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Faculty of Science and Technology
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# Culture Enhancement for Exergames for Individuals with Intellectual Disability

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Master Thesis in Computer Science - INF-3981

# Acronyms

**AR** Augmented Reality

**ID** Intellectual Disability

**PA** Physical Activity

**AGA** Activity Game Avatar

**IDE** Integrated Development Environment

**TTS** Text-To-Speech

**WHO** World Health Organization

# Abstract

**Background** Individuals with intellectual disabilities (ID) often face barriers when trying to engage in physical activity. Exergames, which combine physical exercise with gaming technology, have shown the potential to promote physical activity among this group of individuals. However, the suitability of exergames for individuals with ID from different cultural backgrounds has received limited attention.

**Objective** This project is aimed to investigate cultural aspects of exergames for individuals with ID. The main goals were to explore how cultural factors affect engagement and experience, pinpoint culturally suitable design elements, create guidelines for cultural sensitivity, and look at the effects of culture-enhanced exergames.

**Methods** A mixed-methods approach was used. This was a literature review, interviews with individuals with ID from a different cultural background than Norway, expert consultations, and an iterative design process.

**Results** The research showed a few cultural factors affecting the engagement and experience of individuals with ID in exergames, such as language preferences and, specifically to one exergame, local waste sorting regularities. The evaluation of culture-enhanced exergames gave positive impacts on the users' physical activity levels and overall well-being.

**Conclusions** The project examines the impact of cultural variety in the design of exergames for individuals with ID. By addressing these factors, exergames can be made more engaging and accessible to more users in the world.

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# 1 Introduction

## 1.1 Background

The World Health Organization (WHO) states that physical activity is essential for individuals with intellectual disabilities (ID) [26]. Regular physical activity offers a set of benefits for their overall well-being. It helps improve health by keeping a healthy weight, reducing the risk of chronic diseases, and improving cardiovascular fitness. Moreover, physical activity is vital for developing motor skills, such as coordination, balance, strength, and flexibility, improving movement and functional abilities. According to the Norwegian Institute of Public Health, it is estimated that approximately 0.95-1.23% of the population in Norway has an ID [33]. And the prevalence of ID worldwide is around 1% [11].

By recognizing the significance of physical activity, individuals with ID can live healthier by having better physical and mental lives [26]. WHO recommends 150-300 minutes of moderate physical activity or 75-100 minutes of high-intensity training per week for adolescents and young individuals with disabilities [26].

PAID is a project whose purpose is to evaluate whether mobile health (mHealth) exergames can promote physical activity in individuals with ID [20]. Two game-inspired mobile applications for people with ID, Sorterius and AGA, were developed as part of the PAID project. The aim of the two applications is both to motivate users to engage in physical activities, with the main goal of improving

their overall health and wellness [15][17]. AGA is a dance/training application made for the user to follow an avatar's movements. Sorterius is a waste-sorting application that makes the user find virtual waste.

Language and cultural barriers can minimize the accessibility of exergames across different regions. Exergames typically rely on instructions, prompts, and feedback to guide players [5], which may be challenging for individuals with ID who have various language skills or limited comprehension. Adapting games to different languages and cultures can make exergames more accessible for a wider range of users and encourage more physical activity. For instance, 1.1 shows the waste sorting regulations in Lisbon, Portugal, which is quite different from Norway. Thus, making applications such as Sorterius and AGA available to users in different countries would ensure that people from various locations also can benefit from these motivational physical activity games.


**Figure 1.1:** Waste sorting in Lisbon, Portugal
This picture was taken on my visit to CerciOeiras, a Portuguese organization that provides support to individuals with disabilities

## 1.2 Scope and research problem

It is essential to understand how cultural factors influence the engagement and experience of individuals with ID in exergames to ensure their inclusivity and effectiveness. The main research problem :

**RP: In what ways can we enhance the accessibility of exergame applications for European users with intellectual disabilities?**

The main research problem has been broken down into two smaller sub-problems.

Addressing these cultural factors can contribute to the development of exergames that are engaging and accessible for individuals with ID worldwide. The problem statement for the first sub-research problem:

**SPS1: How do European differences in cultural factors impact the engagement and experience of individuals with intellectual disabilities in exergames?**

By understanding and implementing culturally appropriate design elements, exergames can enhance engagement, experience, and accessibility for individuals with ID, ensuring their wider adoption and impact on physical activity levels among this population. The problem statement for the second sub-research problem:

**SPS2: What design elements in exergames can be culturally suitable and sensitive to individuals with intellectual disabilities from diverse cultural backgrounds?**

## 1.3 Limitations

First, the language barrier might be an issue as the researcher (myself) does not speak any languages other than Norwegian and English. This could restrain communication during interviews and limit the depth of insights obtained from individuals with ID from diverse cultural backgrounds.

Second, recruiting participants, particularly individuals with ID, proved to be challenging in Norway [19] and, therefore, might be an issue in other countries. Communication difficulties and obtaining informed consent could also be major obstacles.

Last, the geographical distance between the researcher and users of the application outside of Norway could present logistical difficulties.

Addressing these limitations will contribute to the development of culturally

appropriate exergames for individuals with ID from diverse cultural backgrounds.

## 1.4 Thesis structure

**Chapter 2: Theoretical Framework** presents the background information relevant to this project.

**Chapter 3: Method** describes the methods used in this project.

**Chapter 4: Requirements** outlines the process of identifying requirements for the project, covering both functional and non-functional aspects.

**Chapter 5: Design & Implementation** presents the design of the applications as well as the implementation described in detail.

**Chapter 6: Tests & Results** describes the various tests carried out and the results.

**Chapter 7: Discussion** discusses the results of this project and suggestions for future work.

**Chapter 8: Conclusion** summarizes the thesis and what has been concluded.

# 2

# Theoretical Framework

## 2.1 Intellectual Disability

Norsk Helseinformatikks (NHI, Norwegian Health Informatics) definition of intellectual disability is a condition with incomplete development understanding, very low intelligence, to a degree to where special service, training, or therapeutic ways are necessary [27]. NHI states that these three definitions can describe ID:

- "Intellectual capacity must be clearly below average"
- "Adaptive behavior is deficient, i.e. reduced independence and social functioning in relation to the relevant age and cultural group"
- "The condition must be present during childhood and adolescence"

### 2.1.1 Different levels of Intellectual Disability

There are two classification systems for ID in the United States: the American Association on Intellectual and Developmental Disabilities (AAIDD) and the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) of the American Psychiatric Association. These systems evaluate ID severity to determine the level of assistance required for optimal personal functioning, using an individual's intelligence quotient (IQ), daily skills, and the specific

classification system employed. The ID is then categorized into one of four types, as illustrated in table 2.1.1 [10].

| **Severity Category and Approximate Percent Distribution of Cases by Severity** | **DSM-IV[1] Criteria (severity levels were based only on IQ categories** | **DSM-5[2] Criteria (severity classified on the basis of daily skills)** | **AAIDD[3] Criteria (severity classified on the basis of the intensity of support needed)** | **SSI[4] Listings Criteria (The SSI listings do not specify severity levels, but indicate different standards for a meeting or equaling listing level severity.)** |
|---|---|---|---|---|
| Mild, 85% | Approximate IQ range 50 – 69 | Can live independently with minimum levels of support. | Intermittent support is needed during transitions or periods of uncertainty. | IQ of 60 through 70 and a physical or other mental impairment imposing an additional and significant limitation of function |
| Moderate, 10% | Approximate IQ range 36 – 49 | Independent living may be achieved with moderate support, such as those available in group homes. | Limited support needed in daily situations. | A valid verbal, performance, or full-scale IQ of 59 or less |
| Severe, 3.5% | Approximate IQ range 20 – 35 | Requires daily assistance with self-care activities and safety supervision. | Extensive support needed for daily activities. | A valid verbal, performance, or full-scale IQ of 59 or less |
| Profound, 1.5% | IQ < 20 | Requires 24-hour care. | Pervasive support needed for every aspect of daily routines. | A valid verbal, performance, or full-scale IQ of 59 or less |

**Table 2.1:** ID Classifications Table. Original title from source: "Classifications of Intellectual Disability Severity" [10]

1. Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition
2. Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
3. American Association on Intellectual and Developmental Disabilities
4. Supplemental Security Income

### Mild Level of Intellectual Disability

Table 2.1.1 illustrates that most individuals diagnosed with ID fall within the mild disability category, with IQ scores ranging from 50 to 69. This group represents approximately 85% of all individuals with intellectual impairments [10]. Those falling under this category experience limitations in their social and daily functioning and their conceptual development [10]. Despite this, they require minimal assistance to live independently and perform essential daily tasks such as eating, washing, dressing, and controlling bodily functions [3].

### Moderate Level of Intellectual Disability

According to Table 2.1.1, individuals with moderate ID can manage their personal care, navigate familiar environments, and acquire basic skills for their well-being and safety. However, they may require assistance to attain a certain degree of independence. As shown in the table above, this need for support is evident.

Adults with moderate ID typically do not live independently, as noted in the ICD-10 by the World Health Organization. Nevertheless, many individuals in this category display social development skills, such as basic communication, participation in social activities, and the ability to form connections with others [3].

### Severe Level of Intellectual Disability

The lower levels of achievement described in the moderate level of ID are often observed in individuals with severe levels of ID as well [3]. These individuals often have motor impairment and other related deficiencies; language and communication difficulties, limited social skills, and adaptive behaviour deficits [3]. Based on these deficiencies, there may be a significant injury or developmental issue with the central nervous system.

Due to the extent of their cognitive and physical limitations, individuals with severe levels of ID may require constant support and supervision to perform daily tasks and activities [10]. They may also face challenges in accessing education, employment, and healthcare services, which can further impede their development and quality of life [10]. However, with appropriate interventions

and support, individuals with severe levels of ID can still make progress and achieve greater levels of independence and engagement in their daily lives. This may involve specialized educational and vocational training, physical and occupational therapy, communication and social skills training, and other forms of individualized support and care [3].

#### Profound Level of Intellectual Disability

Individuals with a significant developmental handicap typically have an IQ below 20, and those with a profound developmental impairment often have severely impaired capacity for both understanding and communicating through spoken language [3]. However, some people with this level of ID might become proficient in basic types of non-verbal communication. Additionally, profound developmental impairments can limit an individual's physical abilities, making it difficult for them to perform basic tasks such as caring for themselves. As a result, ongoing assistance and support are necessary to ensure that their basic needs are met [3].

### 2.1.2 Visual Impairments

For both adults with ID and adults with Down syndrome, the most prevalent physical health conditions differ from the general population. The prevalent physical health conditions for the general population have been reported to be, in order, hypertension, painful condition, asthma, coronary heart disease, irritable bowel, dyspepsia and diabetes [13].

Visual impairment can significantly impact the engagement and experience of individuals with ID in exergames. The most prevalent physical health conditions for this user group are shown in Figure 2.1. Many exergames rely on visual signals, graphics, and visual feedback to guide gameplay and give instructions. Individuals with visual impairments may have a hard time perceiving and interpreting these visual elements. This limits their ability to engage and participate in the game fully and can result in decreased enjoyment and possibly frustration for individuals with ID who have visual impairments.

Additionally, individuals with visual impairments may face challenges in navigating the user interface and understanding the game's instructions and objectives. Visual prompts, such as on-screen text or menu options, may not be accessible or legible for individuals with visual impairments. This can create barriers to participation and hinder their overall experience in exergames.

To address the issue of visual impairment, it is essential to consider inclusive

design principles and provide alternative modes of interaction and feedback in exergames. This may include incorporating audio cues, tactile feedback, or customizable options for text size, contrast, and colour schemes. By making exergames more accessible for individuals with visual impairments, their engagement and enjoyment can be enhanced, ensuring a more inclusive and positive gaming experience for this population.

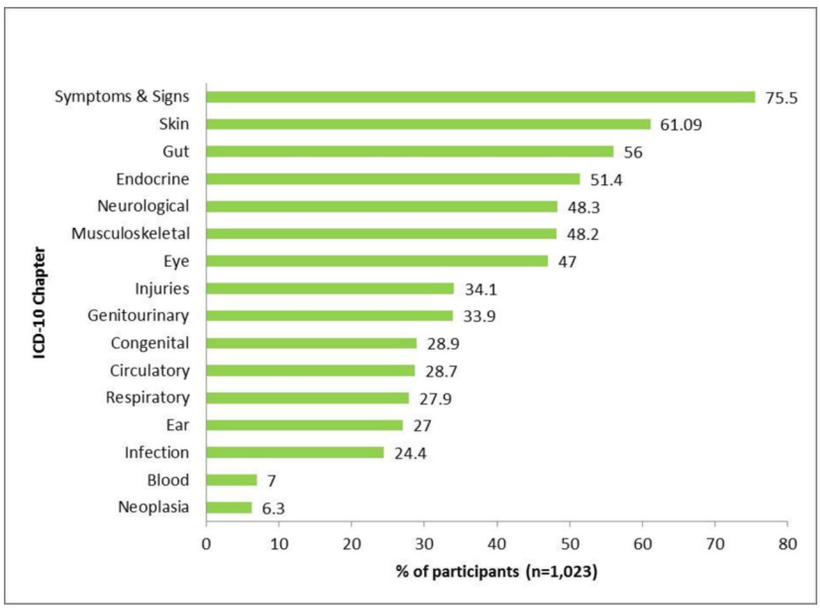



**Figure 2.1:** Visual Impairments - one of the most prevalent physical health conditions of individuals with ID [13]

## 2.2 Serious Games

Many users with impairments struggle with attention deficits, which can be extremely severe and make learning very difficult for them. These challenges can affect various cognitive functions such as memory, reasoning, language, perception, problem-solving, and thinking [6].

Serious games are a type of interactive experience or activity designed with a primary purpose beyond providing pure entertainment [1]. Instead, they are intended to educate, train, inform, or raise awareness about specific subjects, ideas, or skills through game mechanics. These mechanics may include rules, goals, challenges, and rewards, which are used to engage and motivate players. In this way, serious games could facilitate in gaining knowledge, the development of skills, or the exploration of complex concepts in an engaging and interactive manner [1]. Serious games also have the advantage of capturing

and retaining the attention of participants, which can be especially beneficial for individuals with cognitive disorders who struggle with learning. By focusing on the tasks at hand, the severity of their challenges with attention, memory, reasoning, language, perception, problem-solving, and thinking may be reduced [6] [14].

Exergames are a sub-category of *Serious Games* [7] and refer to a type of video game that acquires physical activity from the player to engage in the game. Exercise games are designed to promote physical exercise and improve the overall health and fitness of the player through active participation. Exergames can include activities such as dancing, sports simulations, and virtual reality experiences that require full-body movements or specific muscle groups to be utilized. Essentially, exergames provide an innovative way of combining technology and physical activity to promote a healthier and more active lifestyle [5].

## 2.3 E-health Exergame Mobile Applications

### 2.3.1 Sorterius

Sorterius is a mobile application that combines gaming and physical activity. It was initially created by Magnus Stellander [17] and later improved by Thomas Luzi [19]. Sorterius was initially created in Norwegian, but it has since been implemented as an English prototype [23].

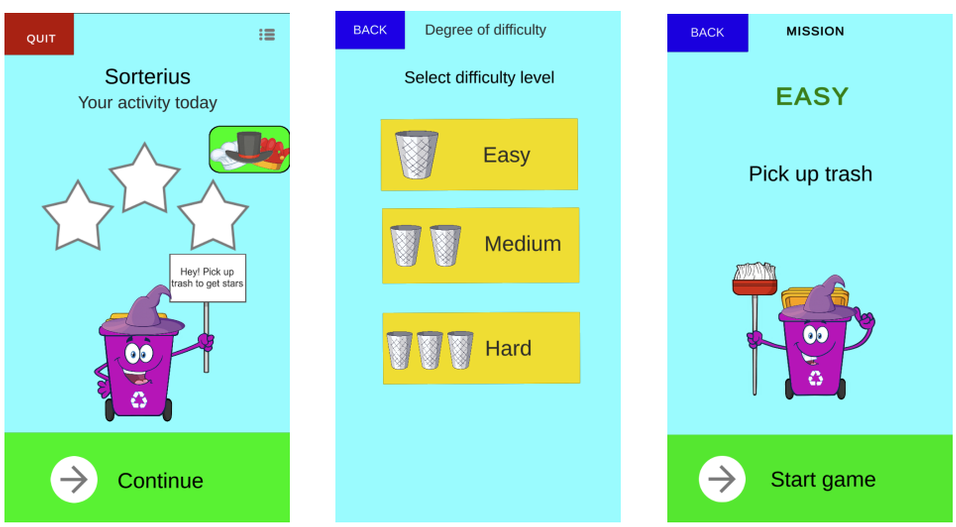
The primary purpose of this software is to encourage and inspire users to engage in physical exercise on a more regular basis. It is customized to meet the requirements of individuals with a range of ID, from mild to moderate levels [17]. The aim is to provide a comprehensive platform that offers guidance and support to help users achieve their fitness goals in a safe and effective way.

#### Storyline

Sorterius is a waste bin that helps the player look for waste; when some waste is found, Sorterius will help sort the waste. The avatar gives instructions to the users, both vocal instructions and sometimes holding up a sign with a written message.

### Gameplay

The start screen will appear when accessing the application, as shown in Figure 2.2a. This screen presents various choices, such as initiating a game, customizing the Sorterius avatar, changing colour or headgear, navigating to the assistant/parent menu, or exiting the app. Furthermore, daily- and weekly game progress can be seen.



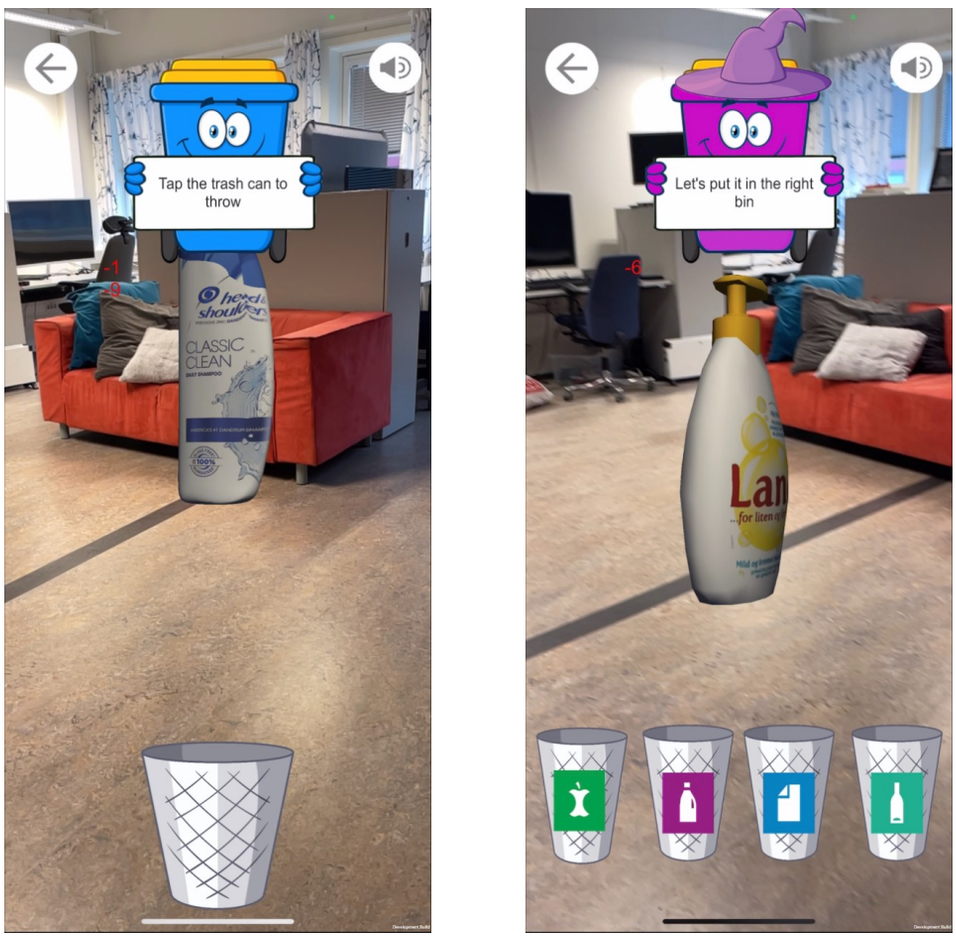

**(a)** Start Screen - the initial screen when Sorterius starts

**(b)** Sorterius Choose Difficulty Screen

**(c)** Sorterius Easy Game Screen

**Figure 2.2:** Screenshots of the Sorterius Gameplay

To begin a new game, the user must select a level of difficulty, see Figures 2.2b and 2.2c. There are three levels to choose from easy, medium and hard. The number of waste bins varies depending on the level chosen. The easy level has one waste bin, shown in Firgure 2.3a, where the goal is to gather all waste into the same bin. The medium level has two waste bins, one organic bin and one plastic bin. The hard level has four waste bins, organic-, plastic-, paper- and glass bin, which is shown in Figure 2.3b. The waste is sorted according to national sorting symbols commonly used in Norway for waste sorting [21]. Once a level of difficulty has been chosen, the user can start playing the game. The game uses the smartphone's camera to follow the player's movements. As the player walks, waste objects will appear on the screen. Then the task is to collect the waste and place it in the correct bin.




**(a)** Sorterius Easy Game Screen - Gameplay

**(b)** Sorterius Hard Game Screen - Gameplay

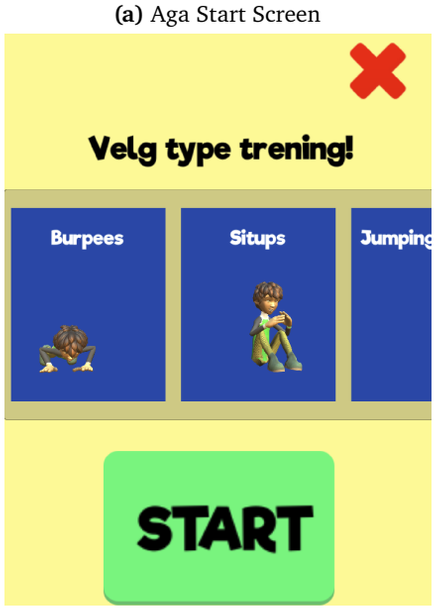
**Figure 2.3:** Screenshots of the Sorterius Gameplay

### 2.3.2 Activity Game Avatar

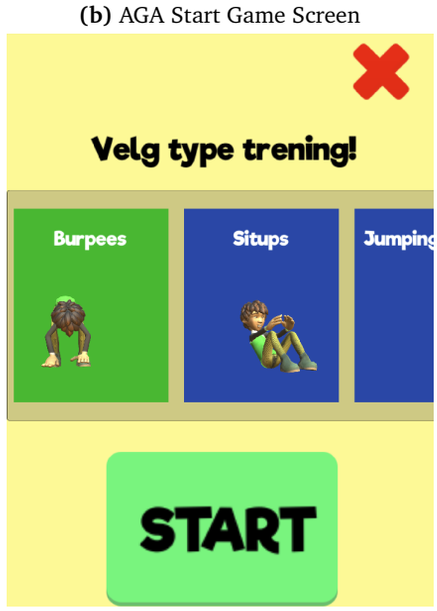
Activity Game Avatar (AGA) is a mobile application created by Marius Wiik that is designed to encourage individuals with ID to engage in physical activity [15]. The app was also further improved by Thomas Eilertsen [16]. The game is user-friendly and provides a fun and interactive way for users to stay active and healthy. Its goal is to promote physical activity and improve the overall well-being of individuals with intellectual disabilities.


**(a)** Aga Start Screen


**(b)** AGA Start Game Screen




**(c)** AGA Game Screen, no activity selected yet




**(d)** AGA Game Screen, when activity selected

**Figure 2.4:** Screenshots of the AGA Gameplay

### Avatar

When opening the application on a smartphone or a tablet, the configured avatar screen will be present, as seen in Figure 2.4a. The avatar should have a name, an age and can be either a boy or a girl. Furthermore, the user can

choose between different hair and clothes for the avatar, such as hair colour, pants, shirts and shoes. After customizing the avatar, the game will send the user to the main screen. This screen consists of the logo, the avatar already made, and two buttons, one going back to the customization menu and one button to start the game.

#### Workout

Once a game has started, the user will be sent to the game start menu Figure 2.4b. where they will be able to see how many stars have been collected, go to the settings menu, start a workout and turn off the sound. When starting a workout, Figure 2.4c, the user can choose between six different workouts; burpees, sit-ups, jumping jacks, the chicken dance, squats and samba. Once a workout is selected, Figure 2.4d, the avatar will start instructing. The user will then have, by default, 30 seconds to do the workout, and a suited song is played. During the workout, the user can see the count up to 30 and also be able to stop the workout. When finished, the user gets a star and 30 points. After collecting enough points, the avatar gets a pet with them within the game; these are shown on the main screen.

#### Settings Menu

The settings menu has the options to go into settings, see the number of points the user has collected, see a leaderboard, get tips & help, and go back to the main menu, where the character can be customized. Within the settings, the user has the ability to establish the duration of their workout as well as the pace at which the avatar will dance or exercise.

### 2.3.3 Game Engine

The applications have been developed using the Unity gaming platform, which is known for its versatility and ability to support game development across different devices, such as personal computers, mobile phones, and gaming consoles. Unity is equipped with scripting languages such as C# and C++, widely used within the gaming industry for game development purposes [32].

## 2.4 MOVE-IT

Individuals with intellectual disabilities tend to lead more inactive lives compared to the general population. Engaging in regular moderate-intensity physical exercise has been proven to reduce the risk of cardiovascular disease and improve one's daily functioning abilities [24]. Exergames were initially created to promote physical activity, but most of these games are not suitable for individuals with ID. Moreover, those responsible for assisting such individuals, including staff and relatives, often lack the necessary knowledge and skills to encourage the use of exergames [24].

MOVE-IT is a program that was created to encourage the use of exergaming among individuals with mild to moderate intellectual disabilities, using innovative information and communication technologies (ICT) [24].

The MOVE-IT team is based on skilled professionals from various fields, coming from different organizations worldwide:

- CerciOeiras [5]
- The Arctic University of Norway [6]
- Universitat Politècnica de València [7]
- Ospedale Riabilitativo di Alta Specializzazione [8]
- Istituto per la vigilanza sulle assicurazioni [9]

5. https://www.cercioeiras.pt/pt
6. https://www.uit.no
7. https://www.upv.es/en
8. https://www.ospedalemotta.it/it/
9. https://www.ivass.it/homepage/index.html

# 3

# Method

The methods chapter is essential to this thesis as it describes the research design, procedures, and techniques used to collect and analyze the data found. This chapter provides a comprehensive explanation of the methodology utilized to address this study's research questions and objectives.

Figure 3.1 is an outline of the progress of my research for this project, including the methods and months that occurred. The green sections present the year 2022, with each specific month indicated on the dotted line in the center of each section. The blue sections represent all the work completed to date in the current year, 2023. This timeline is intended to give a clear overview of the project's progress, helping readers gain a better understanding of the work that has been accomplished.

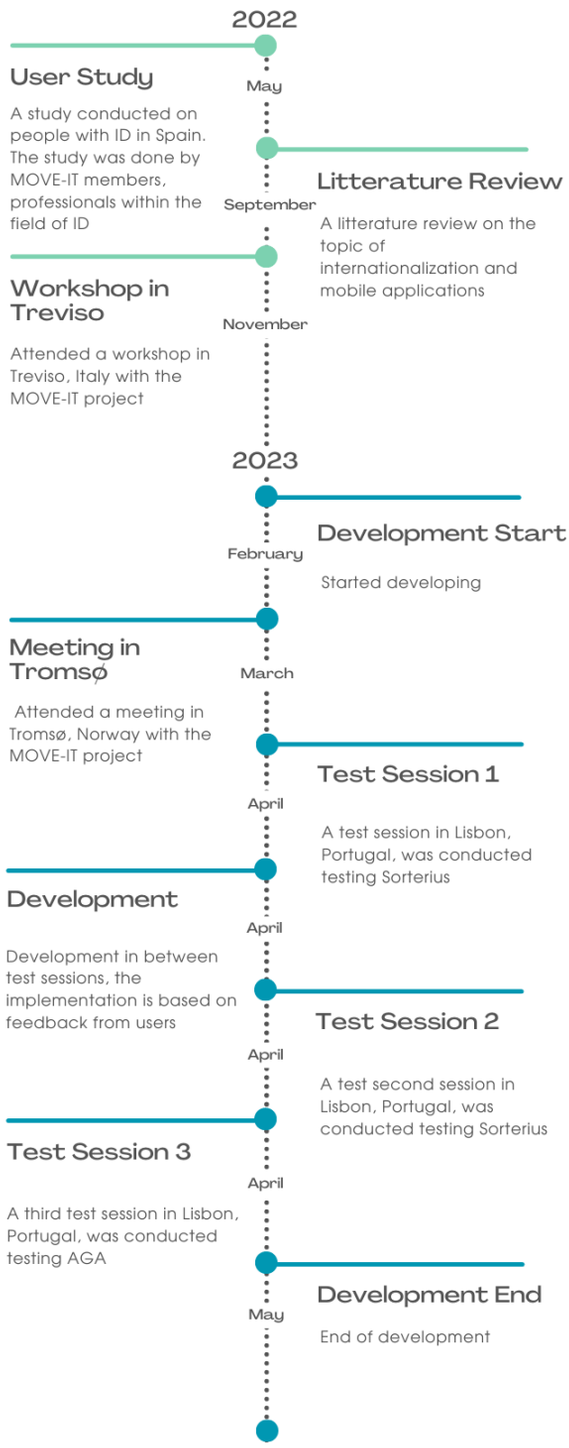



**Figure 3.1:** A timeline outlining the progress of this master thesis project.

## 3.1 Literature Review

The initial literature review conducted for another project, the Capstone Project [23], focused on the topic of internationalization and mobile applications. The following search only gave one relevant result titled 'Improving pocket paint usability via material design compliance and internationalization & localization support on application level' [12]. The search query used:

```
(internationalization OR internationalization OR i18n )
AND
("mobile application" OR "mobile app" OR "iPhone application"
OR "iPhone app" OR "android application" OR "android app" OR
m?health OR e?health OR "software application" OR "software app" )
```

While the one resulting article provided useful insights into improving the usability of pocket paint through material design, internationalization and localization support, it was clear that further research was necessary to find due to the limited scope of the initial literature review. Therefore, additional data collection and analysis were started on to gain a better understanding of the subject matter.

## 3.2 MOVE-IT

The MOVE-IT project was initiated with the aim of improving the knowledge of caretakers for individuals with ID. As part of the project, a study was conducted involving individuals with mild or moderate ID [24]. The study included a participatory health informatics approach to investigate their ideas, preferences, and attitudes toward supporting digital health solutions that aid their health management. The ultimate goal of the study is to promote physical activity among individuals with ID.

### 3.2.1 Workshop - Treviso

I attended a workshop in Treviso, Italy, held by MOVE-IT in November 2022. During the workshop, an already conducted user test of Sorterius and AGA was presented. The test began in May 2022 and had been managed by members of the MOVE-IT project. The user test is further explained in Section 3.3. Additionally, in the workshop, I had the opportunity to present an English prototype of Sorterius developed in the Capstone Project [23].

#### English Prototype of Sorterius

At the meeting, I presented the prototype of the English version of Sorterius. Twelve attendees from various backgrounds were at the meeting, including psychomotor specialists, neuropsychologists, physiotherapists, and technology experts. Each of them tested the application, and as an active attendee at the meeting, I presented the application before the testing. After, we discussed different scenarios, which led to valuable feedback being provided. The meeting was productive, with professionals sharing their insights and recommendations on Sorterius. Based on the testing and also the feedback from a diverse group of professionals, we came to a consensus that the English prototype of Sorterius is well-suited for international use. Some of the requirements for making Sorterius multi-language are based on this workshop and are stated in Chapter 4.

### 3.2.2 Meeting - Tromsø

MOVE-IT hosted a meeting in early March at UiT, the Arctic University of Norway in Tromsø. Since the development process had started, I presented the current functionalities of Sorterius and AGA in the meeting, as well as the upcoming plans for the implementation. After presenting both applications, the new implementations of Sorterius were tested, and further improvements were discussed in the meeting with the participants. New (in progress) features for Sorterius were:

- dynamically changeable text
- dynamically changeable audio

These features are further explained in Chapter 5.

During the recent MOVE-IT meetings, Ana, Duarte and Mafalda were introduced and invited to their institution, CerciOeiras, in Lisbon, Portugal. They are Psychomotor specialists at CerciOeiras. In addition, they have knowledge and expertise in the field of individuals with ID.

### 3.2.3 CerciOeiras

CerciOeiras is a non-profit organization based in Portugal that provides support to individuals with disabilities and their families. The organization was founded in 1976 with the aim of providing a wide range of services to the community [22]. Examples of these services include education, vocational training, and

social integration programs. Over the years, the organization has been dedicated to helping individuals to acquire the skills and knowledge necessary to achieve their goals and live fulfilled lives. Through their various programs, the organization has empowered countless people to overcome barriers to success and become productive members of society [22].

Their main objective is to encourage and enable individuals with disabilities to attain their full potential by offering them the essential resources and support for their personal, social, and professional growth [22].

The timing of the visit to CerciOeiras and the methods for user testing was agreed upon during the last meeting in Tromsø. Subsequent planning and coordination were done using communication channels such as Teams and email.

## 3.3 Requirement forms based on user tests by MOVE-IT members

In the MOVE-IT workshop in Treviso, I attended in November 2022, I was presented with a user test that multiple members of the MOVE-IT project had already conducted in May of the same year. The user test was on several mHealth applications, including Sorterius and AGA. The test sessions were held in Spain and involved two different groups of participants: professionals and individuals with ID. To ensure that all participants had equal access to the applications, they were provided with printed images of the game views and detailed instructions on how to play [28].

The testing was divided into four sessions, with the first session taking place on May 5th, 2022. Each session was hosted by two institutions that offer a range of services to individuals with ID and were staffed by multidisciplinary teams, including social workers, psychologists, speech therapists, and physical therapists.

This testing aimed to assess the usability and effectiveness of the Sorterius app for individuals with ID. By involving a diverse group of participants and conducting the test sessions in a controlled environment, researchers were able to gather valuable insights into how the app can be tailored to meet the needs of different users. Overall, the sessions has been a success and provided important data to inform future app development and accessibility efforts.

Requirements for users in the user testing [28]:

- be an adult (18+ years)
- live in Valencia
- use the services in the occupational center
- the degree of intellectual disability should be from mild to moderate
- be able to comprehend the verbal Spanish language

Requirements for professionals in the user testing [28]:

- be an adult (18+ years)
- having at least a year of experience in caregiving for individuals with ID.
- be able to comprehend the verbal Spanish language

Throughout the sessions, users gave their feedback on Sorterius and AGA. Their requirements for improving the application according to their needs, experiences and challenges encountered during the test session were discussed. The research team performed an iterative methodology to interpret the data by coming to a consensus on which comments were relevant for further developing the application. All comments were looked through carefully and put into a requirement form. The requirements are categorized below as general, functional, and motivational.

### General functionalities

These are the basic requirements or functionalities they identified during the user test sessions.

| **Requirement type** | **Requirement** |
|---|---|
| Design | Reduce the number of screens |
| Design | Use a consistent design |
| Design | Avoid the use of a hidden menu |
| Design | Include a main screen that presents links to all functions (accessible links) |
| Design | Show clearly described the overall objective and objectives specific for each activity (ensure that users understand them) |
| Design | Included on the main screen |

| | |
|---|---|
| Design | Use pictograms and texts |
| Design | Include brief audio descriptions of the tasks |
| Design | Show the previous activities done by the user |
| Functional | Include the story in which the digital solution is based on to users through audio narratives |
| Functional | Include a simple planner to support users in the time management |
| Functional | Include an accessible historical function |
| Functional | Limit (or avoid) to include tasks in which users have to manage their effort |
| Functional | Include emotion management functionality |
| Functional | Include both outdoor and indoor activities |
| Functional | Reminders should be optional and configurable (or avoid them) |
| Functional | Develop an independent platform to configure the digital solution and adapt it to the user´s specific needs and abilities |

**Table 3.1:** General functionalities - MOVE-IT

### Social functionalities

The applications' social functionalities focus on how the communication with friends and family members are through the application and also how social networks can help users find motivation. Below are some suggestions for social functionalities made by users during this user test:

| **Requirement type** | **Requirement** |
|---|---|
| Design | Include short motivational messages designed by friends or relatives including their names |
| Design | Include leader boards based on number of steps |
| Functional | Provide information regarding PA events |
| Functional | Include motivational messages designed by friends or relatives |
| Functional | Include a classification based on PA data with real users |
| Functional | Promote collaborative activities and objectives (family and friends) |

| | |
|---|---|
| Functional | Develop a second app that provides feedback to familiy members / friends and that allows them to send a personalized message to users |

**Table 3.2:** Social functionalities - MOVE-IT

### Motivational functionalities

These functionalities can be features developed to use the applications more often. The following are some suggestions made by users during this user test:

| **Requirement type** | **Requirement** |
|---|---|
| Design | Reduce the number of screens |
| Design | Include short messages regarding the benefits of PA |
| Design | Use user´s name or username in the motivational messages |
| Design | Show the PA feedback with the number of steps (not time) |
| Design | Include points as a reward system |
| Design | Define activities as missions |
| Design | Include the possibility to unlock activities when the user reaches a goal |
| Design | Show challenges similar to the main PA |
| Design | Include the option that proposed challenges could be rejected by the user |
| Design | Categorization of the challenges based on their level of difficulty |
| Design | Present a short list of challenges allowing the user to select which one he /she wants to perform |
| Functional | Include information regarding the benefits of PA |
| Functional | Use "user targeting" technique of personalization |
| Functional | Provide feedback on PA data, both during and after the session |
| Functional | Include a well-defined strategy of points (objectives and activities) |
| Functional | Define a strategy to present locked activities |
| Functional | Include challenges adapted to their abilities |

**Table 3.3:** Motivational functionalities - MOVE-IT

During the presentation of this user test in the MOVE-IT seminar in Treviso, we discussed the requirements and possible areas of improvement in Sorterius and AGA to improve their accessibility. We then discussed the feasibility of these features. Some of these features were found relevant for this project and can be found in Chapter 4.

## 3.4 User Testing in Portugal

CerciOeiras operates in the municipality of Oeiras, located in the Lisbon district of Portugal. Their organization has an impact on providing inclusivity in Portugal by providing support to individuals with disabilities, where they have both residents and a daycare center.

My curiosity drove me to travel from Norway to Portugal to dive further into my research question: *In what ways can we enhance the accessibility of exergame applications for European users with intellectual disabilities?* and explore what cultural differences of exergames, such as Sorteius and AGA, could be. I was eager to understand better how these exergames are received from a user's perspective in a culture other than Norway. To achieve this, the applications were tested by several individuals within the user group. The test result and evaluation are described in detail in Chapter 6.

### 3.4.1 Handle Protected Data

After being invited to Lisbon to CerciOeiras, the process of preparing for the test session started. A few steps had to be ensured so the project was in compliance with regulations. The first step was reaching out to the Regional Committee for Medical and Healthcare Research Ethics (REK) by phone, and they informed me the request was not relevant to the project and, thus, an application to REK was unnecessary. Second, a call to SIKT was made to see if the project met their criteria. SIKT is the Norwegian Agency for Shared Services in Education and Research [29]. Since there are different regulations between Norway and Portugal, there was uncertainty about the requirements for this project. After talking with an agency that handles data protection questions, the con-

clusion was to fill in an application to SIKT. Later, an application with SIKT was submitted and further approved.

### 3.4.2 Insights from an expert

In a recent interaction, a psychologist, Henriette Michalsen, was consulted. Henriette specializes in investigating physical activity patterns among individuals with ID, and she has gained expertise in using technology to improve her research in this field. A meeting was arranged with her to gather her insights on testing mobile health applications for individuals with ID. Her experience in this area makes her a valuable resource for this purpose. Henriette also assisted in creating interview guides and offered insights for conducting the actual testing.

### 3.4.3 Interview Guides

Before testing, interview guides were created. These guides are based on the System Usability Scale(SUS) and questions regarding waste sorting in Sorterius.

#### System Usability Scale

The SUS is a helpful tool used to evaluate the perceived usability of a system through a questionnaire [2]. John Brooke, the author of "SUS - A quick and dirty usability scale" developed this tool, which has become a very standard measure of usability for evaluating systems [2]. The SUS consists of ten statements rated on a five-point Likert scale. The statements ask users to rate their agreement with statements such as:

- "I think that I would like to use this system frequently"
- "I found the system unnecessarily complex"

The scores for each question are added up and converted into a score out of 100, known as the SUS score [2]. The SUS score is calculated by adding up all the scores from each statement and multiplying it by 2.5, and then dividing it by the number of users included in the test. The score from each question is calculated by subtracting one from the value of every odd-numbered statement and subtracting the value of each even-numbered statement from the number five. One is the lowest value a statement can have, and five is the highest. SUS is an effective tool for evaluating the usability of a system. Instead of focusing on

specific usability problems, SUS focuses on the users' perception of the system [2]. The SUS calculations are further explained in Chapter 6.

Due to testing the application in Lisbon, the SUS questionnaire had to be translated into Portuguese. Sometimes, using SUS in a language other than English can lead to misunderstandings. It has been found through research that non-native English speakers may struggle with comprehending the precise meaning of the word "cumbersome" [9]. This issue could potentially impact their overall score.

### Waste Sorting

In the second part of the interview guides, Sorterius was discussed in relation to how its icons could impact users culturally. The goal was to dive further into sub-problem statement 2: *What design elements in exergames can be culturally suitable and sensitive to individuals with intellectual disabilities from diverse cultural backgrounds?*, this to determine whether some users would find it more engaging to have familiar and recognizable icons.


**(a)** Paper waste in Portugal **(b)** Plastic waste in Portugal

**Figure 3.2:** Wastebins items on waste bins in the streets of Lisbon, Portugal These pictures was taken during my visit to Lisbon for this user test.

The following questions were asked of the users:

1. Did you think it was fun sorting the garbage items in Sorterius?

2. Did you think the game would have been more interesting if there were more familiar garbage items?

The full interview sheets can be found in Appendix 8.

Figure 3.2 shows the different colours of waste bins that they use in Portugal. And Figure 3.3 shows the different items used to explain what goes in the waste bins.

**Figure 3.3:** Waste bins in the streets of Lisbon, Portugal

### 3.4.4 Observation

Testing Sorterius and AGA with individuals with ID required careful observation of their interaction with the game. The key observations considered during the testing:

- **Usability:** Is the user able to easily maneuver through the interface and complete the tasks in the game? Such as looking into font size, colour contrast, and where the button is placed were also observed.

- **Language Support:** Does the user understand and engage with the game in their languages? Language-related problems like inaccurate translations were also looked into.

- **Engagement:** Is the player showing interest and enthusiasm in the game? Are they willing to keep playing, or do they get bored easily?

- **Comprehension:** Are the game mechanics and objectives comprehensible to the player? Are the instructions straightforward and easy to comprehend?

- **Motor skills:** Does the game pose a challenge to the user's motor skills? Additionally, are the controls user-friendly and intuitive?

- **Accessibility:** Is it easy for the user to navigate through the game menus and options?

- **Enjoyment:** Is the player enjoying the game and feeling motivated to keep playing and enhance their skills?

- **Localization:** Does the player understand the country-specific objects? Such as waste sorting icons and also waste objects specific to Norway.

### 3.4.5 Test Sessions

During the testing phase, six individuals who were unknown to both Sorterius and AGA tested both applications and gave feedback. This allowed for a thorough evaluation of the applications from a user perspective. The testing phase was divided into three sessions, split into multiple days. Sessions one and two included testing Sorterius, and session three included testing AGA. After gathering feedback from users at a session, in between sessions, I worked on developing features that the participants requested.

For testing Sorterius, CerciOeiras has an impressive outdoor area, which proved to be an ideal setting when walking around looking for virtual-waste. The weather was pleasant throughout my visit to the institution, this allowed for us to conduct the testing both indoors and outdoors. Before testing, all participants were given information about this project and what Sorterius was all about. Due to the challenge of different languages, all information was given

in Portuguese by the employees at CerciOeiras. At first testing Sorterius, one of the participants got an iPhone and started the application. Some instructions about the different levels were given. After that, no instructions were given to see their interaction with the game. Further, more participants got to test the application. AGA was tested with multiple users at the same time. They were all given instructions on how the gameplay in AGA worked before starting.

After the tests, the users answered the SUS questionnaires and interview questions. Due to most participants not being able to read and myself not speaking Portuguese, the employees read the statements of SUS out loud to the user, and the users gave their answers. The same procedure was done for the interview questions.

## 3.5 Development Tools

### 3.5.1 Software

#### Visual Studio Code

Visual Studio Code, often shortened as VS Code, is a highly popular source code editor developed by Microsoft [34]. VS Code supports a wide range of programming languages and offers tools for code editing, debugging, and version control. It has an intuitive user interface and can integrate with different frameworks and tools. Visual Studio Code has become an indispensable choice for many developers, myself included. The program was used to write and execute C# programming scripts for Sorterius and AGA.

#### Xcode

Xcode is Apple's integrated development environment (IDE) for building applications on macOS, iOS, watchOS, and tvOS. It offers a set of tools for coding, designing user interfaces, debugging, testing, and deploying apps. Xcode's streamlined interface, debugging capabilities, and simulator for testing on various devices make it a useful tool for app development within Apple's ecosystem. [35]. Xcode was used for building the applications on iOS devices.

### 3.5.2 Hardware

#### Development Platform

All development was done using these two platforms:

- Mac Mini (M1, 2020) with Apple's Silicon processor (RISC-architecture) with macOS Ventura 13.3.1 installed
- Mac Book Pro (Intel 2017), with macOS Ventura 13.3.1 installed

#### Mobile Platform

It is important that an application is compatible and usable across multiple devices. That is why these two different iPhone versions, an iPad and an Android, were tested on. This ensures wider accessibility for more users.

- iPhone XR IOS 16.4.1
- iPhone XR IOS 16.4.1(a)
- iPad 8th gen. IOS 16.4.1
- Samsung Galaxy S21, One UI version 5.1, Android version 13

# 4

# Requirements

This chapter covers the approaches used to establish requirements, including both functional and non-functional requirements identified for the project.

## 4.1 Defining requirements

This project builds upon the progress achieved in the Capstone project and focuses on developing mobile health applications that are more accessible and user-friendly for individuals with ID, as well as practices and guidelines for designing culturally adapted exergames for people with intellectual disabilities. It is important ensuring that these applications are inclusive and support the diverse needs of all users. This project aims to make healthcare technology more accessible and helps individuals with ID with their health and well-being.

When defining requirements, weekly meetings with supervisors have been very helpful, and meetings with professionals within the field. Also, reviewing relevant literature on ID and user interfaces to ensure accessibility and inclusivity for more users.

The requirements are split into two sections functional requirements and non-functional requirements. Functional requirements of the app detail what it is intended to do, while the non-functional requirements specify the anticipated level of performance [8]. The former outlines the app's specific features

and functions, while the latter defines how well those functions should perform.

## 4.2 Functional Requirements

The Volere Requirements Specification Template is a framework designed to assist in capturing and documenting software requirements in a structured and systematic manner. This thesis uses the template for providing a clear and concise structure for capturing functional requirements. [8]

- Requirement #: Unique identifier
- Description: One sentence stating the requirement intention
- Rationale: An short description of why the requirement is important
- Source: Who raised the requirement?
- Fit-Criterion: A criteria for testing the solution for the requirement
- Priority: The importance of the requirement, measured in low, medium or high
- Dependency: Requirements that are dependent on others to be implemented

The functional requirements are split into two tables, Table 4.2 and 4.2, one with requirements for Sorterius and one with requirements for AGA. Each requirement is based on one of the problem statements described in Chapter 1. In both the requirements table, the problem statements connected to a specific requirement are presented in the PS column.

### Sorterius

**Table 4.1:** Functional Requirements Sorterius

| # | Desription | Rationale | Source | Fit Criterion | Priority | PS [1] |
|---|---|---|---|---|---|---|
| 1 | The application should support Spanish-speaking users. | Providing the Spanish language is essential to meeting users' needs in Spain. | MOVE-IT workshop in Treviso | A Spanish user should be able to understand everything within the application. | High | PS |
| 2 | The application should support Portuguese-speaking users. | Providing the Portuguese language is essential to meeting users' needs in Portugal. | MOVE-IT workshop in Treviso | A Portuguese user should be able to understand everything within the application. | High | PS |
| 3 | The application should support Italian-speaking users. | Providing the Italian language is essential to meeting users' needs in Italy. | MOVE-IT workshop in Treviso | An Italian user should be able to understand everything within the application. | High | PS |
| 4 | The application should display garbage sorting icons recognizable from what they use in Spain when the language Spanish is selected. | Providing Spanish garbage sorting icons could be important for creating a positive user experience and building interest with users in Spain. | Author, advisors | An Spanish user should be able to recognize, based on the waste sorting icon, each type of waste bin within the application. | Low | SPS2 |

1. Problem Statement. Can be found in Chapter 1

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | The application should display garbage sorting icons recognizable from what they use in Portugal when the language Portuguese is selected. | Providing Portuguese garbage sorting icons could be important for creating a positive user experience and building interest with users in Portugal. | Author, advisors | An Portuguese user should be able to recognize, based on the waste sorting icon, each type of waste bin within the application. | Low | SPS2 |
| 6 | The application should display garbage sorting icons recognizable from what they use in Italy when the language Italian is selected. | Providing Italian garbage sorting icons could be important for creating a positive user experience and building interest with users in Italy. | Author, advisors | An Italian user should be able to recognize, based on the waste sorting icon, each type of waste bin within the application. | Low | SPS2 |
| 7 | The application should display garbage sorting recognizable from what they use in Norway when the language Norwegian is selected. | Providing Norwegian garbage sorting icons could be important for creating a positive user experience and building interest with users in Norway. | Author, advisors | An Norwegian user should be able to recognize, based on the waste sorting icon, each type of waste bin within the application. | Low | SPS2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8 | The application should display the right colour of the garbage bins used in Spain when the Spanish language is selected. | Providing the same colours for waste bins that are used in Spain could be important for creating a positive user experience and building interest with users in Spain. | Author | An Spanish user should be able to recognize, based on the waste bin colour, each type of waste bin within the application. | Low | SPS2 |
| 9 | The application should display the right colour of the garbage bins used in Portugal when the Portuguese language is selected. | Providing the same colours for waste bins that are used in Portugal could be important for creating a positive user experience and building interest with users in Portugal. | Author | An Portuguese user should be able to recognize, based on the waste bin colour, each type of waste bin within the application. | Low | SPS2 |
| 10 | The application should display the right colour of the garbage bins used in Italy when the Italian language is selected. | Providing the same colours for waste bins that are used in Italy could be important for creating a positive user experience and building interest with users in Italy. | Author | An Italian user should be able to recognize, based on the waste bin colour, each type of waste bin within the application. | Low | SPS2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | The application should display the right colour of the garbage bins used in Norway when the Norwegian language is selected. | Providing the same colours for waste bins that are used in Norway could be important for creating a positive user experience and building interest with users in Norway. | Author | An Norwegian user should be able to recognize, based on the waste bin colour, each type of waste bin within the application. | Low | SPS2 |
| 12 | The application should allow users to switch between different language options during the game. | For users who wish to use the app in various languages, the ability to switch languages is a crucial feature. Therefore, language switching should be a significant factor to consider for making the app multilanguage. | Author | Users change between languages dynamically during runtime. | High | PS |
| 13 | The application should be correctly translated. | The user should have the language in the application in their language, not Brazilian Portuguese, for instance. | Author | A Portuguese user should be able to understand everything within the application. | Medium | PS |

### Activity Game Avatar (AGA)

**Table 4.2:** Functional Requirements AGA

| # | Desription | Rationale | Source | Fit Criterion | Priority | PS |
|---|---|---|---|---|---|---|
| 1 | The application should support Spanish-speaking users. | Providing the Spanish language is essential to meeting users' needs in Spain. | MOVE-IT workshop in Treviso | A Spanish user should be able to understand everything within the application. | High | PS |
| 2 | The application should support Portuguese-speaking users. | Providing the Portuguese language is essential to meeting users' needs in Portugal. | MOVE-IT workshop in Treviso | A Portuguese user should be able to understand everything within the application. | High | PS |
| 3 | The application should support Italian-speaking users. | Providing the Italian language is essential to meeting users' needs in Italy. | MOVE-IT workshop in Treviso | An Italian user should be able to understand everything within the application. | High | PS |
| 4 | The application should give the user the option to set their preferred language at the initialization of the game. | In the initialization of the game, the user should be able to set their preferred language. | Author | When initializing the application, the user should be able to set their preferred language. | Medium | PS |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | The application should allow users to switch between different language options during the game. | For users who wish to use the app in various languages, the ability to switch languages is a crucial feature. Therefore, language switching should be a significant factor in making the app multilanguage. | Author | Users change between languages dynamically during runtime. | High | PS |
| 6 | The application should use pictograms and texts to explain the game content. | Users who cannot read should and wish to use the application should have the ability to do so | MOVE-IT user test in Spain | A user that cannot read should be able to start a game | Medium | PS |
| 7 | Reduce the number of screens | The user should not need to go through numerous of screens to get to the gameplay. | MOVE-IT user test in Spain | A user should quickly be able to start e game. | Medium | PS |

### 4.2.1 Non-functional requirements

#### User Interface (UI)

The UI should be easy to comprehend for individuals with varying levels of ID [17]. The game's interface should be designed in such a way that it is convenient and easy to understand for users. The navigation system should be straightforward and intuitive, allowing players to move through the game without

encountering any difficulties or confusion. It is essential to make sure that the players can easily access all the necessary functions and features without having to spend a lot of time searching for them. In short, the game's interface should be user-friendly and well-organized, providing a smooth and enjoyable experience for all players.

### Safety

It's crucial that the application is designed with safety in mind for players who are exploring the game world and searching for objects. It's important that the game doesn't put users in any physical danger.

### Maintainability

It's important to ensure that any modification or new functionality added to the application can be maintained and further approved by future developers, even after the end of this project. This means that the implementation should be done in a way that is easy to manage and build upon in the future.

# 5

# Design & Implementation

## 5.1 Design

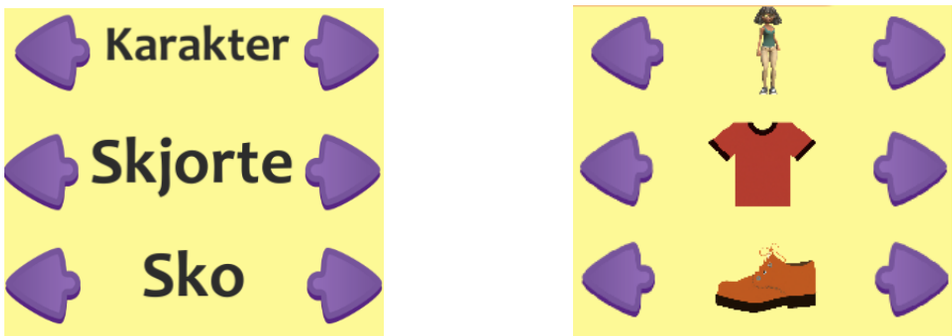
### 5.1.1 Pictograms and Text Integration

We have implemented a design modification in AGA that aims to improve comprehensibility for users with varying language abilities. This modification involves the careful selection and integration of pictograms alongside text in the game's interface. The pictograms represent key actions, instructions, and concepts to provide a visual cue that helps users navigate the game, regardless of their language proficiency. Additionally, the use of pictograms complements textual information to help to understand and improve clarity within the game. By combining text and pictograms, instructions and prompts become easily comprehensible, facilitating engagement and participation.


**Figure 5.1:** AGA Game Points Menu

Figure 5.1 shows the pets in the game and their resembling points. Originally

the points were described using text, such as 'cat.' The pictograms are created based on the game objects that were originally used in the AGA.




**(a)** Customization menu with text for describing

**(b)** Customization menu using pictogram for describing

**Figure 5.2:** AGA - Avatar Customization Menu

[1]

Figure 5.2 shows the modification of the avatar customization menu. Figure 5.2a presents the original solution with text, and Figure 5.2b shows the current solution, where the text is changed with pictograms. The avatar pictogram is created based on the game object of an avatar that is originally used in the game.

### 5.1.2 Start Menu Redesign

The start menu of AGA got a redesign to ensure a localized user experience. The start menu has been updated to include a language selection option that makes it easier for users to choose their preferred language for the game. This improvement helps users with different language preferences, ensuring better language support and increased accessibility. The redesign also included the use of colour schemes and graphical elements that align with the game's theme and purpose, see Figure 5.3.

### 5.1.3 Language Menu

Sorterius has a parent/assistant menu. Sorterius incorporates a language menu with flags located at the top of the screen, giving users an intuitive way to select their preferred language. Figure 5.4 shows the flags for the specific coun-

1. DALL E used to generate pictograms https://labs.openai.com/


**Figure 5.3:** AGA Start Menu.

tries[2].

**Figure 5.4:** Flags used for localization.

Users can choose their preferred language from a menu that shows flags representing each language. Flags are universally recognized symbols that make language selection easy and intuitive for users. Figure 5.5 shows that the language menu is placed at the top of the screen for good accessibility to users.

### 5.1.4 Screen Reduction

In order to improve the user experience by simplifying the interface, fewer screens were implemented in AGA. We made the interface cleaner and more focused by removing unnecessary elements. This simplification makes it easy for users to navigate the game with clarity. To minimize user effort and cognitive load, we consolidated information that was previously scattered across multiple screens into a single, comprehensive view. This makes it easier for users to get

2. https://flagdownload.com/

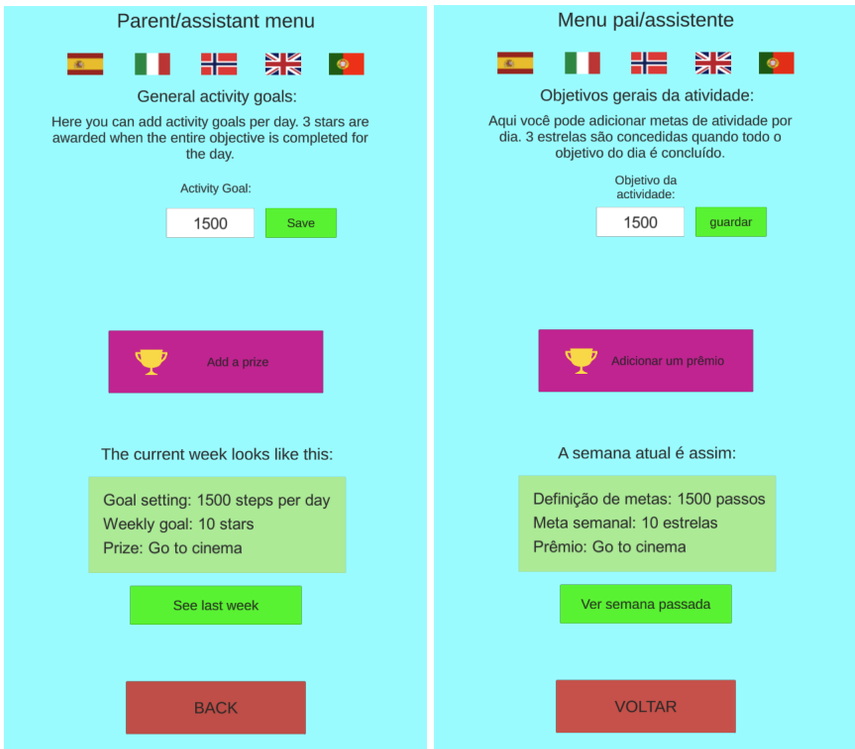



**Figure 5.5:** Sorterius language menu in English and Portuguese.

the information they need.

## 5.2 Implementation

The localization handler script, developed in C#, provides dynamically changeable text and audio localization capabilities for Unity-based games. When used in a Unity-based game, the script can switch between different languages at run-time. It manages the association between the text translations and the corresponding audio files. The script loads the appropriate audio file based on the selected language. Additionally, the script handles the localization of text-based elements, such as UI labels, dialogues, menus, and in-game text. It retrieves the correct translations for these elements, ensuring that the game's text content is also localized and accurate. However, the audio files need to be pre-generated to fit the criteria of the script. By using pre-generated audio files, the localization handler script presents a universal solution for providing dynamic and customizable audio and text localization in Unity-based games.

Within the Unity game engine, the default text component that comes with

Unity, known as the built-in text component (UI.Text), was converted into TextMeshPro components.

### TextMesh Pro

TextMesh Pro (TMPro) is a third-party package/asset for Unity that has advanced text rendering and styling capabilities [30]. It is designed to enhance the default Unity text component (UI.Text) by offering improved visual quality, text formatting and layout control, rich text support, and additional features. TMPro has several advantages compared to the built-in text component, such as better text clarity, flexible text styling options, support for custom fonts, and efficient text rendering performance. It is widely used in Unity game development to create including UI labels, dialogues, subtitles and in-game messages.

By replacing these built-in text components with TextMeshPro components, the game benefits from more flexibility in customizing the appearance of text elements. For instance, the text components of TMPro can be found by either a tag or by its component name. This could not have been done by using the UI.text components already implemented in a Unity game.

Also, by using the `gameObject.GetComponent<TextMeshPro>()` method, the script interacts with TMPro components to show the localized text within the game. This allows for localizing various text-based elements. Moreover, the script makes it easier to localize audio resources, like voiceovers or text-to-speech pre-generated files, by linking them with particular language translations. By dynamically switching between languages at run-time, the localization handler script ensures localization of the Unity-based game it is configured to.

However, there are a few small tweaks that are needed to be done before initializing the script. First, the names of a TMPro component will be the component key and will need to be listed within the script used within that scene (unless the use of a *DoNotDestroyOnLoad* [31]. Other rules apply to that) that will be utilized. Second, the filenames of the audio files will need to be the same as the keys. The translated text and audio filenames are all gathered in a text file, and it is currently configured to use CSV files.

### Comma-Separated Values (CSV)

CSV files are written in a plain-text file format that is used to store tabular data, such as databases/spreadsheets. It is a simple and widely supported format for displaying data that is structured in a human-readable form [4]. In such

a file, every line normally represents a row of data, and the values within the row are separated by, for instance, commas/semicolons/tabs. The first line of a CSV file often contains the names of the columns, which are used to identify the data in each field of the subsequent rows.

All decisions regarding text and audio are further discussed in Chapter 7.

### Sorterius

Using the localization handler script within Sorterius improves user accessibility for use by others than only Norwegian-speaking users this by implementing dynamically changeable audio and text localization. The script is integrated within the game and enables users to choose the language they want through a settings menu. Once a language is chosen, the script handles the loading of the appropriate localization assets, including pre-generated audio files and text translations. In Sorterius, the audio files used are pre-generated text-to-speech (TTS) MP3 files. During gameplay, the script dynamically manages audio playback, ensuring the correct audio clips associated with the selected language are played. It also handles the localization of text-based elements by updating them to show the correct translations.

The data is structured in a CSV file presenting the columns by a key and the languages that are to be used in the game. See Table 5.1.

**Table 5.1:** Data structured in text-file

| key | audio | en | no | pt |
|---|---|---|---|---|
| quitButton | 0 | quit | avslutt | desisti |

### Activity Game Avatar

The implementation of the localization handler script in AGA does only rely on dynamic text localization. This is due to the application not containing any audio except for music that is not needed to be translated. By integrating the script into the application, users can choose their preferred language through a language selection feature. When initializing the game, the user is asked to select their preferred language. During application usage, the script updates and displays the relevant translations for UI labels, menus, dialogues, and any other text-based content.

# 6

# Tests & Results

This chapter introduces the evaluation from the test sessions, the test results from interviews of individuals with ID, and the final score of the System Usability Scale of both Sorterius and AGA.

## 6.1 Test Sessions in Portugal

The tests wer conducted at CerciOeiras in Lisbon, Portugal in April 2023.

### 6.1.1 Participants

A group of five individuals with ID evaluated the functionality and usability of all the applications. Most of the participants had prior experience with smartphones and/or tablets. Among the group, four out of five participants could not read. Three individuals lived with their respective families in Lisbon, Portugal, and only visited the CerciOeiras center during the day, while the remaining two resided within the facility itself.

### 6.1.2 Devices

The tests were done on IOS devices. The reason for this was due to the test being conducted in Portugal. Due to the development in between testing in Portugal, a MacBook Pro was used. In order to make the development and build process quick and easy, because of the limited time spent in Portugal, we decided only to make a build compatible with iOS applications since we had enough iOS devices for testing with five participants. Three iPhones and two iPads:

- iPhone XR IOS 16.4.1
- iPhone XR IOS 16.4.1(a)
- iPhone XR IOS 16.4.1(a)
- iPad 8th gen. IOS 14.7.1
- iPad 8th gen. IOS 16.4.1

### 6.1.3 Test-Session 1

#### Feedback and Observations

After trying out a new game, all of the participants gave good feedback about the game. Many users described the game as "cool." One user specifically said:

"*We like to move when playing games*"

These are translations of the user's quote from one of the employees. Sorterius is a waste bin avatar that speaks through the game. Figure 6.1 shows Sorterius being tested at CerciOeiras. Since the testing was done in Lisbon, Portugal, when choosing the country"*Portugal*" in the application, the language should be in Portuguese. However, there were some translations that were in Brazilian Portuguese. This was due to some translations being translated by the author using online tools to translate, while locals had translated the rest. It can be challenging to fully understand both languages sometimes, even though those who speak either language can understand the other, and it can be especially difficult for individuals with ID. This is due to the numerous subtle differences between the two. Therefore, translating this into European Portuguese was of utmost importance.

Observations were made regarding augmented reality (AR). In Sorterius, waste is represented as a 3D virtual object shown on the screen of the device. A user thought it was challenging at first to learn the concept that these virtual objects are not present in reality, whereas they only appear on the screen of the applications due to the device's camera. The user would first hold the device in front of them, and once waste appeared on the screen, they would try and grab the waste object behind the phone into the air. However, after discovering additional waste objects in the game, the user gained a better understanding of how the game worked and seemed to understand that the objects were virtual.

**Figure 6.1:** One of the employees at CerciOeiras testing Sorterius

### Result

A SUS score of 100 indicates the highest level of usability for the evaluated systems and is the best score possible. Sorterius achieved a SUS score of 87.5. Figure 6.2 presents the sum of each statement based on each individual score from the participants. And the SUS score is based on the sum of each statement.

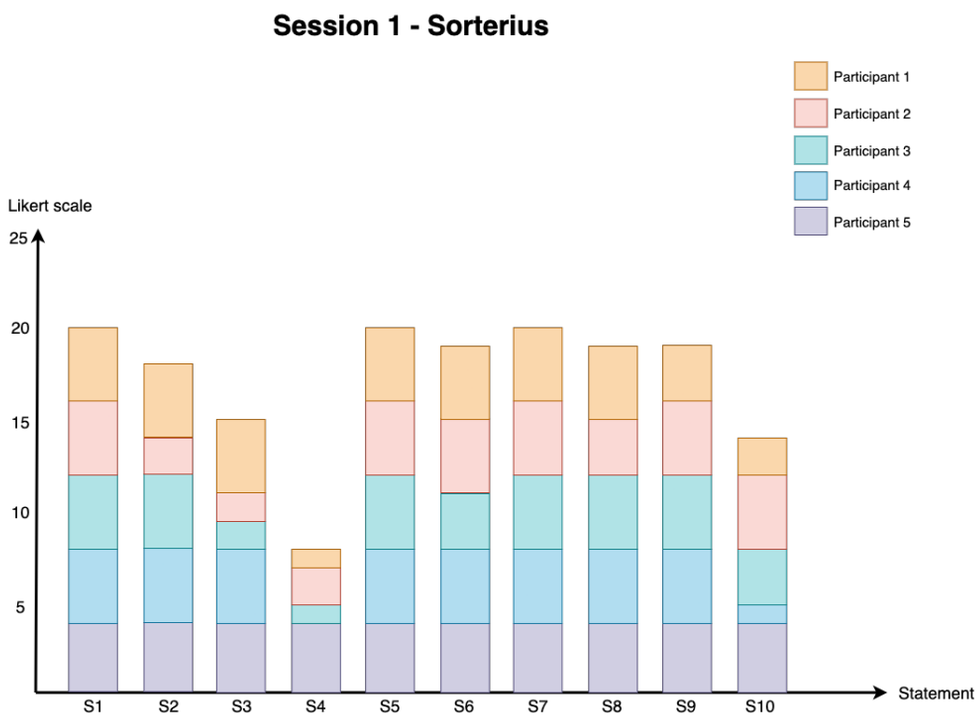



**Figure 6.2:** Sorterius part 1

87.5 is considered an excellent score. This indicates that the system is user-friendly. It suggests that users find the system easy to learn and use and effectively meets their needs, and it matches the observations made during testing and also the answer to the interview questions. All participants were able to use Sorterius, find virtual waste and sort it.

## 6.1.4 Test-Session 2

The participants in session 2 were the same participants as in session 1. In between the test sessions of Sorterius, a few implementations were completed. Some of the languages had to be translated from Brazilian Portuguese to European Portuguese, and bug fixes had been corrected.

### Feedback and Observations

During the second session of testing Sorterius, it was observed that numerous users experienced that their walking activity increased compared to their normal routines. One user, who is not usually involved in extensive physical activity, surprised the employees by actively using the exergame for a duration of about 30 minutes. The user's commitment to the app was obvious as they did only stop playing when they were specifically asked to do so. We asked the user how they felt regarding the game, and their answer was:

"*I am addicted*", and smiles.

This indicates a strong passion and wishes to keep using the exergame. Also, this occurrence shows the applications' potential to motivate users to engage in physical activity beyond their usual habits.

### Result

The System Usability Scale score had increased after the second test session of Sorterius. The application now achieved a score of 93.5, which is considered an best imaginable score. Compared to the past session, where the score achieved was 87,5, the game's usability has increased. Figure 6.3 presents the Likert-scale value of what each statement was calculated to.

## 6.1.5 Test-Session 3

In the last test session, AGA was tested. The session was done inside using an iPad to display the game. Ideally, a larger screen could have been used, but due to a lack of correct connectivity cables brought to Portugal, an iPad was used. The game was tested with three users at a time.

Figure 6.4 shows the setup we used for testing AGA. The testing was done in a training room at CerciOeiras.

### Feedback and Observations

The player showed both interest and enthusiasm in the game. Once they did a couple of dances/training sessions, they learned how to maneuver the game and choose a dance themselves.

Due to the application being tested with multiple users at the same time, the

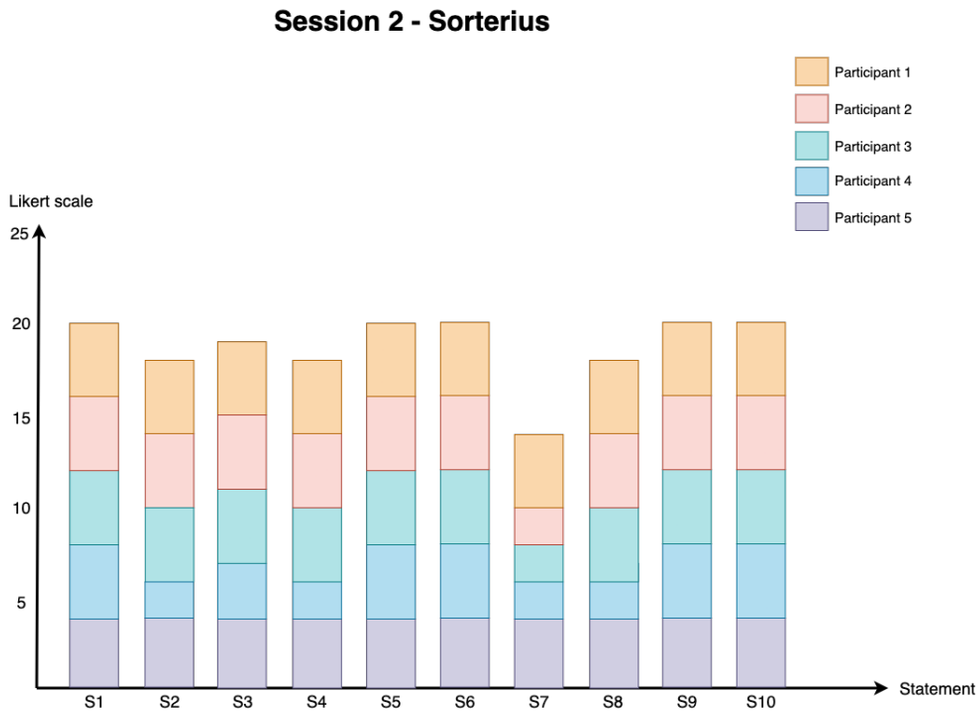



**Figure 6.3:** Sorterius part 2

avatar was selected randomly. This could have been done by a single user to better observe their interaction with the customization menu and also their interest in the avatar.

## Result

The System Usability Scale score for AGA was even higher than the Sorterius SUS tests. The applications achieved a score of 94. In Figure 6.5, we see the score each participant assigned per statement in the SUS questionnaire. The game achieved the participants' attention and motivated them to engage actively. This was accomplished through the mix of music, colourful visuals, and the avatar's movements, which created a good gameplay experience.


**Figure 6.4:** AGA User Testing Setup in Portugal

## 6.2 Evaluation Results

### 6.2.1 Language Support

Sorterius has implemented dynamic language support, allowing users to play the game in multiple languages, such as Norwegian, Spanish, Portuguese, Italian, and English. This language flexibility enhances the user experience, as players can engage with the game's interface and understand the instructions in their preferred language. In contrast, when testing AGA, it was only available in Norwegian. However, from seeing the results of Sorterius, a decision was made to make AGA multi-language.

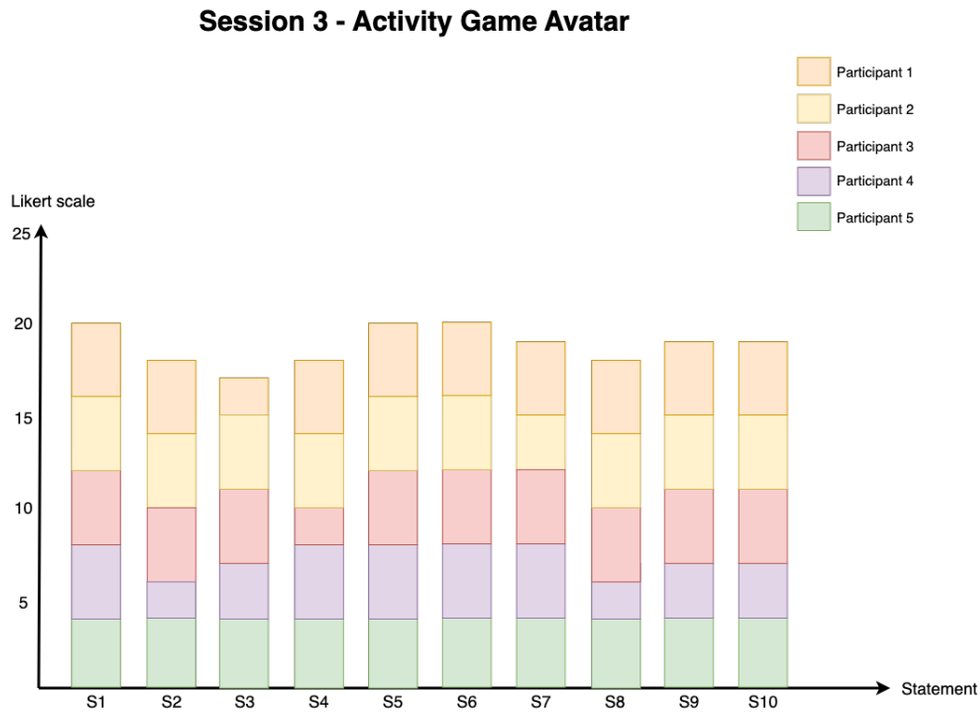



**Figure 6.5:** Activity Game Avatar

### Localization

Sorterius initially did not explore the implementation of waste familiarization. This was due to the feedback from the interview. Participants were asked if they believed it would be more interesting to search for waste objects they were familiar with. They then responded negatively. As a result, this part was not pursued further during the evaluation. However, it was initially planned to include country-specific sorting icons on the waste bins in the game. Unfortunately, due to time constraints, this implementation was not completed in time, and users did not have the opportunity to test the version with localized waste sorting icons.

## 6.2.2 SUS Grading

The SUS scores acquired for both Sorterius and AGA reflect their excellent usability and user satisfaction. According to the grading scale in Figure 6.6, it has been defined that both applications have achieved exceptional results, rating the highest possible grade, an A.

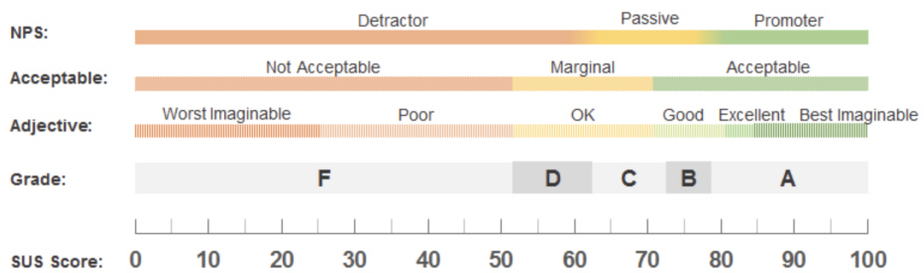
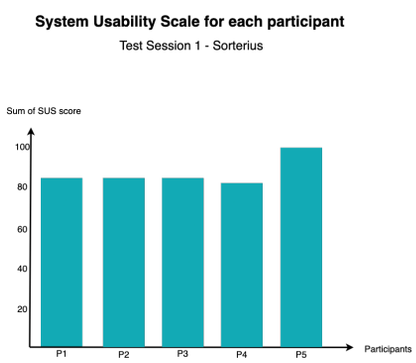
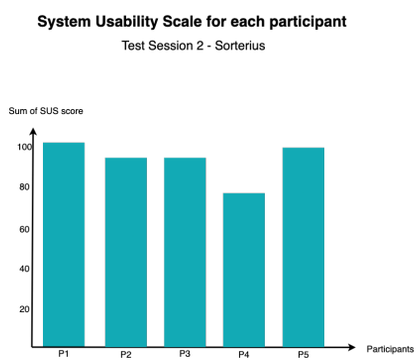



**Figure 6.6:** Different weights of the System Usability Score. Original title from source: "Grades, adjectives, acceptability, and NPS categories associated with raw SUS scores" [25]

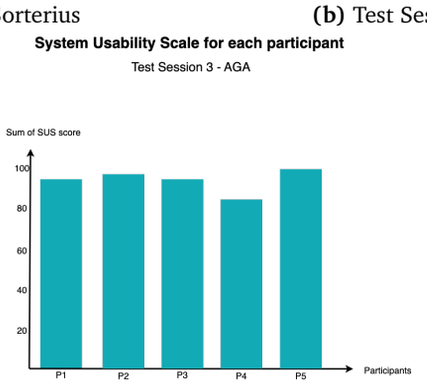
Sorterius achieved an impressive SUS score of 93.5 in the second test session, which is considered the best imaginable score. This indicates that users found Sorterius very user-friendly and intuitive. AGA, on the other hand, achieved an even higher SUS score of 94, overtaking Sorterius in usability. This excellent score demonstrates that AGA not only provided a user-friendly experience but also fascinated participants and motivated them to engage with the game actively. In Figure 6.7, we see the results of test sessions 1, 2 and 3. The figure shows the accumulated score for each participant.




**(a)** Test Session 1 - Sorterius




**(b)** Test Session 2 - Sorterius




**(c)** Test session 3 - Activity Game Avatar

**Figure 6.7:** Score of System Usability Scale of each participant

# /7 Discussion

## 7.1 Strengths and limitations

### Limitations

In order to evaluate the impact of the suggested solution accurately, the tests had to be carried out for an extended period of time. Because of the time limitations, the testing was restricted to a few days of testing and only focused on assessing the application's usability. The visit to Portugal for testing was done over a week and included three test sessions and development in between tests.

### Strengths

This thesis approaches has strengths that involve conducting numerous tests and also collaborating with many professionals who have diverse knowledge of the user group. By doing multiple tests and collaborating with professionals, the thesis achieved a high level of validity. The valuable feedback and insights gathered from interactions such as testing and engaging with professionals ensured that the applications got implemented with the specific needs, challenges, and preferences of the target user group.

## 7.2 Research Problems

In Chapter 1, the research problems were introduced. The main research problem was split into two sub-problems. By looking at this project's research methods, developments, tests and results, these problems have been solved by the following conclusions.

> **SRP1: How do European differences in cultural factors impact the engagement and experience of individuals with intellectual disabilities in exergames?**

In order to answer this question, tests were conducted with individuals who have ID in Portugal. During the tests, the participants gave their personal experiences and views on the games. The analysis of the tests resulted in various observations. Language barriers were a challenge for some players in understanding game instructions. Thus, the need for multilingual assistance was necessary. Additionally, providing translations or subtitles in culturally relevant languages enhances players' understanding and engagement.


**Figure 7.1:** Waste sorting regulation in CerciOeiras

Figure 7.1 presents the waste rules they use at CerciOeiras. As seen in the Figure 7.1, and Figures 3.2 and 3.3, from Chapter 3, the waste sorting in Portugal is quite different from Norway.

**SRP2: What design elements in exergames can be culturally suitable and sensitive to individuals with intellectual disabilities from diverse cultural backgrounds?**

To ensure culturally appropriate exergames for individuals with intellectual disabilities from different cultural backgrounds, it is important to consider culturally appropriate content and user customization. A found during the user tests were done; the participants did not find culturally appropriate content necessary as they still showed interest and engagement with the games, such as Sorterius having Norwegian waste objects and waste sorting items on the waste bins. In the user test in Portugal, the users were asked whether they would find it more interesting using Portuguese waste objects, and neither of them said 'yes'. Additionally, both AGA and Sorterius already have user customization options that allow the personalization of the game experience and the expression of cultural identities. Players can customize character appearance, clothing, and accessories, reflecting their cultural preferences and sense of cultural representation. These design elements promote inclusivity, cultural immersion, and a personalized experience for individuals with intellectual disabilities from diverse cultural backgrounds.

Main research problem:

**RP: In what ways can we enhance the accessibility of exergame applications for European users with intellectual disabilities?**

In order to make exergame applications accessible to European users with ID, different strategies were implemented. The first approach involved providing clear and simple instructions within the game interface, using plain language and visual cues to aid comprehension. This translation was done by professional translators who worked with individuals with intellectual disabilities as well as locals. Additionally, language preferences were taken into account and some text was replaced with pictograms to improve understanding further. This was especially for those who have trouble reading.

We encountered a user-centred design and testing approach throughout the development process. Involving individuals with ID in the design and conducting user testing allowed for valuable feedback that helped improve the accessibility and usability of the application. By implementing these strategies, these exergame applications have been further developed towards a more user-friendly, culturally appropriate, and customized to the unique needs of European users with ID.

## 7.3 Comparisson to past System Usability Scale tests

Sorterius and AGA have both been tested multiple times using the System Usability Scale. In comparison to the past SUS results, the new results show great improvement.

During its first SUS evaluation, Sorterius scored 61, which is equal to the grade D [17]. After further development, the application's score slightly went down to 60, still being the grade D [19]. However, in the recent project, Sorterius achieved a much higher SUS score of 93.5.

A possible reason for why it was such an improvement in between the tests could be because of the developer's attendance during the test sessions in the recent project. In previous tests conducted by Stellander, the developer was not present, which may have caused complications and affected the score. Additionally, having the developer attend during testing may have made users feel more comfortable trying out a new game and could also make better communication

and problem-solving.

In addition, the current project's evaluation of AGA got a greater score compared to previous tests. SUS tests were also conducted by researchers Wiik and Eilertsen on their versions of AGA [15][16], resulting in scores of 68 and 76.8, respectively. 68 is equivalent to a D on the grading scale, while 76.8 is equivalent to a B on the grading scale. The current project achieved a score of 94, which falls under the highest possible category and received an A grade. AGA performed exceptionally well in this project's evaluation.

When testing the application with users in Portugal, the only difference in the first test session of this project was the language support, compared to Luzi's test of Sorterius. Therefore, another factor could be the different users testing the applications. The application could perhaps be more suitable for a country that has a different climate than Norway. For instance, for an application such as Sorterius, outdoor gameplay might influence the gameplay experience and the way virtual waste is integrated into the physical environment. And Portugal has a warmer climate which may give favourable conditions for users to engage in physical activity. People with ID might find it more comfortable and enjoyable to be a part of outdoor activities in a warmer climate. And this could impact the overall motivation and engagement of the users in a positive way during the testing of the applications.

## 7.4 Contributions

### 7.4.1 Educational exergames

The evaluation results provide insights into exergame's design and user experience. The focus on language support, localization, and engaging elements can guide the development of future exergames created for a wide range of users and promote user engagement. These findings highlight the importance of user-friendliness and clear instructions. Furthermore, educational potential of exergames can be, for instance, further explored to impact the users' knowledge and awareness regarding waste management and sustainability.

By incorporating waste sorting mechanics and providing engaging gameplay experiences, these exergames can help educate and help users to make informed decisions regarding waste disposal. The findings from the article highlighting the consequences of incorrect waste sorting practices in Oslo, Norway, strengthen the significance of exergame design that promotes not only physical activity but also enables environmental consciousness.

The article states

"*You can be fined NOK 12,000 for throwing your waste in the wrong waste bag*" [18].

By increasing awareness about the consequences (in some countries) of wrong waste disposal and explaining the importance of correct sorting practices, these exergames can contribute to a more sustainable and eco-conscious society.

## 7.5 Text Formatting in Localization handler script

Compared to file formats like XML or JSON, CSV files are easy to use since they do not contain complicated formatting/metadata. CSV files can be easily edited using spreadsheet software, providing a flexible and accessible way of managing data. The decision to use a CSV file for structuring the data in the applications was made because it is easy to use and maintain. Editing an XML or JSON file can be too complex for editors without prior experience with specifically this data formatting. In previous discussions with participants in the MOVE-IT project, we have used spreadsheets for sharing data. Since they integrate well with CSV files, this format was chosen.

## 7.6 Audio Selection in Sorterius

For Sorteius, we explored different approaches for implementing sound in the application, specifically looking at pre-generated text-to-speech (TTS) files, TTS files generated during runtime, and pre-recorded natural sound files. Each approach has its own advantages and considerations.

### 7.6.1 Runtime Text-to-Speech

Runtime TTS, are text generated on the fly and outputs audio. They offer several advantages. One of them are their dynamic ability, allowing for personalized feedback and interactions with users. By generating speech during runtime, the application can adapt to user-specific inputs, providing a more engaging and customized experience. Moreover, runtime TTS can save storage space as there is no need to store pre-recorded audio files for every possible phrase or

sentence. However, the quality of runtime-generated text-to-speech may vary depending on the TTS engine used, and it may sound less natural or somewhat robotic compared to pre-generated TTS files.

### 7.6.2 Pre-recorded Natural Sound

Pre-recorded natural sound, including voiceovers and sound effects, gives a high level of audio quality and authenticity. It is suitable for specific, predefined elements within the application. These pre-recorded audio files can sound natural, improving the user experience. However, pre-recorded natural sound lacks the dynamic and adaptive qualities of TTS audio solutions. It requires much storage space for storing the audio files and does not provide the level of customization and personalization that runtime TTS can offer. In addition, finding individuals who are proficient in each language that the application can be translated into is necessary and can be difficult.

### 7.6.3 Pre-generated Text-to-Speech Files

One of the primary advantages of using pre-generated TTS files is their high quality. These files are created in advance using TTS engines and can deliver voiceovers and sound effects that correspond to the human voice. Additionally, pre-generated TTS files do not require additional processing during runtime, resulting in optimal performance. Although, a significant disadvantage is the storage space required to store these audio files, as a large number of files may be needed to cover various phrases and sentences within the application. This would not be an issue for Sorterius as there are only a couple of sound files in the application. For this project, pre-generated TTS files were the chosen approach. This decision was based on the need for high-quality correlated with the easy integration into the application's localization mechanism.

## 7.7 Further Work

### 7.7.1 Compatible for users in wheelchair

While the current version of AGA provides an engaging and accessible exergame experience for a wide range of users, there is an opportunity to enhance its compatibility further for individuals using wheelchairs.

Seated dance routines offer a good way to enhance wheelchair compatibility for AGA. These routines could be designed for users in wheelchairs, involving

upper body movements, hand gestures, and coordination with the game's visual and audio cues. The integration of seated dance routines would provide an engaging and physically active experience for individuals who may not be able to perform standing movements.

# /8

# Conclusion

This project explored the cultural aspects of exergames for individuals with ID and highlighted the importance of cultural sensitivity in designing inclusive and engaging exergame experiences. By exploring how cultural factors affect engagement and experience, identifying culturally suitable design elements, creating guidelines for cultural sensitivity, and evaluating culture-enhanced exergames, this research contributes to enhancing the accessibility and impact of exergames for individuals with ID from different cultural backgrounds.

The findings indicate that several cultural factors influence the engagement and experience of individuals with ID in exergames. Language preferences occurred as an important factor, stating the importance of providing language support and options in exergame interfaces. Additionally, the project identified the cultural relevance of local waste sorting regularities, demonstrating the need to consider specific cultural practices and regulations when designing exergames with environmental themes.

The evaluation of culture-enhanced exergames demonstrated positive impacts on users' physical activity levels and overall well-being. By including culturally appropriate elements can make the experience more meaningful and engaging, especially for individuals from diverse cultural backgrounds.

The projects' mixed-methods approach, including interviews, consultations with professionals, and an iterative design process, provided comprehensive insights into the cultural aspects of exergames for individuals with ID.

This project highlights the importance of cultural variety in the creation of exergames for people with ID. By taking into account and including cultural aspects, exergames can be customized to suit the requirements and choices of various user groups, resulting in more engaging and accessible experiences. With continuous research and advancement, exergames can have a good effect on the lives of individuals with ID from various cultural backgrounds, encouraging inclusiveness, physical activity, and overall well-being globally.

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# Appendix

## Questionnaire

The questions below can be answered with the numbers 1-5. Where 1 represents **'strongly disagree'** and 5 represents **'strongly agree'**.

| **Questions** | 1 | 2 | 3 | 4 | 5 | Comments |
|---|---|---|---|---|---|---|
| I think that I would like to use this game frequently. | | | | | | |
| I found the game unnecessarily complex. | | | | | | |
| I thought the game was easy to use. | | | | | | |
| I think I would need help to use this game. | | | | | | |
| I thought the different parts of this game worked well together and were connected in a good way. | | | | | | |
| I thought there was too much inconsistency in this game. | | | | | | |
| I would imagine that most people would learn to use this game very quickly. | | | | | | |
| I found the game very difficult to use. | | | | | | |
| I felt very confident using the game. | | | | | | |
| I needed to learn a lot of things before I could get going with this game. | | | | | | |

**Figure 1:** System Usability Score Questionnaire

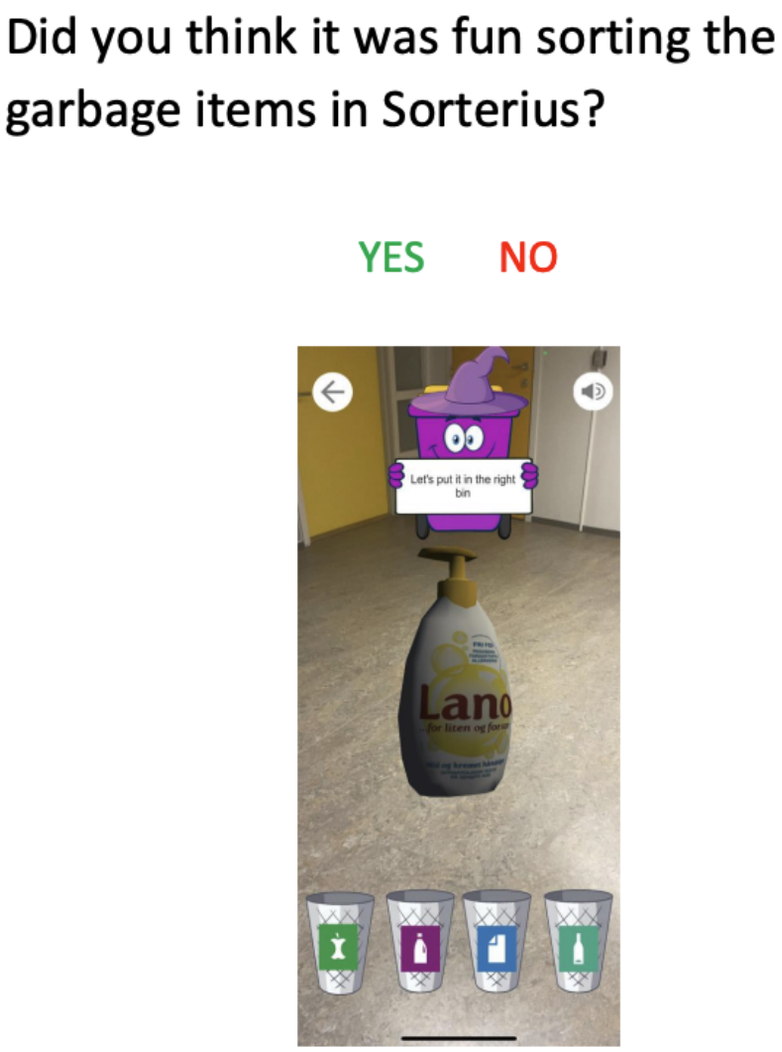


**Figure 2:** Sorterius Interview Question 1


**Figure 3:** Sorterius Interview Question 2