, the users can collect points by finding QR codes in the wild (requirement #8). The idea is that support staff or caretakers can place QR codes anywhere they would like, which translates to points when they are scanned. One example is placing them on a hiking path in walking distance from where they start, then letting the users "hunt" and arrange trips together to gather points while doing physical exercise. Caretakers can easily personalize trips to fit the users' capabilities by adjusting the number of points earned and how far away they place the codes. Figure 5.23 shows an example of a poster with the code and amount of points on it. The designs of the posters can be changed to increase visibility when placed in nature as long as the QR code stays the same. Figure 5.24 shows what the app looks like when scanning the QR code. There is no need to press any button; the application continuously scans for the QR code and automatically registers and yield points when it detects a code. The QR codes have to contain the number of points it should yield and no additional text, and can easily be created online for free and printed out by support staff.[3]
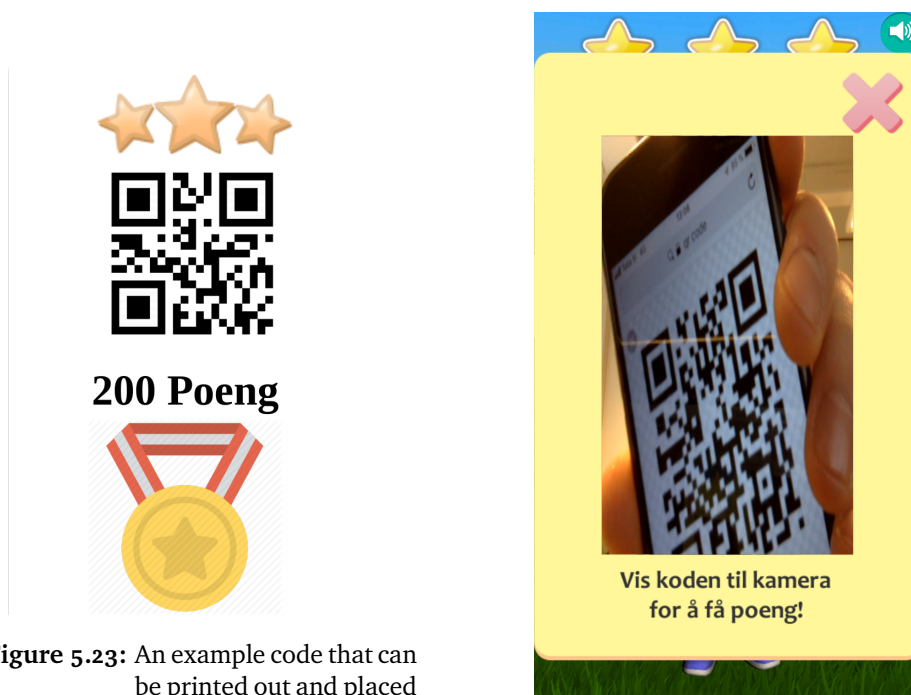
Figure 5.23: An example code that can be printed out and placed anywhere.
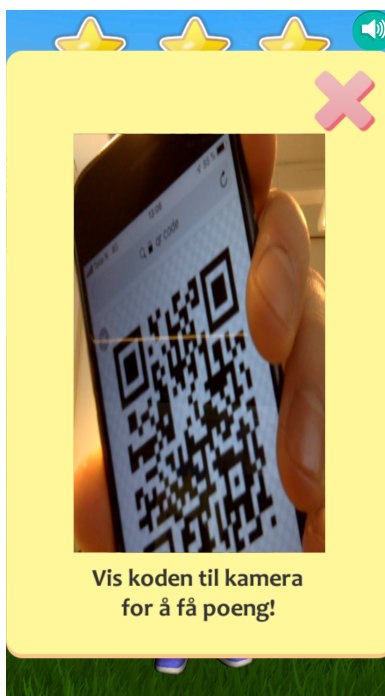
Figure 5.24: What the app looks like when scanning a QR code

3. For the examples, we used `https://www.qr-code-generator.com/` to create QR codes

5.8   Notifications

Figure 5.25 shows what the notifications look like all three places where they can appear on the device. Notifications are used to remind users to use the application after a period of inactivity and therefore helps satisfying requirement #7.
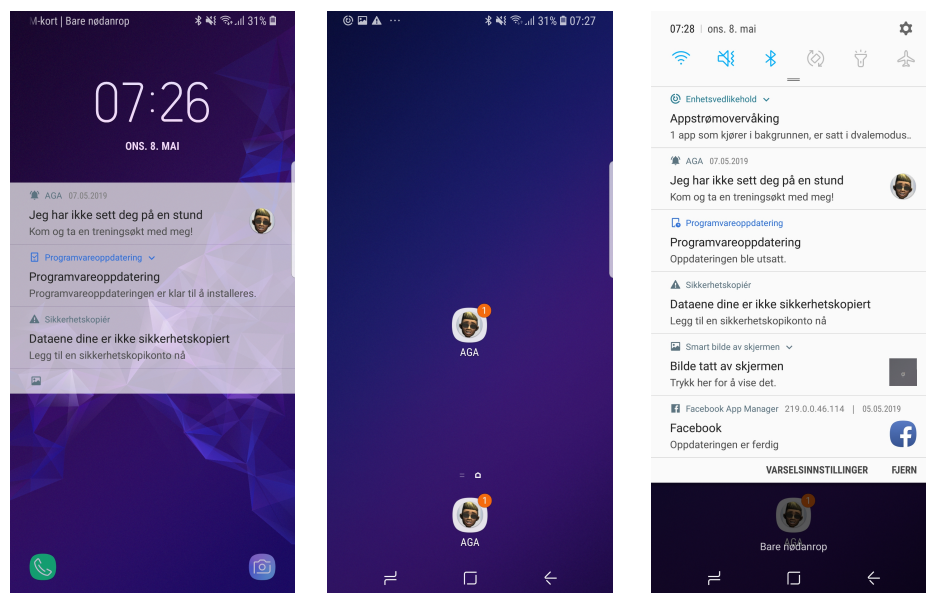
Figure 5.25: Notification shown after inactivity. Notification showing on **Left**: Lock screen. **Middle**: Icon badge **Right**: Notification center

5.9   Terrain

As the backdrop for the character, we wanted to use some outside setting to promote exploring nature and doing physical activities while being outdoors. We created a small terrain with some hills, trees, and grass which reacts to an added wind source to give the backdrop some life. Figure 5.26 shows the terrain. The left side is an aerial view where the lines represent what the camera sees. The right shows the terrain through the camera without any of the UI elements or character blocking it. As seen in the aerial view, the camera does not see the entire available terrain which is done for potential future iterations in case we want to have the camera and character move around the terrain.
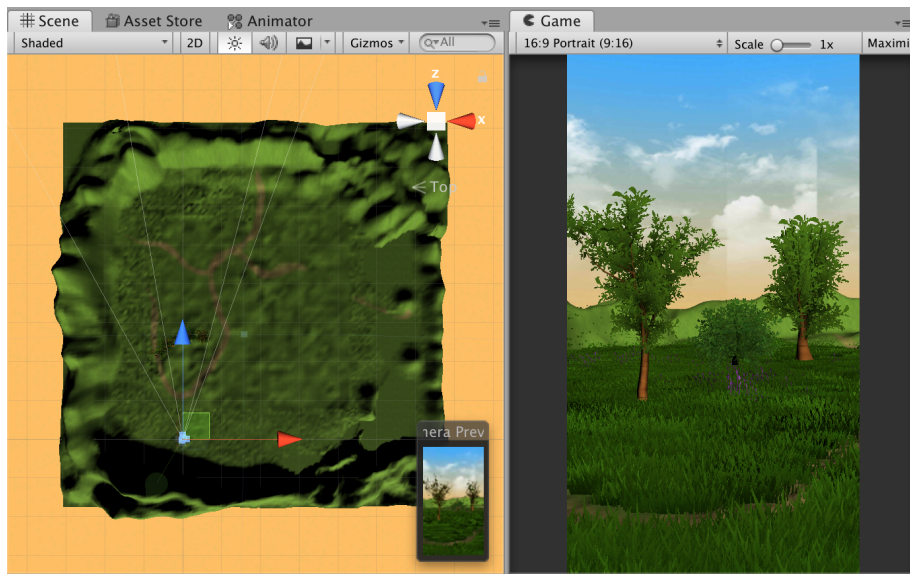
Figure 5.26: Aerial and camera view of the terrain

5.10 Summary

In this chapter, we looked at the design of all features included in the application, along with an explanation of how they work to give an idea of the flow while using it. We also explain which requirement each feature is designed to implement. Initially, the user creates their own avatar and is introduced to the application through the idle screen where all other functionality is readily available with only a few clicks. We have looked at a design which creates an accessible UI for people with ID through flat colors, big text, and buttons with icons.

/6

Implementation

In the following chapter, we have a closer look at the implementation of our 3D exercise app. We talk about how to work with 3D models and how we coordinate movement and made the application easily extensible. After that we briefly discuss how we implemented some of the core features and we talk about how the scripting was organized before mentioning how we iterated upon the application throughout the development process.

6.1 3D Models

The 3D characters are a vital part of the application. However, creating 3D models using tools such as Blender[1] can be considered to be a trade of its own and would take a very long time to learn. The choice was then made to find the 3D models online using the Unity Asset Store. After some research, the choices were between a free package created by the Unity team themselves, or buy a third party package. The free package is called Unity Multipurpose Avatar (UMA)[2] which provides highly customizable characters with interchangeable clothing. UMA offers a wide range of customizability where you can alter almost any feature on the character like the size of ears, the width of cheeks, size of

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1. Blender: `https://www.blender.org/`
2. `https://assetstore.unity.com/packages/3d/characters/uma-2-unity-multipurpose-avatar-35611`

belly amongst other things, and besides, provides an entire dynamic character system for managing clothing and wardrobe which would be fitting for what we needed. The other alternative which was not free is called Toon Teens[3] and contains a set number of 3D character models and include some clothing and animations. When deciding between the two and after discussing it with an expert[4], we decided that the one that fits best with what we are trying to achieve were the Toon Teens models. These models give a more playful and fun feel while the UMA models might look a bit too serious or even frightening. To quote the expert:

> "*I would go for 'Toon Teens' as I think it will be more fun to use these. It might be to complex (for the user) to consider body shapes, ears, mouth etc. Use strong colors and cool clothes rather than details in looks*".

Figure 6.1 shows a comparison between the two packages with UMA on top and Toon Teens at the bottom.

Figure 6.1: A comparison between two 3D model packages

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3. `https://assetstore.unity.com/packages/3d/characters/humanoids/toon-teens-135404`
4. Conversation with Henriette Michalsen 25.03.2019

6.2   Animating a 3D model

Despite mainly getting animations provided by Mixamo[5], they still need to be connected to the 3D model. The 3D models we used are built like humanoid characters, and Unity3D has built-in specialized support for humanoids as they are so common. This feature of Unity3D makes it easy for developers to bind animations to an avatar that contains bones which in turn is applied to the 3D model. Figure 6.2 shows what an avatar rig looks like with some of the applied bones to the left and the import settings for animations to the right. As we can see in the import settings, we assign the avatar to the animation, and the animation type has to be set to humanoid to map movements correctly. Then we bake the root transform into pose around the original position so that the orientation is not affected by the animation clip, which is important so that the avatar does not wander off camera while doing exercises.
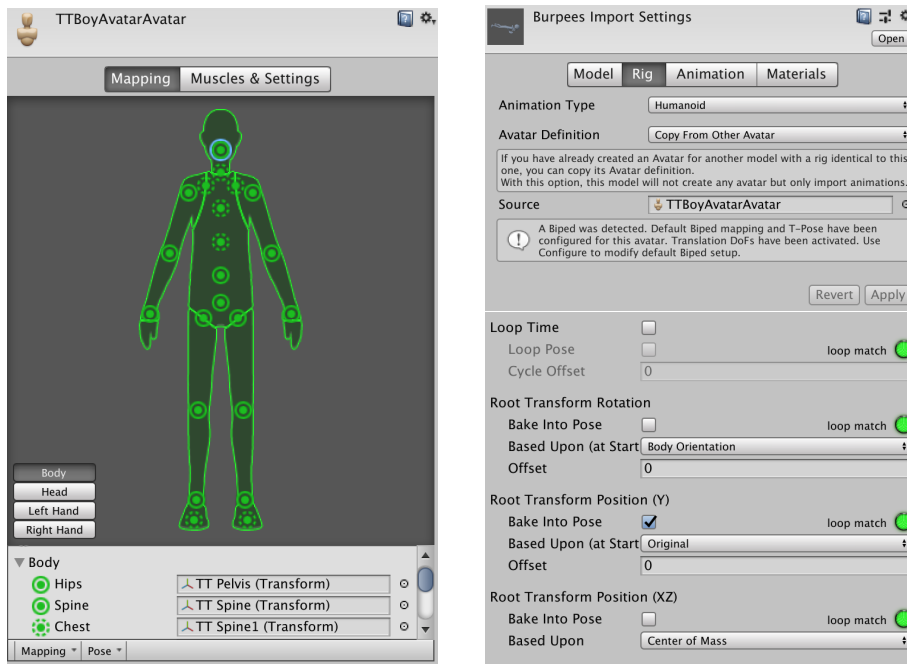
Figure 6.2: Overview of an avatar and animation import settings

The 3D models came with 26 different blend shapes which we can manipulate individually to animate facial expressions. These include control over eyebrows, eyes and different parts of the mouth. Through the animation tool, we could create facial expressions using keyframes which we could put as a separate layer in the animation controller. Figure 6.3 shows two examples of facial

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5. Mixamo: `https://www.mixamo.com/`

expressions created in this project. The one on the left is a silly face while the one on the right is scared.
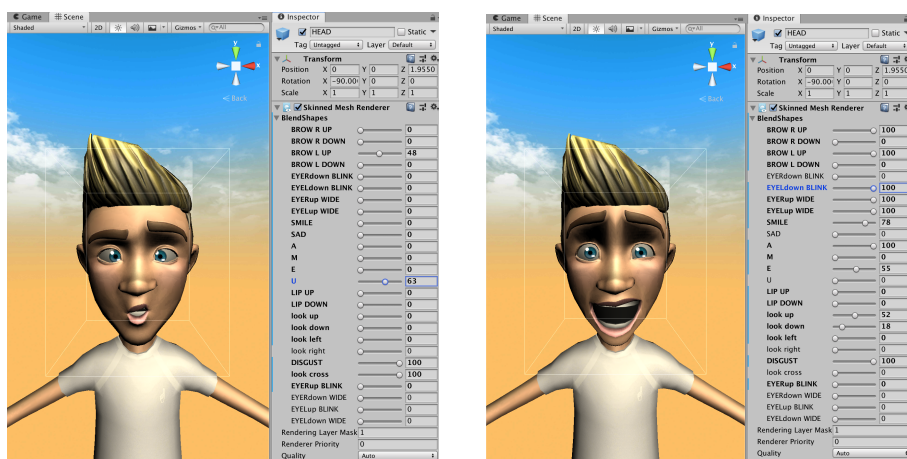
Figure 6.3: Showing blend shapes to create facial expressions

6.3   Animation Controller

To control and keep track of all animations for exercising, celebration and idling without having to recreate the animations for every character, we used the Unity Mecanim animation system [103]. Mecanim provides us with the ability of retargeting animations from one 3D model to another by creating animation controllers which are then dynamically applied to 3D models. Other vital features of Mecanim we used includes the possibility of previewing animation clips and animation flows in addition to being able to manage the animation flows using a visual tool. The visual tool works like a state machine where you can add states and relationships between them as well as creating sub-state machines to add abstraction levels that help with organizing. We created three main controllers; two for character creation, one for boys and girls, and one main controller which contains all animations relating to exercise, dancing, and celebration which is then programmatically applied to the character after creation. Figure 6.4 shows the state machine for the animations played for the boy characters while on the character customization screen described in section 5.1. The state machine gives a clear view of what is happening: Upon entry, the controller cycles between poses in an infinite loop, which is what we want during character creation. The girl models have a similar state machine for their poses as they are different from the boys'.
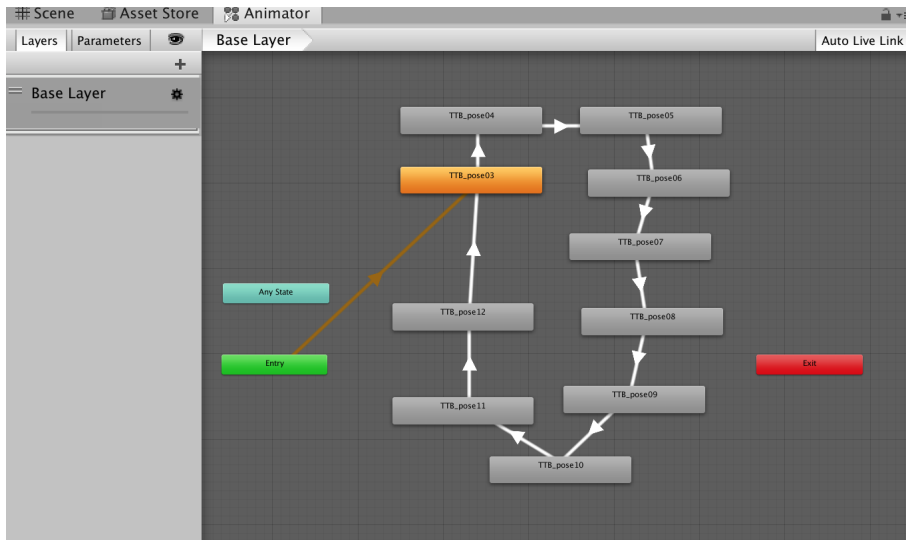
Figure 6.4: Animation controller state machine for poses during character customization
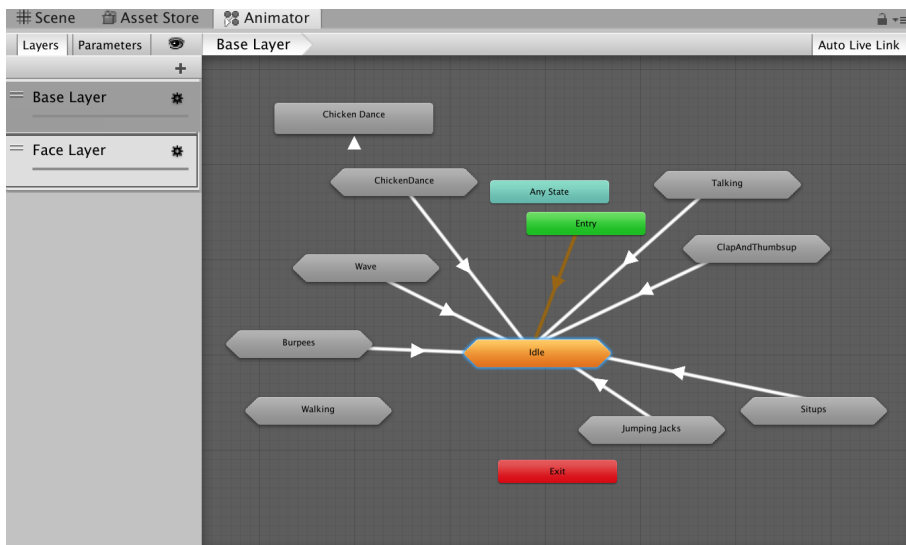
Figure 6.5: The top level state machine for the main animation controller

Figure 6.5 shows the top level of the state machine from the main animation controller applied to all characters. From the figure, we can see that it initially goes straight to idle, which is what the user sees after character creation. From here it can transition to any number of sub-state machines like "*Talking*" for talking animations or any exercise the user chooses, before going back to idle when it finishes. The main animator also has a secondary layer called the face layer, which controls the faces of the characters by manipulating blend shapes to create facial expressions.

Each of the sub-state machines has a different structure depending on what their action is. Figure 6.6 shows the sub-state machine for the idle animations where it cycles through different idle poses. The transitions between animations can be configured in length (not shown on the image) to make one animation play longer than the others. Figure 6.7 depicts the sub-state machine for one of the exercise previews shown when selecting an exercise. In this example, it is just the burpee animation playing in a loop.

Lastly, we want to show what the sub-state machine looks like after the user has selected an exercise in figure 6.8. Some exercises have an intro and an outro animation. For example, in the situps animation, the intro would be the character sitting down and getting ready to do situps, while the outro would be the character standing back up before going back to idle. In this figure, we can see that the state machine starts by playing the intro clip before looping on burpees until being told to transition to the outro clip and finally going back up one level and back to idle. The same figure also shows more of the Unity user interface where it previews the animation and shows other available settings.
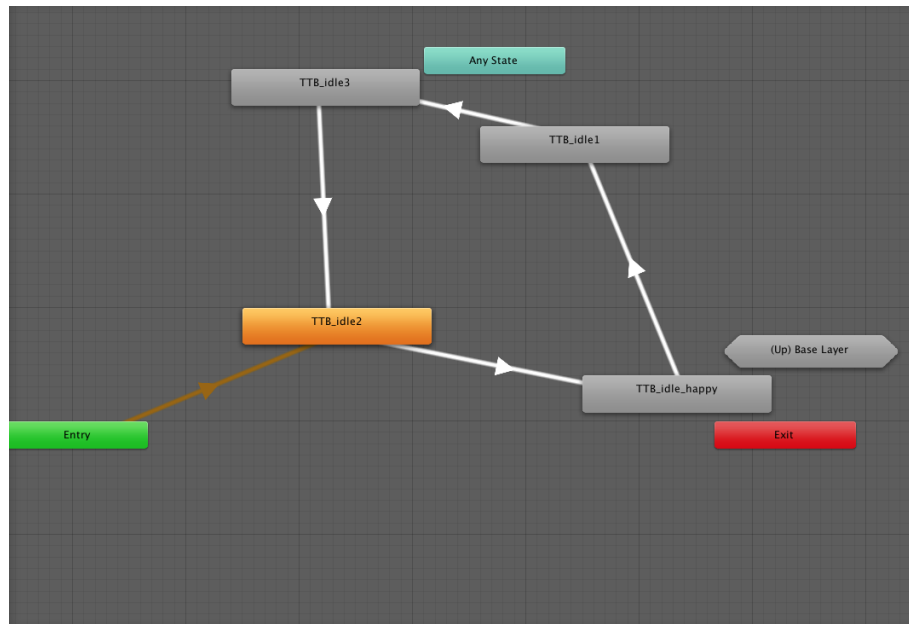
Figure 6.6: Idle sub state machine
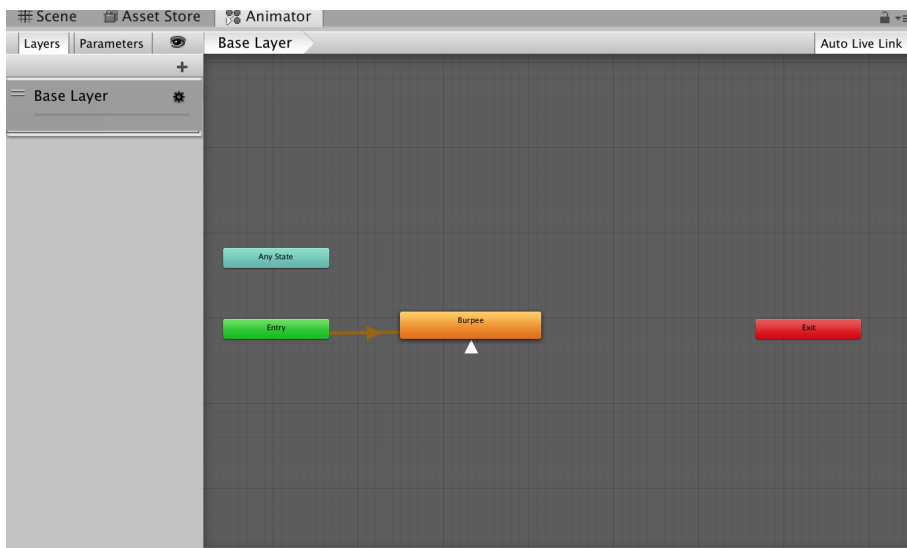
Figure 6.7: The sub state machine for burpee preview
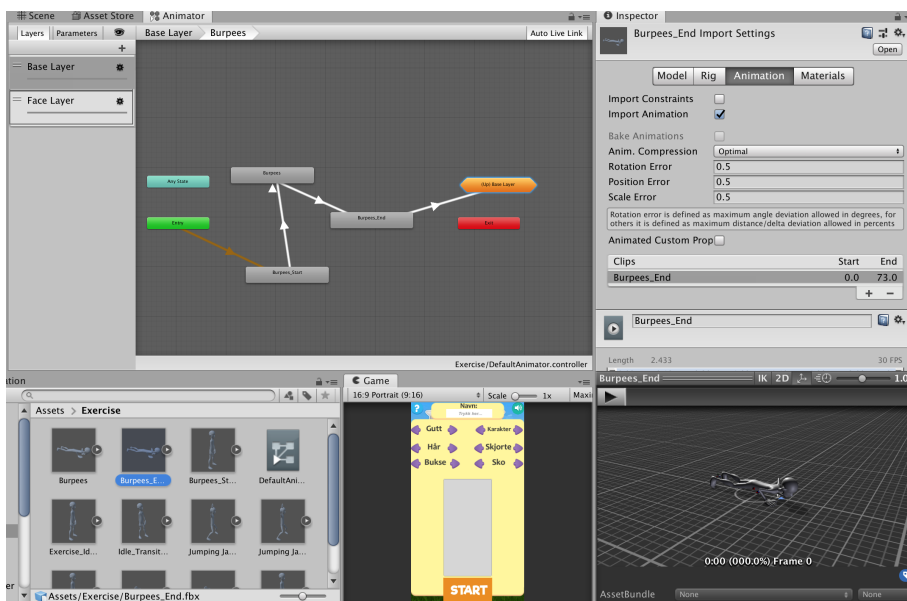
Figure 6.8: The sub state machine for the burpees exercise also showing preview

6.4   Adding New Exercises and Textures

A design goal from the start was making it easy to add new exercises to the application which is essential both in that not everyone is a programmer and adding new exercises is vital to keeping the application fresh and suitable for as many people as possible. There are two steps in creating and adding a new exercise, both of which can be done using the graphical user interface in Unity3D and does not require any code. The first step is to create an animation controller which is the controller for the exercise preview seen when selecting an exercise and after creating it, we add it to the list of controllers as seen in figure 6.9. Right below the animation controllers, you can also add accompanying audio clips to the exercise. In the figure only the chicken dance has an added audio clip, so all the other exercises use the default one.

When adding exercises, accurate naming is necessary for the scripts to identify and label them correctly. The new animation controller has to contain the name of the exercise and end with the word *Controller*. Everything before the word *controller* is used as the name for the exercise throughout the application in both presenting exercises and when it is stored in the exercise history of the user. We have to use the same name in the next step where you have to add a sub-state machine in the main animation controller containing the animation clips. The name of the animation clip has to be the same as the exercise to transition to the state successfully and if the exercise has intro and outro clips as described in section 6.3 they are added with the same name but ending with *_Start* and *_End* for the intro and outro clips respectively which can be seen in figure 6.8.

Adding new textures to clothing is very simple. Drag and drop the new texture to the correct list depending on if you are adding textures for a shirt, pants or something else. We use some of the textures for both genders, such as pants and shoes. Figure 6.10 shows some of the added textures, and when adding a new one the texture instantly becomes available in the app for that piece of clothing.
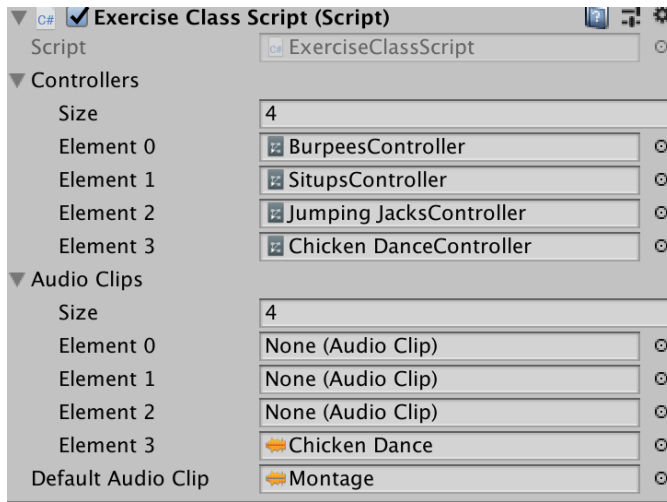
Figure 6.9: The list of preview animation controllers and audio clips
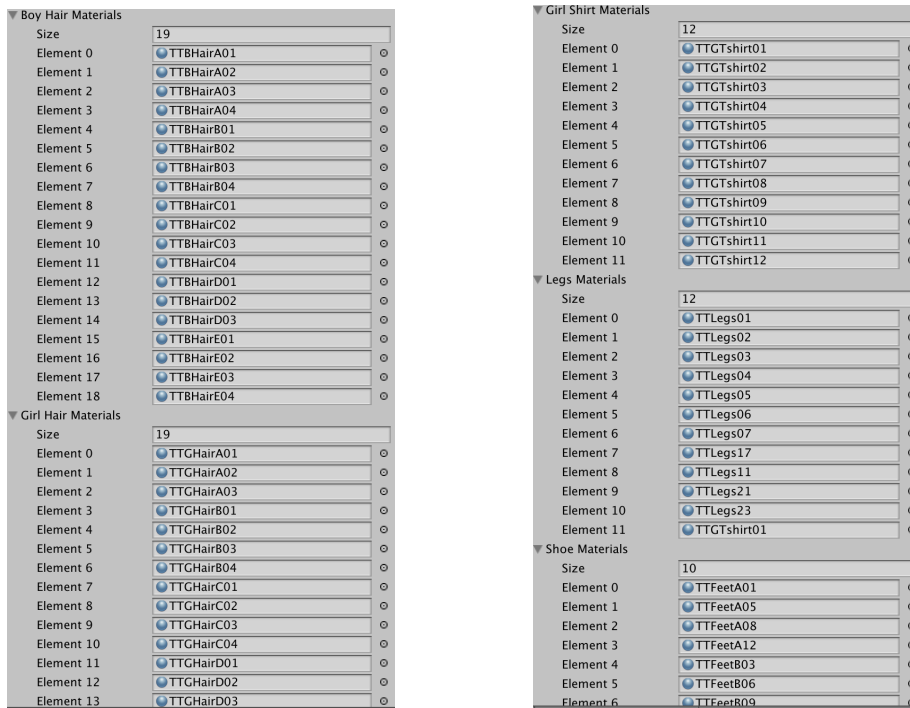
Figure 6.10: List of textures where you can add new clothing colors

6.5   Notifications

There are two main ways of implementing notifications in a mobile application. The first one is to use push notifications, which pushes a message from a remote server to the device. Push notifications are useful if the goal is to control when and how a notification is delivered remotely but has the challenge of needing two things; an interface for creating and pushing notifications which lives outside the scope of the application, and a server that handles the actual distribution of notifications to the correct devices. For this project, however, local notifications are sufficient. We used local notifications by scheduling them for every day at 16:00. When the user opens the application, the application is paused (put in the background) or exited, we clear the notifications for the current day and register new ones for the following ten days. If a user does not open the application before 16:00 the day after it was last used, a notification pops up saying that it has been some time since it last saw the user and prompts them to come to do some exercises. The notifications show on the lock screen, as an application badge, and in the notification center but if a user ignores the notification for 10 days straight, the application will no longer notify until the user starts it again. Stopping after ten days is to enable the user to come back at their terms and not consider the application to be too pushy.

6.6   Text-to-Speech and Speech Bubbles

Initially, the TTS engine used was a regular Google Translate HTTP GET request which returned an audio file. However, this is not meant to be used programmatically and would sometimes return a CAPTCHA[6] challenge which is difficult to respond to automatically. The solution was to change over to using Google Cloud Platform (GCP) Text-to-Speech [7]. GCP is not a free service, though the first 4 million synthesized characters are free and $4.00 USD/1M characters after that. Using GCP also enabled more features when using TTS that the previous solution did not offer like providing male voices for male characters and female voices for female characters. Besides, using GCP, we could now slow down the synthesize speed so that the voice talked slower for it to be more understandable. GCP also provides statistics of usage and latency as shown in figure 6.11

We often use TTS in conjunction with speech bubbles, which are the textual representation of what is being read out loud. Using speech bubbles with TTS and that we wanted the character to move its lips to make it look like its

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6. CAPTCHA: `https://en.wikipedia.org/wiki/CAPTCHA`
7. GCP: `https://cloud.google.com/text-to-speech/`

speaking gave us an implementation challenge as the asynchronous nature of HTTP requests means the fetching of TTS audio clips has to happen in a coroutine which runs in a different thread. Since we never know when the routine finishes, it is challenging to know how long the audio clips are due to them not being static in length. Not knowing the audio clip length means that we do not know how long the talking animation should play or how long we should show the speech bubble. Online resources show that an average human talks at a rate of 100-130 words per minute. These numbers were used to calculate the length of the string that we are going to synthesize and from there decide the length of animation playback and the speech bubble.

Figure 6.11: The Google Cloud Platform dashboard for the Text-to-Speech API

6.7   Scripting

Scripting is a big part of creating a game or mobile application using Unity3D. The scripts are what manipulates game objects to do things whether its UI changes, playing a sound, starting an animation, or adding behavior to an object in general. In this project, we tried to keep a separation of concerns where there were one instance of each script that did one specific job and if other scripts needed the same functionality they had to reference that instance, in other words, scripts were in practice singletons. Having one instance allowed us to write functionality like the user profile which contains information on completed workouts, functions to calculate a score, the user's name and so on where all the scripts that need access get the same information and do not

have to keep track of an instance of the profile script for their own. Figure 6.12 shows the dependency graph for the scripts created for the project. Many of the scripts depend on what called the Main script as it contains logic and data that others need and serves as an organizer for the application. We also see many scripts accessing the profile, but only the profile accessing high scores directly.
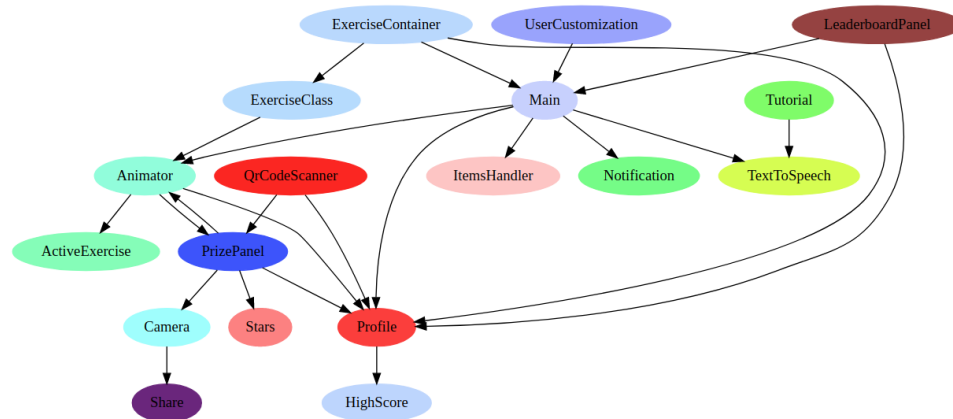
Figure 6.12: The dependency graph of all scripts in the project.

6.8   Application Iteration

As this is the first time developing an application for people with ID we were reliant on feedback from experts to know that we were was headed in the right direction. The application started very barebone with no controllable UI and only one single non-customizable animated character that moved when pressing temporary buttons placed arbitrarily on the screen. When receiving feedback that this looked promising, we continued creating the UI. The original design also celebrated with upbeat music and clapping after every exercise instead of only when receiving a star. We changed the constant celebration after a supervision meeting where feedback from supervisors was that it could be "too much" and from there we conceived the idea of a progress bar to earn a star. The same goes for being able to change animation speeds. Originally it was only one speed, but after an expert[8] tried the app, one of the feedback was that it might be too fast for some people. She also agreed on the over-the-top praise after every workout could be changed.

Iteration has been an essential aspect of the project as feedback is imperative to stay on the right path. Ideally, we would want to iterate on feedback directly

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from the client (i.e., a user with ID) like an agile project often does in the industry. Given the circumstances, that was not possible, and we used the next best thing, which are experts in the field like researchers and staff.

6.9 Summary

This chapter took a closer look at some details when implementing the application and explained the technicalities behind some of the features. We can see that rigging and animating 3D models can be tricky, but after our initial efforts we have created a system which is easy to expand in terms of exercises and dances. We also looked at how the application can be expanded in the future with more clothing options before talking briefly on how we iterated on feedback from experts in the field during development.

/7

Tests and Results

In this chapter, we present our test results from the interview and calculate the SUS score of our application based on scores from the interview as well as the reference group meeting. We do not restrict ourselves to only offering answers to questions, but also general feedback received outside the frame of the interview.

7.1 Pretest Questions

Before starting the actual interview, we asked the staff to tell us how many users had tried the application and what kind of technical experience they might have from before. The staff could tell us that they had been able to test the application with two users, in the interest of anonymity called *Alice* and *Bob* from here on out (names do not determine actual gender). No one had any other forms of technological assistance, but both of them had mobile phones while Bob also had a tablet that he used regularly. Both are reported to be eager technology users and frequently use tablets and computers to play games, watch YouTube, and to listen to music using Spotify. How frequently they do these activities is not very clear as the institution has set times where the users are allowed to use technology for entertainment while they are there, which is usually an hour at a time. However, when they are allowed, they jump right into it without hesitating.

7.2 Effectiveness & Efficiency

As previously mentioned, measuring effectiveness comes down to how many errors the user did when performing a task, which is a hard thing to ask as what signifies an error in this context is not easy to define. When asking the staff if the users managed to create a character on their own in the application, they could tell us that it was mostly no problem and there were no specific things they had a hard time doing or finding on the screen; in fact, they found it to be an entertaining aspect. When the users tried to start an exercise, Bob had no trouble figuring it out and opened the exercise selection menu and started an exercise without any intervention from staff. However, Alice needed some assistance starting an exercise as she did not know which button to press.

On the topic of efficiency, which is usually measured by how long a user spends performing a task, this is also hard for staff to give an exact answer to, but could give us an indication. When asked if they spent much time starting an exercise, the staff answered that Bob had full control and did it in no time while Alice needed some help, which matches the above answer on effectiveness. When asked in what capacity the users were able to follow and mimic the characters, staff could report that both users did excellent in this department and caught on fast. Bob could even follow the tempo on all exercises except when doing burpees while Alice had more trouble following the tempo of the character but did not find matching the tempo to big an important thing, but rather the movement was the exciting part.

7.3 System Usability Scale

1: 5 — 1 — 4 — 3 — 3 — 2 — 4 — 1 — 4 — 2
2: 4 — 2 — 4 — 4 — 4 — 1 — 3 — 2 — 3 — 3
3: 4 — 3 — 3 — 4 — 3 — 3 — 4 — 3 — 3 — 5
4: 5 — 2 — 5 — 2 — 5 — 1 — 5 — 1 — 5 — 3
5: 4 — 3 — 3 — 4 — 4 — 2 — 4 — 2 — 3 — 3

Above is the points scored in the SUS for statement 1-10 in each of the five results [1], but an individual score cannot be considered meaningful on its own and has to be seen in the context of surrounding statements. Each statement contributes 0-4 points to the total score based on where on the scale it landed.

1. See appendix D for a complete list of statements

Odd numbered statements (1, 3, 5, 7, 9) gets one point subtracted from it while the rest gets the maximum score of 5 minus its position on the scale [89]. Figure 7.1 shows the results for each statement for every one of the five completed questionnaires. After applying the formula as mentioned above and summing them, and by multiplying the results by 2.5, we get $(136 * 2.5)/5 = \mathbf{68}$ as the average final SUS score.
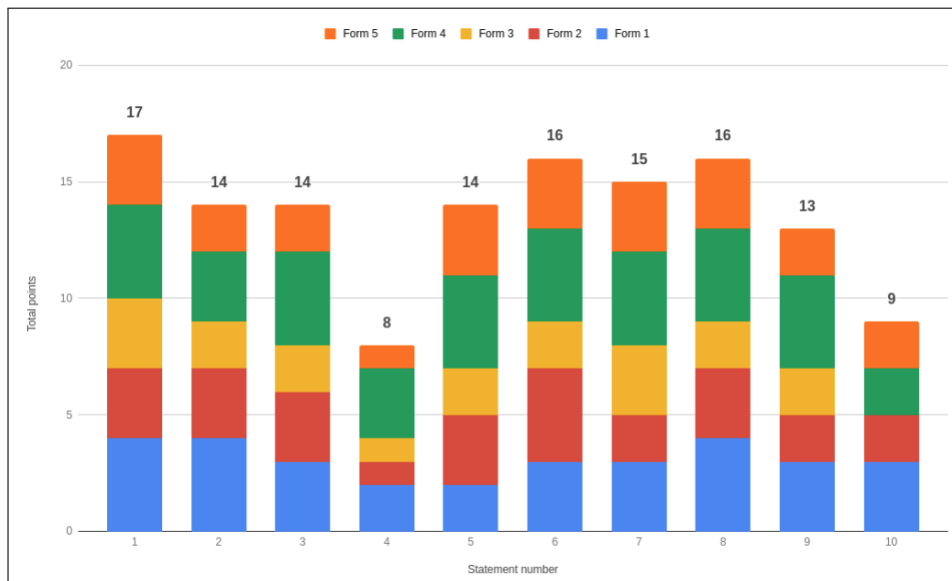
Figure 7.1: System Usability Scale questionnaire results

7.4 General Feedback

Before, during, and after the interview, there were tidbits of compelling information staff could tell us that could affect future versions of the application. Alice wanted girl characters that had short hair, which is something currently not implemented. It is interesting that they had enough interest in the character creation part to notice this missing. When Alice got started, she was hard to stop — getting three stars up to several times shows she had an interest in using the application and the most popular exercises were the chicken dance, the samba and doing jumping jacks. Alice experienced getting three stars and taking a selfie as fun but had problems finding the photo on the device afterward. The staff could also inform us that the phone got too small, so they mainly used the tablet and that users were so technologically proficient that they exited the app on several occasions to use the tablet for other things such as YouTube. The application showed to be so popular at the institution that they were sad when we came to take it back, so we decided to leave it there

for them to enjoy a little longer.

7.5   Summary

This chapter presented the results from our testing in terms of our SUS score, which landed on 68, feedback on effectiveness and efficiency, and general feedback from staff at the institution where we tested it. The general feedback was positive: staff reported that users had little to no problems using the application and seemed to genuinely enjoy using it. We have also seen that both staff and users at the institution liked the application so much that we had to leave the device at the institution.

8

Discussion

This chapter starts by discussing the results we presented in the previous chapter and talk through the limitations of our test methodology. It answers the original problems presented in the introduction while diving into some shortcomings of the application and continue by talking about where the direction the application can take in terms of functionality and usage before talking about some security considerations.

8.1   Test Result Evaluation

When looking at both effectiveness and efficiency of the users' ability to perform tasks in the application, we saw that none of the users had trouble creating a character, but one of the two subjects had trouble starting an exercise and needed help. The staff said that this was due to the user being confused that the two main buttons for exercise and QR code scanning were too similar and the user did not know which button to press. A future update should address this feedback.

Since the application is currently meant to be running on a personal device, we did not ask about the user's experience with the achievement sharing function, as it would require logging into social media accounts or inserting a sim card in the device. We did not anticipate anyone using it long enough to be getting three stars even though we, for testing purposes, lowered the number of points

required to earn each of them. However, one user did, and regardless of the user liking the selfie feature, they had problems locating the images on the phone, which affects both the applications perceived efficiency and effectiveness.

Another observation was that one user did not mind the fast animation speed and not being able to follow the tempo as that was not an interesting or important thing, which is inconsistent with feedback previously received from experts where they thought it might be too fast. Of course, having the option to turn down animation speeds probably does not hurt.

Next, we evaluate the satisfaction of our application by looking at the SUS score of **68** that we got in the previous chapter. In figure 8.1 we can see a proposed rating table for SUS. From the table we can see that they apply a range where the application is considered not acceptable, marginal or acceptable, gives it a grade from F through A and also an adjective rating. In terms of acceptance, our application scores at the high portion of the marginal range, bordering on acceptable. The grading scale scores us a D, but it gets close to a C, which starts at 70 points. The adjective rating for our application lands on *OK*, but is not far from scoring *GOOD*.
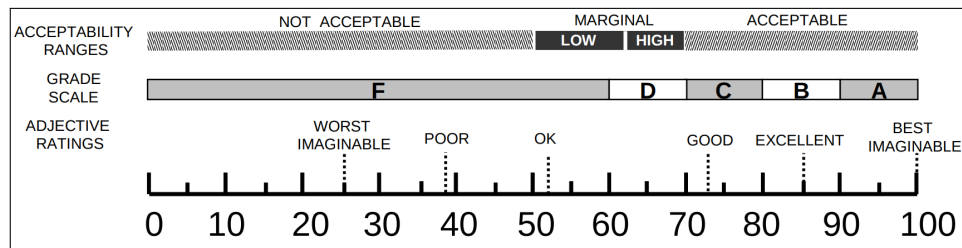
Figure 8.1: The System Usability Scale rating table [104].

Due to the limited test size in terms of real world users, we can not say anything definite about the usability of our application. Having both test subjects that tried it also liking and wanting to interact with it more, in addition to staff being positive as seen through the SUS score, can be intepreted as an indication that there are aspects of our application which works for people with ID. This is also somewhat backed by the results from the reference group meeting, which consists of people that interact with the target group every day. Interestingly, one of the highest scoring SUS questionnaires came from the interview conducted at the institution. It is hard to say for sure, but it might weigh more than the others since those results base themselves on actual users, as opposed to the reference group which just tried the application and did their best to answer what they thought does or does not work on people with ID. Another way of looking at it is that the institution staff answered directly to us, which might

influence the score positively as they might not want to hurt anyone's feelings by giving the application a lousy score.

From the graph in figure 7.1 in section 7.3 we see that two statements stick out, namely statement 4 and 10, which both score significantly lower than the others. Both statements are similar where question 4 is about them stating people with ID needs support from staff, and 10 is them suggesting people with ID needs comprehensive training before being able to use the application. While we generally can not extract any meaning from individual SUS scores, we can use this feedback as guidelines to where the focus should be for future releases; namely making getting started with the application easier.

There are challenges to address in future releases, and we received valuable feedback on what those challenges are through our testing. However, testing the application should span over a more extended period, ideally tens of weeks to measure the long time effects in physical activity and user retention.

8.2   Research Limitations

The limited time allotted for the thesis made it infeasible to conduct a study measuring the long time effects the application had on the physical health of people with ID. These kinds of tests usually span over 15-20 weeks according to previous studies on physical activity in people with ID and require approval from Regional Committees For Medical and Health Research Ethics (REK), which can take months to receive. Having a comparable testing period would be ideal as that would better show how the application contributes to the end goal of getting people with ID more physically active.

In general, when doing usability testing, the best thing is to be on site and observe during tests, as it is possible to witness how users interact with the application. Unfortunately, we were not able to do this due to some uncertainty on the legality of us being present while conducting the tests, and we did not want to take any chances. There is, however, a possible downside to being on site when working with people with ID as some of them may not like changes, and adding a new person to their already familiar circumstances can have a harmful effect on their motivation to participate in the tests.

Initially, the test was going to be a questionnaire that the support staff was to complete themselves before handing them back to us. However, this would fall under data storage and would consequently also require approval from REK, which led to the interview method previously described. Having any testing in the medical field and especially with people who often do not have the

capability of consenting to participate can be very difficult. It is, therefore, not a small feat to have any form of real user testing included in this project.

During the conducted interview, the answers were recorded by us taking notes. Taking notes can be a flawed method as the notes are our interpretation of the answer and can be incomplete to the point where it does not longer convey the intended meaning. Ideally, we would like to do an audio recording of the interview, but this would also fall under the data storage clause mentioned in the previous paragraph.

The number of users that tested the application was not significant. While it is terrific that we got any access to real-world testing, which can be challenging to achieve when doing studies in the health field, having only a few users test the application is not considered optimal. It does not help that answers come through support staff instead of directly from the users. However, having a small test size is not necessarily a bad thing if the ones we do have is from the correct target group as is the case on this project, in addition to having interviewed staff which has first-hand experience with the target group. Some research suggests that we learn much more from the first user than any succeeding user when conducting usability tests, although more users help in eliminating situations where the first user perform actions by accident or in any other way lead the results in an inaccurate direction [105].

When it comes to the SUS questionnaires, they were translated to Norwegian to make them easier to understand for the people who were going to answer the questions, and they were somewhat mutated to fit the context of people with ID. Translating the SUS statements to Norwegian can lead to some of the meaning of the statements can be lost in translation, making them inaccurate. We have done our best to make it more or less directly translated from the English version. Another slight critique towards the SUS and the rest of the questions were that we were not able to ask the users directly and that the results are based on what support staff, experts in the field and parents of people with ID thinks.

8.3   Answering the Research Problems

Returning to the research problems introduced in Chapter 1, we can now look at them with regards to what we have learned and developed, and from there, how we can answer them.

> *Sub-Problem 1: What makes a mobile application accessible for people with intellectual disabilities?*

When developing mobile applications for this group of the population, we have shown that there are many considerations to take into account. We have created an application which adopts several techniques from literature and what we learned in section 2.4 to improve usability. It uses clear contrasting colors in the menus and keeps important clickable areas like exercise and QR code scanning prominent and easy to hit. Where we use text, we apply big fonts with little to no capital letters and write in short, coherent sentences while also using icons to convey the meaning behind buttons. For the people who have reading difficulties, we include an option to use TTS where messages can be read out loud in a slow and understanding manner. The ability to turn down the workout animation speed also help with the users' ability to understand what is happening on screen. All these non-functional aspects of the application help in making it more accessible for people with ID.

> *Sub-Problem 2: Which features and characteristics of a mobile application can help motivate people with intellectual disabilities to be more physically active?*

Helping people with ID become and stay more physically active is at the core of what we are trying to achieve. The application helps to facilitate physical activity by introducing a training buddy to the user using a 3D character. The training buddies function is to create fun around physical activity and create a connection to the user. The character motivates the user through encouragement and praise when completing workouts and by demonstrating exercise routines. We implemented other features to promote physical activity like a point system where the user can earn stars and achievements which they can share with their friends and family. We also introduced dances with music to keep the repetitiveness of workouts to a minimum and for those who like to be outside; the possibility of going on hunts for QR codes to collect points.

> *Sub-Problem 3: How can a mobile application retain users with intellectual disabilities over a period of time?*

In addition to being fun and engaging, it is essential to retain users and make them come back and use the application regularly as physical activity is not a one-time thing and must be maintained over time to get results. To keep the users coming back to the application, we have included notifications where the user is reminded to use it every day. We also aim to engage the support staff through the leaderboard functionality where they can arrange tournaments and competitions between departments. If support staff shows interest in using the application, the probability of the users wanting to use the application is higher, which means that the support staff is vital for retention in the long run.

> *How can a 3D avatar running in a mobile application help people with intellectual disabilities become and stay more physically active?*

This was the main problem we started with initially. Through designing a fun and engaging experience with a tailor-made UI and accessibility features targeted at people with ID we created a mobile application which can be another tool in a toolbox for promoting physical activity in people with intellectual disabilities. Using user retention techniques, we try to keep the user motivated over time, hopefully leading to users staying physically active for longer.

8.4   Application Limitations

This section talks about some of the consequences that came from both limited time and our implementation choices. We go through some of the functionality of the application and address things that we should consider fixing in a future release.

8.4.1   Text-to-Speech

Now, all audio clips used for TTS relies on contacting GCP to get the text synthesized. To contact GCP, the phone or tablet where the application runs have to connect to the internet through WiFi or mobile data. The data usage from requests was measured to be as low as 2-3 kilobytes each clip, and with the data plans getting more affordable by the year this should not impose

a significant cost on the users' side in the long term. However, both in the interest of latency and data cost mitigation, the application could cache the audio clips that are static, i.e., those who do not include the name of the user. Another possible solution would be to use the native TTS engine built into most Android phones. Using this, however, is far inferior in terms of configurability and speech quality and using an external service for TTS means effortless cross-platform compatibility if we wanted to make the application available on other platforms in the future.

8.4.2   Exercises

As previously described, the user can earn points in two ways. One is by scanning a QR code found in the wild like shown in section 5.7. There is currently no way of stopping the user from using the same code over and over again. We briefly discussed this issue with the staff at the institution center where we conducted our tests, and they indicated that it would not be a problem and if getting more points meant that the users wanted to go outside, it was great. A way to avoid this is to limit the number of times a specific code can be scanned within a timespan; for example, every 12 hours. Chances are they have gone home in the meantime and have to go outside on another hike to collect the points again. However, when starting regular exercises, the user gets points based on how long they perform the exercise. There is currently nothing stopping them from starting an exercise, putting the phone down and stopping it after an hour only to potentially score many points. That means that the current version should be used under supervision if possible to not easily cheat the system. As for a solution, possible mitigation would be to use the app in conjunction with some hardware placed on the user like an exercise bracelet that contains an accelerometer to validate that the user is moving and pause the exercise if they are not.

On the topic of exercises. When developing the application, the main focus was to get the avatar up, running, and moving. There were only small amounts of considerations put into *what kinds* of exercise routines were included. Some of them might be too physically demanding for many people to perform. We propose to put in some more straightforward routines like lunges where the user can control the difficulty.

8.4.3   Too competitive?

Implementing the leaderboard was initially thought to have two functions, namely motivating the support staff and giving a social component to the application through teamwork. However, someone might see this as too competitive

and get upset or frustrated if they don't win. When dealing with people with ID, one should be careful with using competitions [106]. The leaderboard feature might need a redesign where it is more person oriented and presented as what the user has managed to do and perhaps progress of personal goals that can be set (i.e., reach X points).

Another note on the leaderboard is that it needs a back end to be complete. Currently, it only tracks the points local to the user and does not synchronize with other users and departments.

8.4.4   Number and Color of Menu Buttons

As mentioned in section 2.4.1, the number of menu buttons should not exceed five in order to follow design guidelines. However, the application in its current form has a total of 6 buttons where four of them are in each corner and the two main ones in the middle. The four corner buttons are also small in size and therefore not in compliance with the design principle stating that clickable areas should be large and comfortable to hit. We added many of these buttons in a late iteration of the application such as the button to start the tutorial which didn't exist and was only available the first time the application launched before deciding to have a way to start it manually whenever it was needed. The settings button was added in the last iteration as the application did not have a settings screen before this and the leaderboard button in the lower right used to be where the progress bar is currently located, but got bumped down to give the progress bar a prominent placement. Even though most of these buttons do not represent core features, it might need to be addressed to remove some of the clutter on the main screen.

As observed from the usability test, one user had trouble distinguishing the two main buttons from each other. The staff recommended to have them in two different colors, which is an easy thing to fix for the next iteration. Having the main buttons in different colors also enables us to change the tutorial to say "*press the green button to....*" instead of "*press this button*".
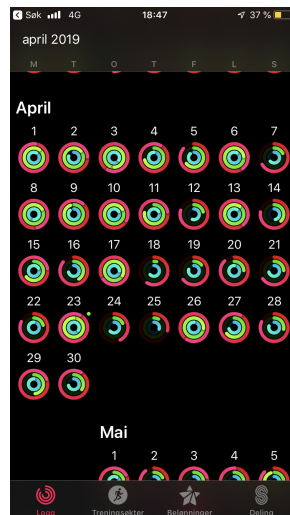
Figure 8.2: iOS activity app overview

8.5   Future Work

As it is now, the application has some shortcomings that need addressing before deploying on a larger scale. This section discusses possible features to expand the application and some improvement to existing ones.

8.5.1   Polishing the Exercise Experience

We already have TTS, but a possibly good idea for accessibility could be to add speech-to-text, meaning a user can talk to the application to control it. For example would a command like "Start workout" open the exercise screen or a maybe a simple word like "dance" could start a random dance. We think this would be an excellent quality of life addition to the application if implemented correctly.

Now the users are rewarded with stars when they complete enough exercises to fill the progress bar. However, when a new day begins the stars reset. We wanted to add some an exercise history where the user can see past days where they acquired three stars and the selfie they took alongside with it. This feature is inspired by the activity app on Apples iOS as seen in figure 8.2, where each day in the month is shown and rings represent the amount of activity for that day. In our solution, we would show between 0 and 3 stars instead of the rings. The same screen could also show which hiking destinations had been reached previously by logging which, when and how many times a QR code had been scanned.

Besides, each day can show more information about progression concerning previous days using graphs to show the improvement in terms of how long they exercise or how many points they have earned. The same information could then be sent to a back end server where caretakers could get access to a dashboard to remotely be able to monitor the users' progress and identify when intervention or adjustment is needed. The same back end and dashboard could be used by caretakers to set up challenges in the application. These challenges could be pushed to the device and could be of the type: "*Complete three stars five days and get a movie ticket*". The reward itself could be tailored to the persons need, and there could also be a possibility to upload a photo of the reward to be shown in the application as motivation. Rewards could also be "bought" in a store within the application where the user has to collect points and can spend them on rewards that caretakers have added, though the meaning of points as a currency can be a hard message to convey to some people with ID depending on their cognitive abilities.

When starting an exercise, the counter starts immediately. Some fitness applications from the state of the art study had countdowns before the start. Having a countdown would be an excellent addition to give the user some time to prepare to do the exercise and should be included in a future version. An exercise is also looped indefinitely, meaning the user has to do single repetitive movement all the time until he or she stops it and does something else. We would like to see the possibility of a combination of exercises from a list and make the application cycle through them one by one to introduce variation in the activity. We could also implement the possibility of storing favorite routines for easy and quick access, which is also something many other fitness applications offers. Currently, when calculating points after an exercise, they are based on a static number and not based on the intensity of the exercise or the capabilities of the user. We would like to see the point calculations to be configurable so that support staff could set the application up according to the users' physical fitness and motivational level.

When the user gets three stars, they get the possibility of taking a selfie with a filter to share their performance through the desired channel. We recommend adding more filters like this for variation.

8.5.2   Unlockables

The original design included an inventory system with unlockable items, pets, and more. The inspiration came from popular games like Fortnite [107] with a free-to-play model where users can play for free but unlock new items and costumes using money, only that our currency would instead be physical activity. Implementing this showed too challenging to realize within the timespan we

had for the project. We would like to see this in a future version of the application where new items could be used as prizes when completing challenges. As of now, two pets, a chicken and a cat complete with animations can be found in the app, but there are, as of now, no ways of unlocking and enabling them. The idea was that the pets would have an animation during workouts that made them look excited about what the character was doing. Figure 8.3 shows the two pets after being manually inserted into the game. Implementing this feature satisfies the only requirement specification not addressed by the rest of the application, namely requirement #13 from appendix B.
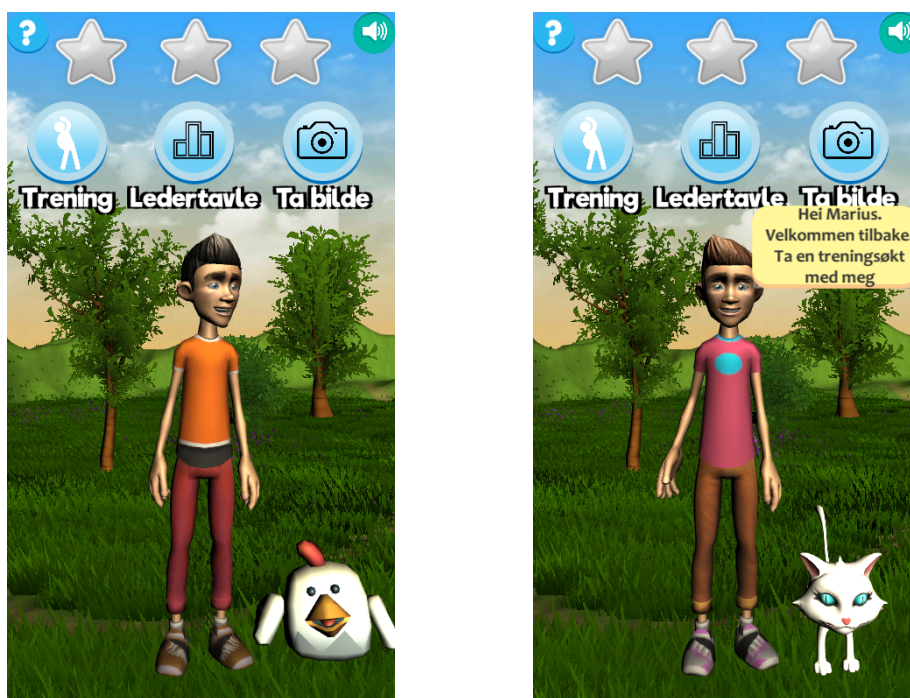
Figure 8.3: Two of the pets that were meant to be unlockable

8.5.3   User Profiles

When the institution tested the application, we set it up so that when it started, we created a new profile, and discarded any previous progress and characters. This was so that multiple people could try the experience and is contrary to how the application was designed to be where the users are meant to install the application on their own devices, and the progress persisted through restarts. From the reference group meeting, we got the suggestion to include a feature where they create multiple user profiles so that many users could share the same device and be able to switch between them to load their character, points, and stars. Having user profiles is a good idea as it eliminates the need for

a personal device, and the institution can buy a few devices for the users to share.

8.5.4   Other Features

We would also like to see music added to the idle and character creation screens to set the mood. This music would have to be controlled by turning the volume down or the music off when TTS is active for the users to hear what the TTS is saying.

An initial thought was that the avatar should be incorporable in any other application to be a familiar face in different settings like in educational applications. We would like to see the character model with all assets lives on a back end server and can be requested through an API and put in any application that supports the assets.

Currently, there is one background for the character to appear in, namely with the trees with the grass and hills. We would like to see several choices for backgrounds in the future where the character can be seen in different locations like more urban environments and with themes such as the wild west and space.

From the usability tests, we got feedback that the users would sometimes exit the application and use the tablet for other things such as YouTube which is not permitted. Preventing this is not a feature we can deliver, but most Android and iOS devices have the possibility of PIN-locking them to stay in one app which should be applied before any further rounds of testing. We also received feedback that one user had trouble finding the photos taken through the achievement feature. After some investigation we found that to be the case as we do not save the image to the gallery of the phone, but on the local storage for the application since it was initially thought to be viewed through the application in a future release. A feature to save it to the gallery is absolutely something that should be added.

8.6   Security and Privacy

Security and privacy are both critical subjects to consider when designing and implementing any piece of software. In regards to this application, the privacy and security aspects we need to consider is limited. Since we do not have any data transmission out of the application besides the connection to GCP, which is already encrypted using SSL, the security mostly has to be considered locally

on the device. The application does not store any personal information besides the users' activity history which is stored locally on the device but can, in theory, be accessed by anyone with physical access to the mobile phone or tablet. We took care as not to store any information on external storage the mobile device might have since they can effortlessly be taken out of the device and data can be extracted. This "vulnerability" ties well into the best mitigation technique for this and many other applications; users should use screen locks such as PIN codes or biometric authentication on their devices to keep unwanted users away from their personal data. However, even these security measures can be bypassed, so physically securing your phone is always the best way to secure your data.

To get full utilization of the leader board functionality and implement synchronization through a back end further consideration on privacy and security with regards to what data it sends out and how it does it is required. Symmetric encryption, data anonymization, and using SSL/TLS are excellent places to start. Besides, we have to consider the General Data Protection Regulation (GDPR), which can be an especially tricky subject when dealing with people with ID.

8.7   Miscellaneous

Long after finishing the systematic review, we realized that the search keywords might be lacking to catch different kinds of ID. If we were to to the review again we would add keywords such as "cognitive disabilities", "developmental disabilities", "mental handicap", "autism" and "Down syndrome". However, several of the articles already reviewed are targeted at people with Down syndrome or autism, so there is an overlap, and we hope not too many articles were missed.

When adding music to the exercises and dances, the music used is copyrighted. After consulting with supervisors, we concluded that as this is a nonprofit research project, it should not be a problem. If an application like this were to be commercialized, the music has to be switched out, or we have to request explicit permission.

A paper was written about this, and two other projects sharing the same goal, and have been submitted to the 18th IFIP Conference on e-Business, e-Services and e-Society 2019 (i3e). Currently, the paper is assumed to be approved and published in the proceedings, and the paper can be found in appendix E.

For a presentation of the research project, a video was created by one of the

project researchers showcasing how to use this and two other applications surrounding physical activity for people with ID. This video is attached to the thesis submission and distributed alongside the code.

8.8 Summary

From our discussions, we can see that by the application scoring a 68 on the SUS scale and in general receiving excellent feedback from the users, the staff at the institution and from the reference group meeting we can say that the application has potential. We can, with confidence, say that the application already is a viable tool to have for promoting physical activity in people with intellectual disabilities. With further tweaks discussed earlier in the chapter and future work, the application can become even stronger by implementing more features and polishing the existing ones. We have seen that we answered the original research problems by researching techniques relating to mobile design, physical activity interventions in people with ID and implement features to retain the users over time. We briefly talk about how both a video was created and a paper written on this and two other similar projects where the paper is up for publication.

/9

Conclusion

In this thesis, we have investigated ways of helping people with intellectual disabilities become more physically active by using a 3D avatar in a mobile game. We have applied various techniques and implemented features based on results from previous research and currently offered applications in the market both in terms of motivation and user retention to make the application usable and accessible for the target group. The result is a mobile application where the avatar acts as a training motivator and partner for the user and demonstrates exercise routines, cheer the user on when they do good and provide personalization through character customization and individual target goals using a point system.

We have conducted real-world testing, which can not be taken for granted when working on a relatively short project partly in the medical field, where anonymity and personal data protection is of the highest importance. There is still research that remains in identifying the long term effects the application can have on maintaining physical activity levels. From the usability tests, we have learned that the application was well received by the users, despite having some shortcomings, and were actively used in the testing period which indicates it having a positive effect on the levels of physical activity. The users are reported to be able to interact with the application without too much problem and quickly picked up on how to use it. We have also proposed future work, which can help improve usability and the appeal the application has to people with intellectual disabilities and make it a richer experience. There are many directions this application can be taken in the future, some of them

outlined earlier, and the only limiting factor is that of the imagination.

Enabling people with intellectual disabilities to become more physically active has multiple benefits besides yielding higher scores on typical fitness indicators. Everyone should be able to participate and contribute to society as any other citizen, and their humanity should not be overshadowed by the fact that they are disabled. Physical activity has shown to help reduce anxiety and improve mental health, which can lead to a better quality of life for the users and an improvement in general health can further lead to better integration in the society which is currently a concern with this part of the population. The money that goes into health care to treat obesity and mental health issues are also concerns which can be mitigated by getting a healthier population. People with intellectual disabilities often express the desire to get into a romantic relationship, get a paid place of employment and feel like a part of the community [108], and we think that greater overall health can be a good start in reaching those goals and that our application can help with that.

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/A
Systematic Review search terms

This is an overview of search terms used and the databases search along with the number of results. Note: A zero in the eligble column can also mean the result was removed due to being a duplicate.

Database	Search term	Hits	Eligible
IEEE Explore	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	1	1
ACM Digital Library	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	0	0
Pubmed	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	6	2
Scopus	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	39	3
ScienceDirect	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	180	8
Embase	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	20	0
PsycInfo	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	5	0
CINAHL	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND (game OR exergame OR gaming OR exergaming OR app OR application OR mobile OR tablet)	12	0
Games for health journal	"physical activity" AND ("intellectual disability" OR "intellectual disabilities" OR "mental retardation") AND ("game" OR "exergame" OR "exergaming" OR "gaming" OR "mobile" OR "application" OR "tablet")	2	0
Total		265	14
Duplicates		31	

B

Application Requirement Specifications

Following is the complete requirement specifications followed when developing the application

Req #	Type	Description	Rationale	Source	Fit Criteria	Satisfaction	Dissatisfaction	Dependencies
1	9	The application should offer character customization	A more personalized experience can lead to more use. Caters to the need to make exercising fun	Author	A user should be able to customize a characters clothing and appearance. This character should follow throughout the app	5	4	None
2	9	There should be selectable exercises	Core functionality in the application.	Author	User should be presented with different exercise choices with previews	5	4	1
3	9	Points should be rewarded	Rewards are a facilitator to be more physically active	Author	User should get points presented to them when they complete an exercise.	5	3	1,2
4	10	Celebration and praise should happen	Praise has shown to be a facilitator to be more active	Author	When a user completes an exercise they should be celebrated with applause, music, fireworks	5	3	1,2
5	9	Should have a point overview	Can add a social aspect where teams can work together torwads a goal. Can also help encourage support staff	Author	When the user presses the leaderboard button it should present a sorted leaderboard	3	1	1,2,3
6	11	User should get text read to them	Some users might have trouble reading and text to speech can help the cognitive load	Experts	When the anything is presented through text, a voice should read the text out loud. Should be possible to turn off	4	3	None

7	9	User should be reminded to exercise	Being reminded has shown to have an affect on user retention	Author	When a user has been away from the app for some time, they should be reminded to come back through a notification	3	1	None
8	9	Should offer a way of using the application for hiking	Users express the desire to be outside. Can place QR codes in the wild for them to hunt for	Experts	When a user finds a QR code they can scan it and they receive points that count towards the leaderboard	4	1	None
9	10	The application should feature music	Music has shown to be effective tools in getting users engaged in physical activity	Author	When a user selects an exercise, music should be played while they work out	4	3	1,2
10	9	Application should include dances	Dancing has been effective in getting users physically active	Author	When a user selects exercises, they should also get a selection of dances which can be started	4	1	1,2
11	10	The application should be easy to use for the target audience	Having a UI that caters to the target group is very important for usability	Author	The UI should be designed with current usability guidelines in mind	5	5	None
12	9	Users should be able to share achievements	Sharing rewards and accomplishments can be a motivating factor	Experts	The user should be able to share accomplishments like completed exercises through social media	4	1	1,2
13	9	There should be unlockable items	Rewards like new items for the user can be a good facilitator	Author	When a user completes a series of exercises they should be rewarded with new items for the character, pets, tools etc	4	1	1,2

| 14 | 11 | User should get text alternative to voices | It is recommende d to have text alternatives to things that are usually only audible | Author | When something is presented in an audible manner, a speech bubble should show the text representatio n of that | 4 | 2 None |

/C

Study Protocol and Consent Forms

This appendix contains the original consent forms for both staff and users (last page) in addition to the study protocol. These forms were never used in the actual study due to the last minute changes to method of usability testing. This is only available in Norwegian

Forespørsel om deltakelse i forskningsprosjekt

"Forbedre fysisk aktivitet med hjelp av teknologiske hjelpemidler hos personer med psykisk utviklingshemming"

Dette er et spørsmål til deg om å bidra til et forskningsprosjekt som utvikle elektroniske verktøy for å fremme fysisk aktivitet hos personer med utviklingshemming.
I undersøkelsen vil vi kartlegge brukervennlighet av tre mobile treningsapper utviklet av masterstudenter ved UiT Norges Arktiske Universitet. Det er tre forskjellige apper hvor alle har som mål å gjøre aktivitetene gøy å utføre.

Ansvarlige for undersøkelsen er

Navn	Rolle	Mail	Telefon
Audny Anke	Prosjektleder	audny.anke@uit.no	
Gunnar Hartvigsen	Professor	gunnar.hartvigsen@uit.no	77644049
Henriette Michalsen	Doktorgradsstipendiat	henriette.michalsen@uit.no	
Marius Wiik	Mastergradsstudent	marius.wiik@uit.no	40000478
Valter Berg	Mastergradsstudent	vbe013@post.uit.no	97642580
Vebjørn Haugland	Mastergradsstudent	vha044@post.uit.no	99129279

Hva det innebærer å delta

I undersøkelsen vil du prøve èn av de tre applikasjonene. Vi er interessert i hva du synes om appen og hvordan den var å bruke. Dette kan du fortelle en av personalet eller en i familien. Vi vil også spørre personalet om hva de synes om treningsappen

Frivillig deltagelse

Det er frivillig å delta i undersøkelsen og du kan når som helst trekke deg uten at du behøver å oppgi grunn. Dersom du ønsker å delta undertegner du arket med samtykkeerklæring.

Hva skjer med informasjonen om deg?

Vi vil bruke resultatene fra spørreundersøkelsen til å evaluere designet til treningsappene for å finne ut hva vi kan gjøre bedre. Disse resultatene vil bli diskutert i vår masteroppgave. Ingen identifiserbar informasjon vil bli samlet inn eller inkludert i rapporten. Etter at

masteroppgaven er levert 1. Juni vil alle notater hvor det er resultater fra utprøvingen makuleres på en forsvarlig måte.

Mer informasjon kan fås ved henvendelse til en av de ansvarlige for undersøkelsen.

Samtykke til deltagelse i prosjektet

Jeg er villig til å delta i prosjektet

Signatur:

_____

Sted og dato   **Deltakers signatur**

_____

Deltakers navn med trykte blokkbokstaver

Stedfortredende samtykke:

Som nærmeste pårørende til …………………………………… (fullt navn) samtykker jeg til at hun/han kan delta i utprøvingen.

_____

Sted og dato   **Pårørendes signatur**

_____

Pårørendes navn med blokkbokstaver

Protokoll

Schedule

Tid	Aktivitet	Ansvarlig
Mandag 13/05-2019	Oppstart av eksperiment	
	Utlevering av utstyr	Mastergradsstudenter
	Gjennomgang av applikasjoner sammen med ansatte ved institusjon	Mastergradstudenter
	Innsamling av samtykkeskjema	Mastergradsstudenter (gjennom ansatte ved institusjon)
Mandag 13/05-2019 t.o.m. Torsdag 16/05-2019	Bruk av applikasjoner Utfylling av spørreskjema	Ansatte og brukere
Torsdag 16/05-2019	Henting av utstyr	Mastergradsstudenter
	Innsamling av utfylte spørreskjema	Mastergradsstudenter

Tekstuelt format:
Oppstart for eksperimentet er satt til mandag 13/05-2019. Mastergradsstudentene kommer da til Tindfoten Dagsenter om morgenen og har da med alt nødvendig utstyr som kreves for å gjennomføre eksperimentet. Etter ankomst vil mastergradsstudentene utføre en liten gjennomgang av deres respektive applikasjoner, slik at de ansatte kan stille spørsmål hvis de har noen umiddelbart. Det vil også bli utlevert brukermanualer som de ansatte kan slå opp i om de står fast.

Etter gjennomgang og eventuell spørsmålsrunde, vil utstyret bli overlevert til ansatte ved Tindfoten Dagsenter, og de ansatte og brukerne står fritt til å bruke applikasjonene så mye som de vil fra og med mandag 13/05-2019 til og med torsdag 16/05-2019. I denne tidsperioden har de ansatte i samsvar med brukerne mulighet til å notere ned opplevelsen av applikasjonene, og kan bruke det på det avsluttende spørreskjemaet.

Torsdag 16/05-2019 vil mastergradsstudentene igjen komme tilbake til Tindfoten Dagsenter for å hente utstyret og avsluttende spørreskjema.

Deltakelse i Forskningsprosjekt

Du skal:

- Prøve en treningsapp
- Si hva du synes om appen

Det er frivillig å delta og du kan når som helst trekke deg.

Vi vil bruke tilbakemeldingen du gir når vi vurderer appen du har prøvd.

Det vil ikke bli lagret noe data som kan knyttes til deg.

Jeg vil delta på utprøving av utstyr

Signatur:

_____

Samtykke til deltakelse i studien

/D

Interview Questions

This appendix contains the interview questions used to assess the usability of the application. They were asked to staff at Tindfoten Dagsenter and not the user themselves. The interview questions are only available in Norwegian.

Intervju etter testing av applikasjon

Først: Vil stille noen spørsmål relatert til brukerne og hvordan de opplevde appen. Må svares en gang for hver bruker som deltok

Pretest Questionnaire

Spørsmål:
Har brukeren noen andre teknologiske hjelpemidler fra før? Hvilke?
Svar:

Spørsmål:
Har brukeren en mobiltelefon eller nettbrett fra før? Evt hva bruker han/hun den til? Hvor ofte bruker han/hun mobiltelefonen? Evt hvilke apper?
Svar:

Effectiveness

Spørsmål:
Fikk brukeren til å lage en karakter i applikasjonen? Var det noe spesielt han/hun plagdes med? Noe de synes var gøy eller interessant? (forsto ikke, for mange valgmuligheter, morsomt)

Svar:

Spørsmål:
Fikk brukeren til å starte en treningsøkt? Var det noe spesielt han/hun plagdes med i forhold til dette? (Størrelser på knapper, forstå hva man skal trykke på)
Svar:

Efficiency

Spørsmål:
Brukte brukeren lang tid på å starte en treningsøkt? Anslag på hvor lang tid?
Svar:

Spørsmål:
I hvor stor grad klarte brukeren å følge bevegelsene til karakterene? Var det noe de synes var vanskelig med dette? (Type øvelser, hastighet på animasjonen)
Svar:

Generelle spørsmål

Spørsmål:
Var det noe du eller brukerne savnet i applikasjonen?
Svar:

Informer:
Jeg kommer til å stille en del spørsmål som baserer seg på erfaringen dere har hatt til nå med appen og du kan svare i forhold til hva du forventet og hva du synes. Se det gjerne i sammenheng med personer med psykisk utviklingshemming generelt og ikke nødvendigvis kun på de brukerne som brukte appen

System Usability Scale

1. Jeg tror en person med psykisk utviklingshemming ville likt å bruke appen jevnlig

Svært uenig   Svært enig

1	2	3	4	5

2. Jeg tror en person med psykisk utviklingshemming ville synes appen er komplisert

Svært uenig   Svært enig

1	2	3	4	5

3. Jeg tror en person med psykisk utviklingshemming vil synes appen er lett å bruke

Svært uenig   Svært enig

1	2	3	4	5

4. Jeg tror en person med psykisk utviklingshemming trenger støtte fra personell for å bruke appen

Svært uenig   Svært enig

1	2	3	4	5

5. Jeg tror personer med psykisk utviklingshemming vil synes at de forskjellige delene av systemet hang godt sammen.

Svært uenig   Svært enig

1	2	3	4	5

6. Jeg tror en person med psykisk utviklingshemming vil synes det er for mye inkonsistens i systemet. (Det virker "ulogisk")

Svært uenig   Svært enig

1	2	3	4	5

7. Jeg ser for meg at de fleste med psykisk utviklingshemming vil lære å bruke appen raskt

Svært uenig   Svært enig

1	2	3	4	5

8. Jeg tror personer med psykisk utviklingshemming vil synes appen er tungvint å bruke

Svært uenig   Svært enig

1	2	3	4	5

9. Jeg tror personer med psykisk utviklingshemming vil føle seg komfortabel med å bruke appen alene.

Svært uenig   Svært enig

1	2	3	4	5

10. Jeg tror personer med psykisk utviklingshemming trenger omfattende opplæring før de kan begynne å bruke appen

Svært uenig   Svært enig

1	2	3	4	5

/E

Paper Submitted to Conference

This is the paper submitted to the 18th IFIP Conference on e-Business, e-Services and e-Society 2019 (i3e) conference. More specifically to the Digital Transformation for an Inclusive Society (DTIS) workshop which aims to improve the inclusion of people with special needs by digital transformation. More information here: `https://www.i3e2019.com/dtis`. At the time of writing the paper is assumed to be published in their proceedings.

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 scenario-building, 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. In the individual interviews, we will use joint storytelling and scenario building methodology to create a behaviour change story. Then, we will proceed to map out this process on a timeline and identify barriers and potential ways to overcome them. This will occur with as many participants as needed to reach data saturation, .i.e. no new stories are created. Later, these participants will be invited to think aloud while a) interacting with our prototypes, b) reflecting on our prototype's ability to meet their needs, and c) revisiting our behaviour change story.

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 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 meetings 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 favorable 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, candy, threats, etc.) to get a long-term effect. Predicted as most effective among persons with ID is amusing/fun and immediately receiving candy or cake. To achieve a behavioral change takes a structured plan 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.
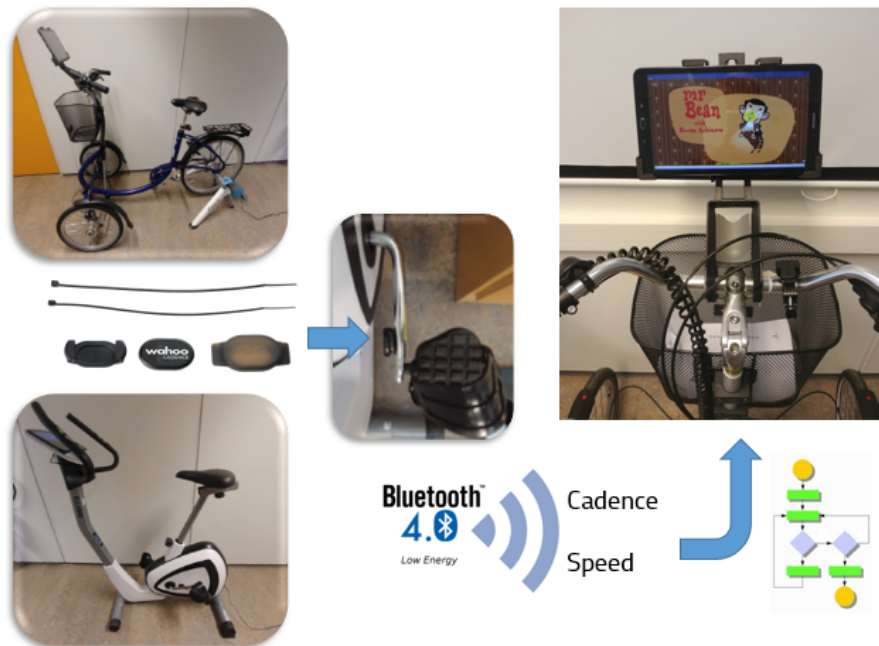

**Fig. 1.** Set up of the in-door bycycle based activity monitor.

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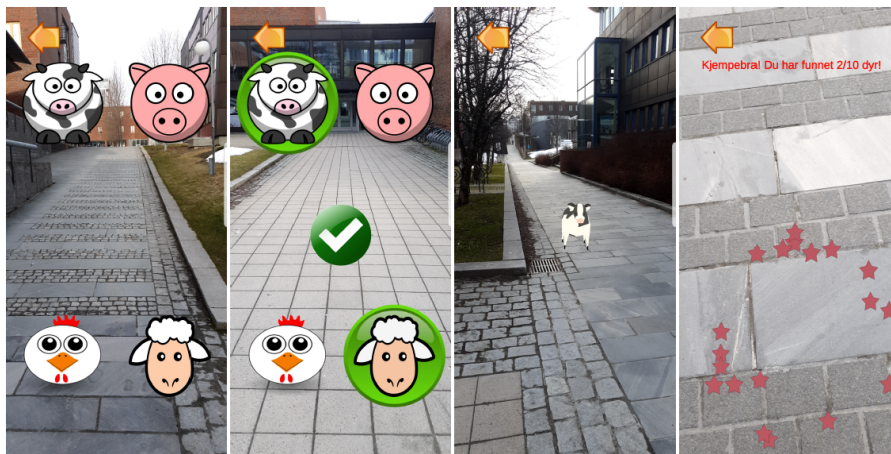
Fig. 2. Graphical user interface of the guided out-door exercise app.

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.
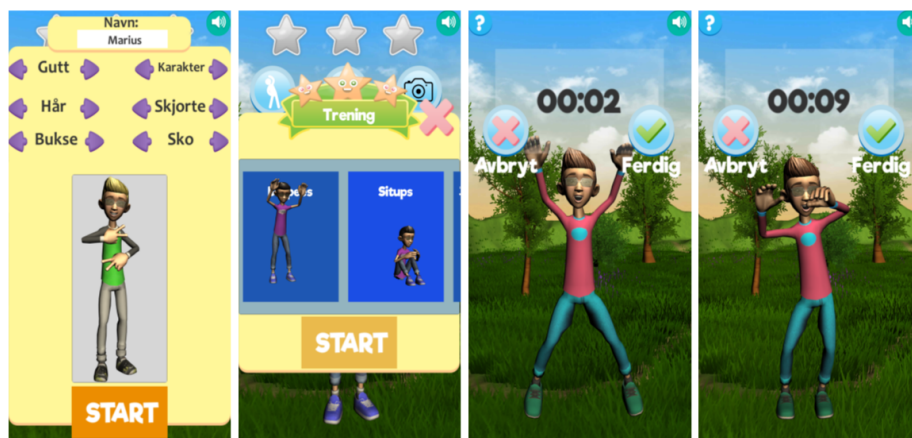

Fig. 3. Screenshots of the guided workouts app and the avatar.

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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/F
User Manual

This is the Norwegian user manual given to the support staff for them to use during the testing. It also includes some QR code examples.

Brukermanual AGA Mobilapplikasjon For Trening

Merk: Da appen ikke er helt ferdigutviklet er det nederst samlet en oversikt over ting som er greit å vite

Når du starter applikasjonen

Når applikasjonen har startet skal man lage seg en karakter som blir din treningskompis. Du starter med å fylle ut navnet ditt på toppen.
Etter det kan man bruke pilene til høyre og venstre for å velge mellom forskjellig kjønn, karakter og hvilke klær man vil ha på karakteren. Når du er klar trykker du på start-knappen

Hovedmenyen

Når du har trykket start kommer du til hovedmenyen.
Øverst ser du antall stjerner du har fått. Målet ditt er å få tre stjerner ved å fylle ringen i midten. Dette gjøres ved å samle poeng.

Man kan samle poeng på to forskjellige måter:
- Ved å starte en treningsøkt
- Ved å finne plakater ute på tur og scanne koden på disse

Nede til høyre i bildet er knappen for å starte veiledning. Denne vil gå igjennom tilgjengelige funksjoner i applikasjonen.
Oppe til høyre er en knapp for å skru av og på taleopplesing av tekst, oppe til venstre kan man endre noen enkle innstillinger og nede til høyre kan man se ledertavlen.

Trening

Trykk på den blå knappen til venstre merket "Trening". Da vil du få en oversikt over treningsøvelser slik som vist på bildet til venstre under. Feltet kan rulles mot venstre for å vise flere øvelser. Når du trykker på en øvelse vil den bli merket. Trykk på Start knappen for å starte øvelsen. På bildet til høyre under ser du hvordan skjermen ser ut under trening. Din oppgave er nå å gjøre det samme som treningskompisen din. Det er ikke viktig å gjøre det i samme tempo. Når du er ferdig vil du få poeng.
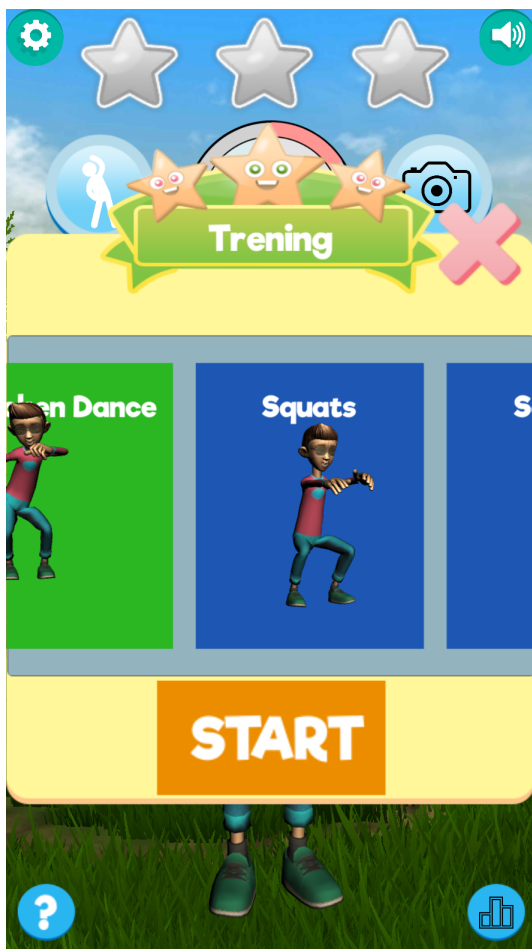
Ledertavle

Den blå knappen nede til høyre på hovedskjermen tar deg til ledertavlen. Her kan du se hvor godt din avdeling ligger i sammenligning med andre **(Merk: Denne funksjonaliteten er ikke ferdigutviklet, så du vil kun se dine egne poeng og noen vi har lagt inn for å vise)**

Kameraknappen

Trykk på denne knappen når du har funnet et turmål som gir poeng. Helt i slutten av denne brukermanualen kan man se eksempler på slike plakater.
Pek kamera mot koden så vil du motta antall poeng som står på plakaten.
Bildet under viser et eksempel på dette.
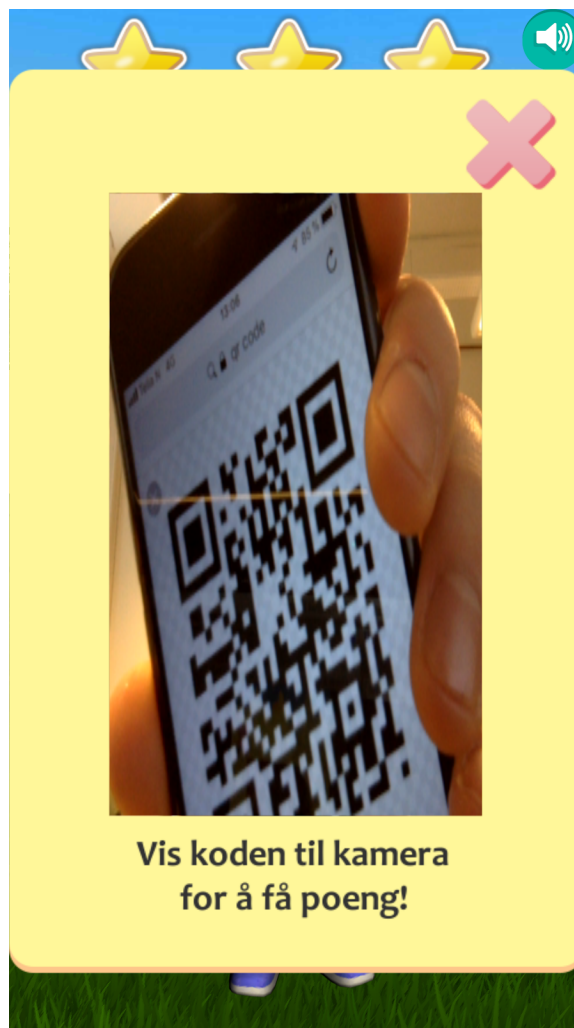
Når du får tre stjerner

Når du endelig har fått tre stjerner kan du ta et bilde av deg selv sammen med stjernene du har tjent og legge det ut på sosiale medier eller sende det til venner og familie for å vise hva du har klart. Du vil få et bilde likt det under hvor du kan trykke på kameraknappen nede i midten for å ta bildet.

Greit å vite

Starte applikasjonen på nytt

I testversjonen levert ut kan man starte på nytt (lage ny karakter, starte poengene på 0) ved å lukke applikasjonen helt og starte den igjen. Dette er også greit å gjøre om applikasjonen blir uresponsiv eller på en annen måte oppfører seg uvanlig.
På telefonen dere har fått utdelt (Samsung Galaxy S9) kan det gjøres ved å sveipe opp fra bunnen for å få fram knappene vist på bildet under. Trykk på knappen til venstre av de tre. Dette vil vise alle applikasjonene som er åpne. Trykk så på "X"-en øverst i høyre på AGA applikasjonen for å lukke den (Eller trykk på "Lukk alle" nederst). Da er det klart for å starte applikasjonen igjen.
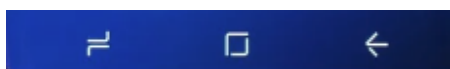
Tekst til Tale

For å aktivere taleopplesing av tekst må telefonen være koblet til WiFi / Trådløst nett. Det kan gjøres ved å trykke på Instillinger → Tilkoblinger → WiFi på Samsung Galaxy S9

Dobbelt opp med klær / hår

Om du plutselig ser at du får dobbelt opp med klær eller hår når du velger, bare fortsett å trykk pilen i en retning til det retter seg. Dette er en kjent feil og blir fikset.

Finne turmål

For å kunne finne turmål med QR koder å scanne må disse først plasseres ut. Tanken er at det skal kunne motivere til å gå en tur hvor man kan se etter og jakte etter koder som gir poeng. På de neste sidene er det eksempler på hvordan disse plakatene kan se ut. Det er lett å lage egne. Alt du trenger å gjøre er å gå på en side som https://www.qr-code-generator.com/ velge at QR koden skal inneholde "Text", skrive et tall (kun et tall, feks 200) i feltet "Message". Trykk så "Create QR code" og så "Download jpg". Dette bildet kan dere bare legge i et word-dokument, legge til ekstra tekst som dere ønsker og skrive ut. Her kan man feks legge opp til å få flere poeng for turmål som er lenger unna.
Merk: Det er ikke lagt inn begrensning mot å scanne samme plakaten mange ganger. Dette er planlagt for fremtidig versjon

⭐⭐⭐

200 Poeng

🏅

⭐⭐⭐

600 Poeng

🏅