

Eirin Svinsås

Maiken Louise Brechan

Thadshajini Paramsothy

# Developing fully immersive Virtual Reality for people with Intellectual Disability

Optimizing ease of use by comparing  
functionalities and assisting tools

Bachelor Thesis in Computer Science

Supervisor: Thomas Holt

May 2023



**NTNU**

Kunnskap for en bedre verden



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# Abstract

The research market lack subject on design features for fully immersive Virtual Reality (VR), but it shows that VR is useful for educational purposes for people with intellectual disability (ID). This thesis answers that void by investigating if VR games are viable for people with ID and compares assisting tools and functionalities in fully immersive VR to suggest guidelines for ease of use in VR. A VR-game situated in a supermarket is developed and tested. The players buy groceries for a dinner and practice the routine grocery shopping. Tasks for the game are find the items, carry them to the self-checkout, scan the items and pay with the selected pin code. Three rounds of testing are conducted on a total of 9 participants with ID. Each round of testing compares different types of movement, highlighting objects and use of different buttons. Results show that using only the trigger button for all actions is the most stable solution. The type of movement with best results is teleportation to teleportation points and teleporting the player in the code, even though participants preferred continuous movement. Lastly, highlighting object to indicate action is best communicated with arrows.

# Sammendrag

Litteratursøk avslører mangel på forskning om design for virtuell virkelighet med full immersjon. Virtuell virkelighet er bevist nyttig for pedagogiske formål for mennesker med nedsatt kognitiv funksjonsevne. Denne avhandlingen besvarer dette ved å undersøke om VR spill er kompatible for mennesker med nedsatt kognitiv funksjonsevne og sammenligne hjelpemidler og funksjoner i VR-spill med full immersjon for å foreslå retningslinjer for brukervennlighet i VR. Et VR-spill som finner sted i en matbutikk, er utviklet og testet. Spillerne kjøper dagligvarer til en middag og øver på den rutinemessige dagligvarehandelen. Oppgavene for spillet inkluderer å finne varene, bære dem til selvbetjeningen, skanne varene og betale med den valgte PIN-koden. Tre runder med testing er gjennomført på totalt 9 deltakere med intellektuell funksjonshemming. Hver testrunde sammenligner forskjellige typer bevegelse, fremheving av objekter og bruk av forskjellige knapper. Resultatene viser at det å bruke bare trigger knappen for alle handlinger er den mest stabile løsningen. Den typen bevegelse med best resultater er teleportering til teleporteringspunkter, selv om deltakerne foretrekker kontinuerlig bevegelse. På fremheving av objekter for å indikere handling viser seg å fungere best med piler.

# Preface

This thesis is carried out in the course IDATT2900 - Bachelor Thesis in Computer Science at the Department of Computer Technology and Informatics at Norwegian University of Science and Technology (NTNU). The knowledge and experience gained from two and a half years in this field of study is used to finalize the thesis. The research and complementary game in VR are produced by the students with input and advice from supervisor Tomas Holt. During this work, the team used the visualization lab at the university and met up frequently to encourage and cooperate with each other.

This thesis is self-defined and is based on the idea of creating games in VR to help people with ID access unlimited volume training on daily routines. The team started working with the subject matter the previous fall in 2022, in the courses IDATT2505 Extended Reality and IDATT2501 Specialization Project. This led to a VR-game based on a morning routine. Positive feedback on the project and the impression of a gap in the research market for VR for this group of people with ID, inspired the team to continue to work on the theme. With the idea of innovating games in VR for people with ID, the group also wanted to research effects, experiences and tendencies within this field. This led to a review on design level, where the team investigated challenges and opportunities in VR for the target group. The game from the previous semester, morning routine, was used during the first test round. Results were used to develop a new game based in a supermarket for further research. The game developed in this project is independent from the previous morning routine game, but the research is carried out on both games.

A special thanks to:

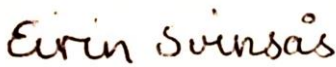
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Eirin Svinsås

Trondheim, 15.05.23



Maiken Louise Brechan

Trondheim, 15.05.23



Thadshajini Paramsothy

Trondheim, 15.05.23

# Thesis Description

This self-defined thesis researches what kind of tools in a fully immersive VR-based game can help achieve desired behavior from the target group, people with ID. The goal of this research is to suggest guidelines for implementation of ease of use, to achieve desired behavior. Hopefully people with ID can be included in the use of this technology, where the potential guidelines can be used by developers to create more user-friendly VR games.

In addition to this research, the team has developed a VR game with audiovisual tools situated in a supermarket. This game has been used to conduct tests through several iterations. New tools are implemented, and already made tools are tweaked after evaluation of each tool.

Initially, this thesis was about measuring the effects of how VR games can help make a difference in the daily lives of people with intellectual disabilities, in terms of practicing daily routines in the VR world. According to the first user test, the team discovered that VR technology was not very familiar to the target group. Therefore, the focus shifted to how the game could be designed to meet the target group's needs, as there were not many guidelines on how to develop VR games for people with ID.



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## Abbreviations

VR	Virtual Reality
ID	Intellectual disability
AR	Augmented Reality
NTNU	Norwegian University of Science and Technology
SCM	Supply chain management
3D	Three-dimensional
GDPR	General Data Protection Regulation
DMP	Data Management Plan
IDE	Integrated Development Environment
DGM	Data generation methods
UI	User interface
VS	Visual Studio
VSC	Visual Studio Code

# 1. Introduction and Relevance

This thesis is based on personal experiences working with people with ID, and the opportunity to develop games in VR. The problem area the team aims to solve is that people with ID struggle a lot adapting to new surroundings and chores. For instance, when they are moving out from their parents' house into municipal housing. People with ID can likely experience stress, tantrums and refusal to do simple things like brushing their teeth or taking medication due to unfamiliar surroundings or happenings. Which is challenging to parents, social workers and the individuals themselves. The team's prior experience and knowledge was that volume training, patience and predictability are key elements to handle these challenges. The team saw an opportunity to potentially solve this with VR, being able to simulate new surroundings and accessing unlimited repetition and practice. This is reflected in the effect goals listed in the vision document, and later rewritten in section 3 – method. With the opportunity to self-define our thesis the team began researching in literature and planning experiments to expose scientific evidence to support the idea.

## 1.1 Research Questions

The final research questions this thesis seeks to answer are:

- Can people with ID master an adapted VR game?
- How can a game in VR best be developed for people with ID?

The research questions were composed from the effect goals, the base idea that VR can be useful for people with ID and the resources the team had available. The process for this selection is covered in method chapter 3.1.2.

## 1.2 Structure

This rapport is divided into the following chapters:

**Chapter 1** – Introduces and describes the background for the thesis.

**Chapter 2** – Provides necessary theory to understand the target group and technology used to develop the game. In addition, it describes the methodology used for collaboration and experiments.

**Chapter 3** – Includes description of the research and development method, as well as the chosen technologies.

**Chapter 4** – Contains the administrative, scientific and engineering results.

**Chapter 5** – Discusses the results and the validity of the research.

**Chapter 6** – States the final conclusions and answers the research questions introduced in the introduction, based on the results and discussion.

**Chapter 7** – States potential future works related to research and development.

**Chapter 8** – Provides an insight into the societal impact of adapted VR games for people with ID.

## 2. Theory and Relevant Literature

Before looking into details of the project it is useful to gain an overview of the context for the problem area. This chapter will provide necessary information for understanding the issue at hand and general knowledge about the used technologies.

### 2.1 Intellectual Disability

#### 2.1.1 Definition

ID is an incomplete mental development leading to restraints in general psychological functioning and adaptive behavior. This is evaluated in comparison with other people with the same age, gender, and social background. The restraints in psychological functioning are caused by cognitive issues that can be explained through translanguaging as "A disturbance in the brain's functioning causing lowered ability to perceive, consider, process, remember, retrieve information and act with an own will according to the circumstances" (Tetzchner, 2008, pp.585). The limitations can be observed in several areas such as communications, academic skills, personal-care and independence (What is ID?, no date). In the field of medicine, the term is defined as a general neurodevelopmental disorder and this includes several diagnoses such as genetic conditions, complications during pregnancy and birth, diseases, and toxic exposures (Dubovicky, 2010). Therefore, this can be considered as a very heterogeneous and complex group. To showcase the variety, an overview of the different categories of ID is listed below.

Generally, there are four levels of ID where each level is defined by IQ and the deviation in current development from regular developing children (Gill, 2019):

Level	IQ range	Characterized
Mild	50-69	Social immaturity, problems reading and writing, can be fully independent, learning to talk late, lowered understanding of conversation
Moderate	35-49	Can learn to count, unable to live alone, difficulties in communication, language and understanding, can manage in familiar places
Severe	20-34	Severe damage to central nervous system, noticeable motor impairment
Profound	Below 20	Unable to understand and comply requests and instructions, immobility, incontinence, nonverbal, constant need for help and supervision

Table 1: Levels of ID

When setting the diagnosis the social worker does a mapping of the entire cognitive functioning, so that all aspects are considered. These are: memory, logic thinking, orientation of surroundings, communication skills, concept of time, perception, ability to concentrate, sensory experience and problem solving. When deciding the level of ID, a comprehensive assessment is done. The variations within each degree of ID are also very complex. For instance, a contradiction is when a person excels in frequent communication but lacks an understanding of their surroundings, or conversely, has no communication skills but possesses the ability to recall places and uses that skill to navigate and move around. Both cases can be both mild and moderate ID, depending on the rest of the cognitive profile (Utredning og diagnostisering av utviklingshemming, no date). An investigation of diagnosis happens on the initiative of parents, doctors or teachers, and the measured degree of ID at the time of investigation can be different compared to the degree of ID at other ages (Utredning og diagnostisering av utviklingshemming, no date).

### 2.1.2 Challenges of ID

People with intellectual disabilities are often looked upon as unmotivated towards learning, due to their lack in initiative to handle tasks and how they often avoid situations where they must take responsibility (Drew and Hardman, 2007). Rygvold and Ogden argue that this is due to a taught helplessness that can be handled by giving a foundational mastery of the tasks. If learning is adapted to the individual and sets the individual up for mastery, the lack of motivation and drivenness can improve (Rygvold and Ogden, 2017). Since individuals with ID struggle retrieving meaning from context, circumstance and perception of time, learning something new requires an exaggerated amount of structure and predictability (Rygvold and Ogden, 2017). Structure and predictability in this pedagogical context mean informing about tasks in detail. This is to be frequently repeated because bad short-term memory makes people with ID spend more time understanding a task.

The learning strategies taught within the field of special pedagogy are (Rygvold and Ogden, 2017):

- Repeat what they are to learn frequently.
- Remove distractions.
- Start easy.
- Use all varieties of learning materials available.
- Use activities, since theoretical content is not available for people with ID due to, they lack the ability of abstraction.
- Do over learning: repeat many times even after they have mastered the task.

Generalization is the ability to transfer taught knowledge to other situations. People with ID seem to have good generalization skills when the taught task is visually similar to the new task. Learning for people with ID is based on repetition so that the brain can start recognizing and create connections through volume training (Rygvold and Ogden, 2017).



## 2.2 Technology

### 2.2.1 Light definition of VR

VR is a well-known technology today and is used in various fields such as video games, medicine, and education. Applications that use this technology allow users to see a computer-generated environment using objects that create realistic images, sounds and other sensations that make the user immerse into this world. There are three categories of VR: non-immersive, semi-immersive and fully immersive. Fully immersive VR is complete with sight and sounds. For the user to experience fully immersive VR with physical presence in the virtual world, it is necessary to use interactive devices such as headsets, head mounted displays, controllers, or bodysuits (Virtual Reality: another world within sight, no date). This VR equipment receives and sends information to a computer that helps the user interact with the virtual world. So, when the user moves with, for example, a VR headset, this happens in relation to the artificial world.

### 2.2.2 The three pillars of VR

The mentioned definition of VR is one of many. To gain a better understanding of VR, this part will elaborate on the three pillars of VR. Professor Mütterlein published the article "*The Three Pillars of Virtual Reality? Investigating the Roles of Immersion, Presence, and Interactivity*". The article states that immersion, presence, and interactivity, must be present to experience the VR technology (Mütterlein, 2018).

Immersion is a broad term used for the feeling of being in an environment physically or mentally. Physical immersion is used for the medium of VR (Craig and Sherman, 2018, pp. 10). Physical immersion contributes through technology such as a VR system that you can physically wear or touch. This replaces or enhances the stimuli of some of the user's senses (Craig and Sherman, 2018, p. 10). The VR headset is a good example of achieving physical immersion in that it shows the user a virtual world based on their location and provides synthetic stimuli to the sight in response to their position and movement.

Presence is related to the user's experience of being in another environment or space than their physical surroundings (Mütterlein, 2018). The presence lies in the subjective experience of being in a different environment than the physical surroundings. So, the VR technology should give the user the feeling of being in another location like for example the Eiffel Tower.

Interactivity refers to the user's physical ability to influence the environment in the VR world (Craig and Sherman, 2018, pp. 12). This can be done by changing your viewpoint in the VR world by physically moving your head. Another way is to be able to change your location by moving around the world with your feet or using the buttons on a physical hand controller to teleport wherever you want. These physical hand controllers can also be used to lift objects or push objects away. It all depends on what kind of functionality the hand is programmed to have. However, this VR equipment should give the user a sense of inclusion and immersion between them and the VR world using the equipment of a VR system.

### 2.2.3 Game Engine

Game engine is a software framework that allows developers to create games easily (The Complete Game Engine Overview, no date). A game engine provides systems and services, such as graphics, input devices and event processing. More advanced game engines may also include other game-supporting systems such as physics, artificial intelligence, and support for networking (Claypool, 2013).

## 2.3 Relevant Literature: VR for people with ID

A systematic review of 15 articles on interventions using VR for people with ID resulted in positive findings where the use of a participatory approach can improve abilities in real-world settings (Nabors, 2020). Another study from London magazine, Springer, stated grand potential for VR for people with ID, particularly because education for this group continuous well after schooling age, at least more than the general population. Terms for exploiting this potential is evidence-based design and utilization, and that the future developers fill this gap (Standen, 2006). There is scientific evidence that interventions with VR can be useful for educational purposes on people with ID. Vital to mention that these studies not often relied on fully immersive VR, so using three-dimensional (3D) games on tablets instead of headsets, because of cost-benefit.

Another systematic review of 69 studies where VR was used on people with ID showed that fully immersive VR and VR non-immersive showed more promising results than interventions done with augmented reality (AR) and a trainer, due to the user's presence. The results suggest that people with ID experience virtual environments in a way similar to the physical world, maybe even more than others, and that VR may therefore provide authentic opportunities to practice skills. This study also discussed lack of specific design features and customizability as an important area for future work (Bailey, 2021).

## 2.4 Research and Development Methodology

### 2.4.1 Software Development

Software development methodologies have as a primary goal to ensure a smooth development in accordance with the project specifications. These methodologies are frameworks to structure, plan and control the process, and often require good planning of the software development cycle. There are many types of software development models to suit the developers' needs and preferences. Selecting a development model establishes a way of sharing information between developers, which is best done efficiently (What is Software Development Methodology? 10 Key Methodologies, 2022).

### 2.4.2 Scientific Method

The goal of research methods is to gain credible and durable knowledge. That includes how to find relevant knowledge through source criticism. Self-generated data is also included in

research methods and is separated by deductive and inductive models. In the deductive model, an experiment is often carried out to confirm, deny or revise a hypothesis. This model often contains quantitative methods that seek unambiguous and reproducible answers. The inductive model gathers empirical evidence and tries to find an answer to a problem. Qualitative models are often relevant for the inductive model, as they seek understanding and insight rather than absolute answers. Practically, both methods can be used together or separately. Another important aspect within research methods is to reflect and discuss the executed work and methods. This is to ensure that the obtained knowledge is reliable and could not have been obtained better under other circumstances (Kompendium vitenskapelighet, no date, pp. 11-13).

### 2.4.3 Personal Data

Research requires collecting and handling data and is regulated through different organizations that all have guidelines to follow for handling them, especially personal information. Personal information is defined as data that can directly or indirectly identify a person (Behandle personopplysninger i student- og forskningsprosjekt, no date). This information is protected by these organizations and the regulation of general data protection stated by the EU (Intersoft Consulting, 2018). Research projects are to solicit a permit before handling personal information, which can be anything from name, age, photos, recordings, IP-address to nationality or place of residence. Thereby participating in research where such data is not anonymized requires legal consent (Behandle personopplysninger i student- og forskningsprosjekt, no date).

## 3. Method

The theoretical background gives foundation for the selected methodologies, whereas this chapter will give an overview of the methodologies used in the experiments and further conducted to answer the research questions.

### 3.1 Choice of Development Method

#### 3.1.1 Kanban

The team considered two development methods, Scrum and Kanban. Both support agile development which means they support continuous delivery, adaptability, collaboration and finished functionality as a measure of progress (Moradini, 2021). However, for this project it was more important to have a dynamic and flexible method than the agile features, because of the research aspect. Therefore, the chosen development method was Kanban on the grounds to simplify collaboration, have high productivity and adaptability to changes. In addition, the method was well suited to the scope of the project and the number of developers. Whereas Scrum is better for a higher number of developers (Moradini, 2021). Kanban is a flexible software development methodology that provides an efficient way to communicate about tasks between developers. Kanban uses a tool called Kanban board, to structure tasks into categories such as to-do, in progress and done. The Kanban cards on the board include the task and other optional items like who is working on it, date, and comments. Being able to visualize the status of each task and who is working on it, enhanced transparency for the progress. This additionally supports the Kanban principle which is to limit work in progress to improve efficiency. By making it easier to notice if too many tasks are in progress at the same time (Radigan, no date).

The kanban board was set up in Trello which is a free app and website for such tables. Each kanban card includes task description, responsible person and status. The labels of the categories are open, to do, working on it, done, stuck and closed. Open, was used for tasks and ideas which might be relevant to do. To do, was for items that need to be done. Stuck, was where challenging tasks were placed to avoid clogging the workflow. Closed, was for tasks that turned out to be irrelevant but were still needed for reasons like tracking progress. The team created one kanban board for development/research and one for documentation, which are shown later in this report.

#### 3.1.2 Gantt-chart

Gantt-chart was used for time management, planning and visualizing milestones and activities. It served as a Kanban product backlog, to get an overview of the planned tasks and their priorities. Planned start and duration, actual start and duration, estimated time consumption, actual time consumption, responsible person, and completion percentage for each milestone or activity was included artifacts for each activity. Considering this, the progress was effectively monitored, aiding the team in staying on top of things. An overview of the Gantt-chart is included in attachment B.

### 3.1.3 Unity Plastic SCM

Unity Plastic Supply chain management (SCM) was used for version control and source code management. Plastic SCM is Unity's own version control, which enables fast and efficient collaboration and workflow between developers. Most important is the compatibility with the game engine, which is what distinguishes Plastic SCM from other version controls like GitLab (Unity Plastic SCM Cloud Edition, no date). Using plastic SCM made parallel coding efficient and secured that no work was lost in merge conflicts, because of its ability to differentiate changes within the same scene and handle metadata. Furthermore, by downloading the plugin Version Control package in Unity allowed the team to use the Plastic SCM interface directly within the Unity Editor. At the end of attachment D, system documentation, there is a manual to access the repository and in administrative results a commit/changeset history.

## 3.2 Division of Labor and Roles

The team consisted of three close friends with experience working together on several group projects. The team members were self-driven and took responsibility for their tasks, but the appointed leader oversaw the process and ensured progress. Knowing the different personalities, the team easily assigned roles and responsibilities in the employment contract. The distribution was based on the previous experiences as a team, which lead to a smooth workflow and good dynamic.

## 3.3 Continuation of Fall Project

Since this thesis was partially a continuation of a former project, the game developed in that project was used for the first round of testing. The game was situated in an apartment where the user's task was to complete a morning routine. The tasks were selecting clothes according to the weather, putting away laundry, brushing teeth, taking medicine, eating breakfast, cleaning up after breakfast and packing necessities before leaving. Even though this project was not a direct transfer from the previous project, the subject matter was the same, practicing routines in VR. This game has high relevance for our research. The results from testing this game were taken in consideration for the development of this thesis' game, grocery shopping, to hopefully create a more suitable game for the target group.

## 3.4 Choice of Technology

Several technologies were used in this thesis for administrative and development purposes. This section will describe technological choices and the reasons for them.

### 3.4.1 Chosen Game Engine

Game engines provide many different services, as stated in section 2.2.3 Game Engine. When deciding which game engine to use for the supermarket game, the choice was between Unity and Unreal Engine. In a survey comparing game engines, those were the ones who stood out. Both game engines are cross-platform and offer built-in components for functionalities like rendering, animation, physics and sound, a large community and marketplace for assets. Scripting in unity uses UnityScript, or the recommended high-level language, C#. Unreal Engine uses the intermediate-level language C++ for scripting (Andrade, 2015). Even though C++ is faster than C# in game development, C# has an easier hierarchy to understand, alerts compile errors and has easier memory management. The graphics in Unity are of high quality and have next-level visual effects (Paszkiel, 2020, pp. 101–110). However, Unreal Engine is said to be even better at visuals. On another note, Unity is more beginner friendly (Andrade, 2015). Overall, they are both great options with different strengths. Since the team was already familiar with Unity, developing in unity would be more efficient. Considering that this project also relies on research, fast development is important to have time for experiments. Therefore, the chosen game engine was Unity, due to the ease of use, pre-made components and huge network to seek guidance and advice from.

### 3.4.2 VSC and C#

Scripting was used to make the game dynamic by adding functionality on the game objects. Unity uses C# and other coding languages, but when it comes to compatibility C# stands out (Scripting in Unity for Experienced Programmers, no date). This furthermore made it easy for the team to find resources online when needed. Visual Studio (VS) is Unity's default editor, but Visual Studio Code (VSC) was used to edit the C# files due to more detailed error messages and better code completion. VS code has Unity extensions that can be downloaded for free, which provides support for writing and debugging C# code in relation to Unity (Ritchie, 2016, pp. 15).

### 3.4.3 VR Equipment, Steam, SteamVR and OpenVR



*Figure 1: HTC Vive headset and controllers*

The hardware was supplied by the university, and consisted of an HTC Vive headset, two controllers and two base stations. The base stations sensors track the headset and controllers' exact location in the virtual world, which strengthens the presence and experience of room-scale in VR. An adapter connected the headset to the computer. For this pairing to function with Unity, the computer being utilized had to have both Steam and its corresponding expansion, SteamVR. Further, Steam needed OpenVR to run for it to work (OpenVR, no date). OpenVR is a software development kit and application programming interface developed by Valve for supporting VR headset devices (Velev and Zlateva, 2017). In Unity, OpenVR serves as the interface between the VR hardware and software, which is Unity in this case (Egger et al., 2017). SteamVR, on the other hand, is used to identify the connection to the headset, controls, and tracking sensors.

This setup was already calibrated, and the software was installed on the computer. The team used this prearranged setup, which allocated more time to the development and research.

HTC VIVE controller buttons used in the game and research is shown in figure 2 and table 2 below. (About the VIVE controllers, 2023):

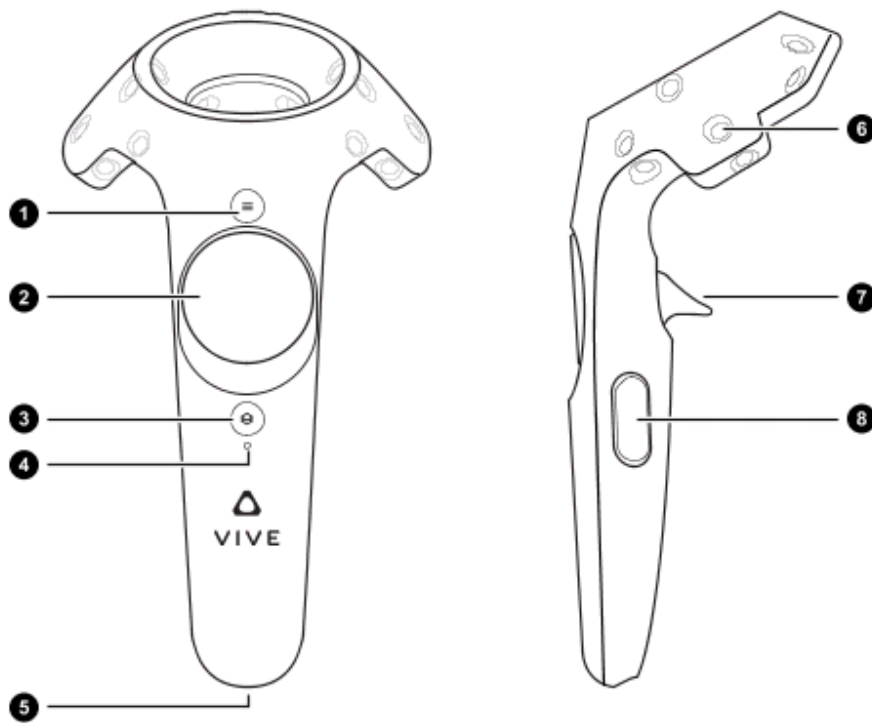


Figure 2: HTC VIVE controllers

Number	Name of button
1	Menu button
2	Trackpad
7	Trigger
8	Grip button

Table 2: Name of buttons

### 3.4.4 XR Interaction Toolkit and SteamVR

XR interaction toolkit handles interaction and many different VR related experiences (XR Interaction Toolkit, no date). Functionalities used from XR interaction toolkit in this project were animating virtual controllers and their movements, teleportation, interacting with User interface (UI) elements and game objects through action input. SteamVR also offers similar features, but the team's experience is that XR Interaction Toolkit works well across different versions of Unity while SteamVR has some compatibility challenges when Unity releases new versions. Therefore, XR Interaction Toolkit was used for the project. However, SteamVR was used in a separate branch because it offers a renderer model that makes the virtual controller look like the physical controller. Which was used to investigate if seeing virtual controllers was better than virtual hands.



### 3.4.5 Blender

Blender is the 3D modeling software used to create necessary GameObjects that cost money in the Unity Asset Store. This decision was based on the tight budget that was premeditated by the investment of a big asset. The budget was out of the team's pocket and was therefore minimized. The asset was purchased to achieve a solid foundation for the development, see the asset in references (Demchenko, 2019). This contributed to the decision to create the rest of the GameObjects by hand. There was different software to choose between such as Adobe Substance 3D Modeler, Autodesk Maya, 3Ds Max, SketchUp or ZBrush. Adobe Substance 3D Modeler, Autodesk Maya and ZBrush have pricey subscriptions which did not fit the team's budget. While 3Ds Max was better to use for AR purposes and ZBrush for precise modeling (Williams, 2023). Which left Blender the preferred choice of technology best suited for the cause and budget.

## 3.5 Research Method

Since this thesis also focuses on research, the development of the game relied on creating features for testing purposes. This made the development more dynamic than standard system development. The processes of research and development were not linear, and the team was aware that there would be a need for changes in the process. However, the goal was to make large scale changes early, so features in the supermarket game would be ready before the experiments.

### 3.5.1 Data Collection

To ensure the preservation of the rights of our research participants, the team members completed the NTNU's introduction course to personal data (Behandle personopplysninger i student- og forskningsprosjekt, no date) which led to a risk assessment for research projects handling personal data at NTNU, see appendix 3 Risikovurdering av forskningsprosjekter med personopplysninger, no date). The team decided to avoid collecting personal data due to three main reasons. Firstly, the target group is a vulnerable group that might not have consent competence or be able to comprehend the meaning of giving up personal information. People with ID who are not evaluated as consent competent have legal guardians provided by the state or a parent, even if they are of age. The second reason the team avoided personal information was the focus of the project, which was researching what works well for everyone in VR, disregarding mental and physical state. The last reason was the project's extent. Obtaining the necessary approval and legal forms is a heavy process that takes a lot of time because the target group falls into the category of vulnerable groups (Forskning på Sårbare Grupper, no date). Another important point was that the group found no reason to distinguish the participants with personal information since the goal for the thesis was to find tendencies in what works and not.

The Data Management Plan (DMP) became to anonymize the research entirely and not handle any personal information. With this project's target group, it was necessary to avoid personal information to the highest extent, which was managed by using aliases and only

observing and documenting behavior in the VR-game. Also, all notes from the testing were noted by the group, so no IP-addresses were ever connected to any participant.

### 3.5.2 Inclusion Criteria

When contacting potential research participants, the team contacted social workers who might know potential participants or others interested, so the invitation went by word of mouth. All participants contacted us regarding the open invitation. The team communicated with parents and social workers to plan each test round. Initially the team wanted to choose either one of the categories mild, moderate or severe ID. However, when reaching out to possible participants a variety of diagnosis' volunteered, but also as mentioned in the theory a diagnosis might not always be accurate to the level of cognitive functioning. In addition, it was hard enough to get volunteers, even outside of the criteria. Dealing with such a complex and sometimes challenging target group, the team decided to allow everyone who volunteered to try. For the participant to be a part of the dataset certain inclusion criteria are applied. The participant should have some level of ID and be able to communicate with the researchers. Lastly, the participant should try to complete the game to the best of their ability. This was to ensure that lack of motivation would not affect the results, contributing to maintain the requirements for scientificity.

### 3.5.3 Four main requirements for scientificity

When conducting research, it is fundamental to secure the scientific nature of the work. Section 2.4.2 Scientific method mentions that the goal of research methods is to gain credible and durable knowledge. Preserving the four main requirements for scientificity is a way to ensure this. Those four requirements are systematic critical reflection, relevance, validity and reliability, and reflexivity. These are addressed in different chapters of the report; critical reflection in discussion, relevance in impact on society and the latter requirements are covered in this section. Validity and reliability regard the extent to which research consistently has the same result if it is repeated under the same circumstances. Reflexivity is how the findings and conclusions are formed by the research process, including bias, using methods eliminating sources of error and revealing the researcher's overall perception of the research activity (Malterud, 2003). The next section will provide a foundation for the approach to the research process, addressing the requirements for scientificity along the way.

### 3.5.4 Research Process

To continuously preserve the requirements for scientificity, it is useful to join with a scientific process such as the one in figure 3 below (Hevner, 2007). This process contains strategies, data generation methods (DGM) and analysis in a compound matter to build a scientific evidence base. This model is used throughout the process. Relevant boxes are marked with a yellow frame. The data generation method "Evaluation" was added due to the "Design"-

cycle in the model by Design Science Research (Hevner, 2007). "Feasibility study" was also an additional feature under strategies.

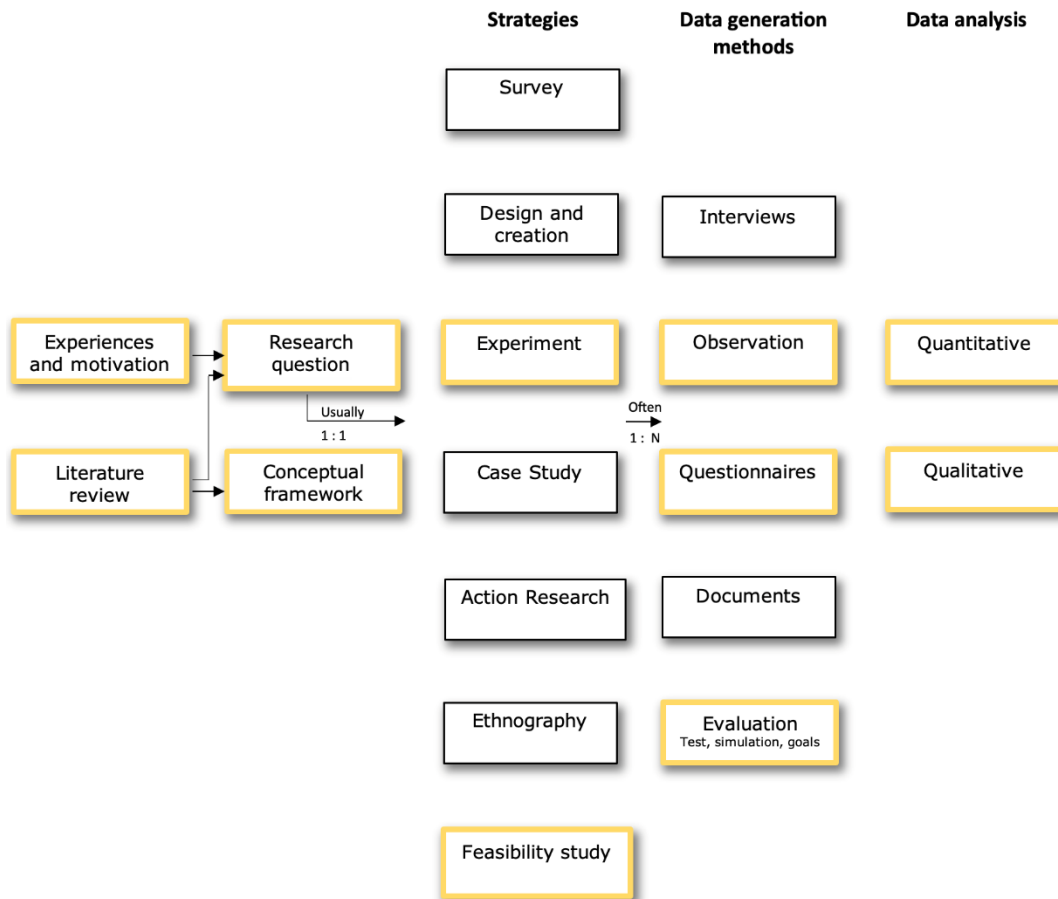


Figure 3: Research process

The team used this model and followed it respectively, so the explanation of the model contains the actual process in this research. The following section will address the implementation of each box.

**Literature review:** Initially a broad literature search was done to gather relevant information on the target group, General Data Protection Regulation (GDPR), research methods, and VR. Literature search is a thorough systematic search for published literatures to identify relevant information (Doing a literature search: a step-by-step guide, 2022). With this the team found appropriate terms for diagnoses, technologies, and methods. The discovered information built a solid foundation for the research and development of the game. An interesting discovery was the lack of research on VR and this target group, particularly regarding practicing routines. The results from the literature search showcased a solid potential for VR in education and that VR for people with ID is advantageous, but there is need for evidence-based work on design features and utilization.

**Experiences and motivation:** The team's experience with development and the target group was the motivation for researching VR for people with ID.

**Research questions:** The research questions are based on knowledge of the target group and the other studies on VR for people with ID. Since many of those studies were conducted on tablets and target groups with a variety of diagnoses, there were not any recommendations on further research on the selected topic. Which is considered a gap in the research market. Therefore, the intention was to start filling this gap. The finished formulated research questions are:

“Can people with ID master an adapted fully immersive VR game?”

“How can a fully immersive game in VR best be developed for people with ID?”

**Conceptual framework:** The chosen conceptual framework was to ensure quality of the research. This research enhances validity by method triangulation, time triangulation and investigator triangulation. This means the study used two or more data generation models, took place at two or more points in time and was executed by two or more researchers comparing results (Oates et al., 2022). Choosing several data generation methods (DGMs) created more data and validated results, since several methods could confirm results. This conceptual framework was one way to meet two of the requirements for scientificity, reliability and validity.

**Feasibility study:** Feasibility study was the chosen strategy for the first research question: “Can people with ID master an adapted VR game?”. A feasibility study is often used in the beginning to figure out if the research is viable. A feasibility study reveals if the topic is possible to research further, how the research may be formed and what to focus on. In addition, it may also disclose any modifications needed in the research method (Bowen et al., 2009). As mentioned in theory, such inductive methods are used to gain understanding and increase the team’s knowledge on the topic. Since the first research question simply aimed to answer if there was a probability that people with ID can master a fully immersive VR game, a feasibility study was a well-suited strategy.

The feasibility study was performed by having six participants test the first VR-game based on a morning routine. An important part of working with the target groups was to use a pedagogical approach, this was done by socializing, explaining, and demonstrating the game. The feasibility study had a great impact on modifications of the planned research. Details and scientific background for the modification in research are described in section 3.5.4.1 Adjustment of research questions. It is recommended to read section 3.5.4.1 and then come back to the next paragraph, Experiments.

**Experiments:** For the second research question, both experiment and case study were proposed strategies. An experiment tries to confirm or deny a hypothesis by looking at the causes and effects of an event. A case study, on the other hand, offers great validation to the results by performing an in-depth analysis of the research (Janse van Rensburg et al., 2013). Since the team is looking to confirm findings rather than gain understanding, a deductive method like experiment suits this study the best. Due to the extent of the project, also a case study would require testing of many helping aids with different combinations. To fit the scale of the thesis, the team decided that collecting a larger amount of superficial data about the effects of the helping aids over multiple experiments would be beneficial over an in-depth case study with fewer helping aids and participants.

The experiments were performed twice on 8 participants and once on 2 participants. With the feasibility study, three rounds of testing were conducted on a total of 9 participants. The procedure was the same as in the feasibility study, except there was no demonstration of the game to keep validity of the research. If the demonstration showed the participants how to play the game, it would be impossible to say if the assisting tools work. However, the team did create scenes in Unity called practice room. The intentions behind the practice room were to ease the user into the game, using buttons and orientation.

**Questionnaires, observation and evaluation:** The DGMs in the feasibility study were observation, questionnaires and evaluation. The team took note of interventions and issues in the game. Thereafter, observations and answers to questions were noted in the questionnaire in appendix 1. To ensure reflexivity and inner validity in the requirements for scientificity, leading questions were avoided, including yes/no or true/false questions, as they can be perceived as leading for this target group. The last part of the feasibility study was discussion and comparison of observations amongst the researchers.

**Qualitative and quantitative:** To analyze the collected data both qualitative and quantitative analysis were performed. Even though most of the generated data was qualitative, a quantitative analysis was applied, creating statistical models to interpret the results. An example of the data analysis is the quantification of how many participants needed help with the use of each button.

#### 3.5.4.1 Adjustment of Research Question and Research Process

Initially there were several suggestions to research questions. One which the team kept in mind was: "Can people with ID benefit from practicing routines in VR games?" This question was discarded after the feasibility study, where the need for better design and guidance through the game was revealed. This need was also supported by the literature search.

As the second research question was composed the team reassessed the effect goals. The updated effect goals are the following:

- Contribute to increase the combined field of research of VR and people with ID.
- Seek scientific results about elements in VR that work for people with ID.
- Seek a valid scientific evidence base.

A model which describes the reasoning behind the change of research question is listed below in figure 4: Technology Acceptance Model (TAM). This model predicts the likelihood that an individual or group of people would adopt a new technology (Alfadda and Mahdi, 2021). The feasibility study located the current state of this topic in "Perceived Ease of Use" which implies the degree to the target audience believing playing the VR game would be free of effort (Alfadda and Mahdi, 2021). The model shows that ease of use needs among other things to be fulfilled before actual system use. A requirement for effect is that the system is being used, meaning that developing a game that is easy to use needs to be prioritized before measuring effects.

To investigate ease of use with this target group, and respectively answer the second research question, the new game situated in a supermarket was to contain a variety of

assisting tools and features to achieve desired behavior. These tools will be tested and then evaluated.

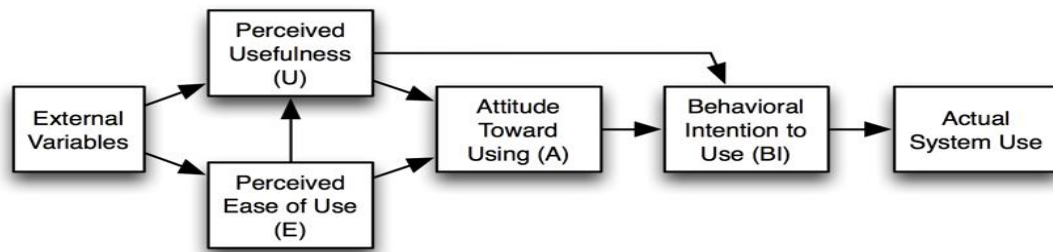


Figure 4: Technology Acceptance Model

## 4. Results

This chapter will firstly describe administrative results, then the Engineering results from the development of the VR-game in a supermarket, where each assisting tool is explained. Lastly, will the scientific results from the feasibility study and experiments testing the different assisting tools be presented.

### 4.1 Administrative

During the execution, the project progress has been tracked by a Gantt-diagram, timetable and Kanban board. This section will provide further details on the outcome of this progress.

The Gantt-diagram and timetable were closely connected. The activities listed in the Gantt-diagram were used in the timetable to log the number of hours spent on a specific activity. Activities, with their belonging artifacts, were planned in the first week of the project. The Gantt-diagram was updated around twice a month, while the timetable was updated every working day. Once a week the team wrote a status report in the timetable. After the change of research question, some activities and artifacts were proportionally changed. In the end, some activities had a significant difference between artifacts like planned start and actual start, planned duration and actual duration, as well as planned hours and actual hours. Examples of activities with a high contrast in hours are theory in main report, method in main report, creating and presenting poster and research.

One activity in the Gantt-diagram was normally split into several more specific Kanban cards on either the Kanban board for documentation/research or the other one for development. The team was consistent with having maximum two cards each on the “working on it” category. Before beginning a task, the team assigned themselves a card and moved it to “working on it”. Kanban cards were frequently moved to different categories fitting for the current status of the task. At the end of the project, 195 cards were present on the development board and 90 cards on the documentation/research board. The figures below show the final documentation/research and development kanban board.

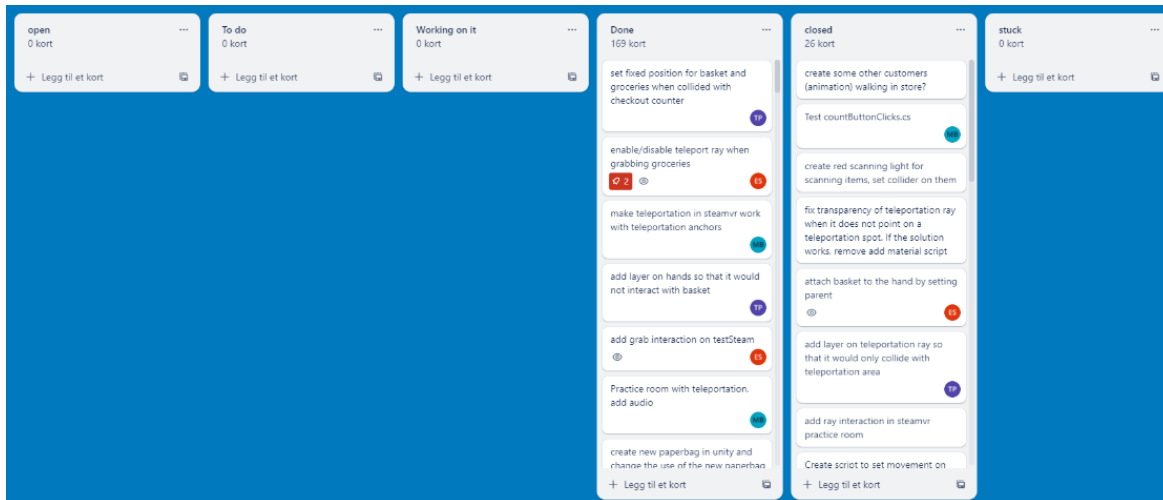


Figure 5: Final Development Kanban Board

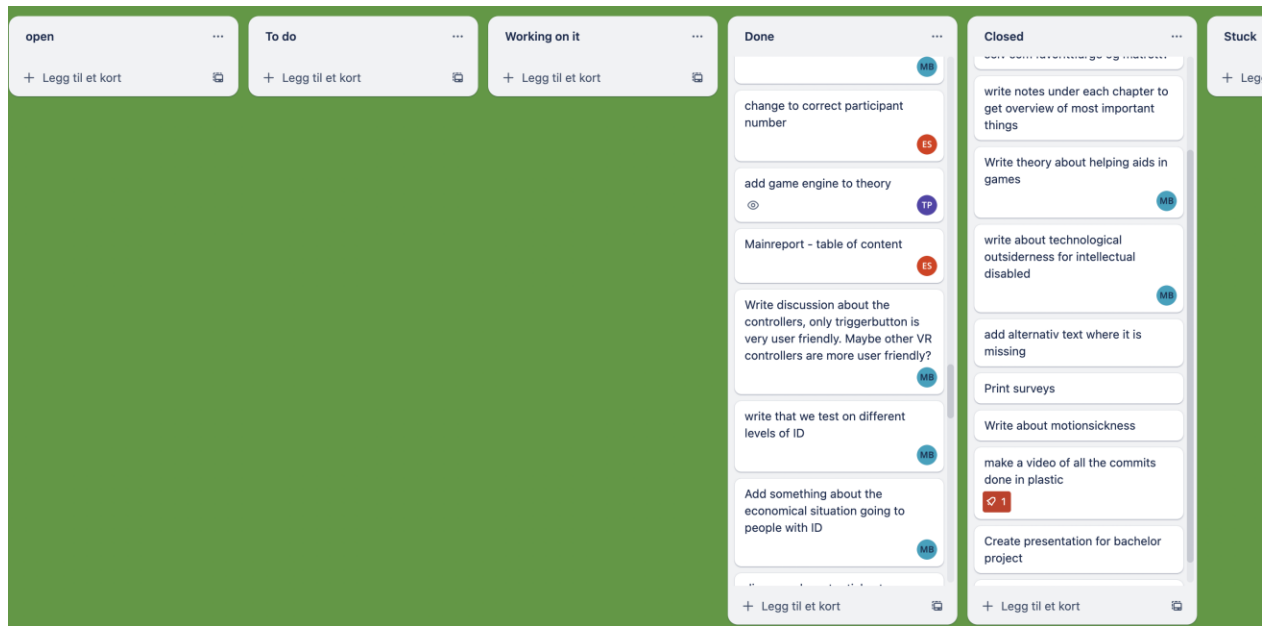


Figure 6: Final Documentation Kanban Board

Using Plastic SCM for collaboration functioned well during the development. The team ended up with a total of 517 commits, shown in figure 7 below. The developers branched out to create new features before merging into the main branch. Figure 8 shows the graphical user interface in Plastic SCM during the development where the uppermost branch is the main branch.

Name	Creation date	Created by	Comment	Branch	Repository	Guid
517	12.05.2023 15:27:16	eirin.svinsaas@gmail.com	merge	/main	DinRutine_SuperMarket@met@cloud	aa637e33-8f8b-4b19-b-
516	12.05.2023 15:23:57	eirin.svinsaas@gmail.com	details on building	/main/cleanup	DinRutine_SuperMarket@met@cloud	e147d080-f59f-4ec3-b8
515	12.05.2023 15:21:09	eirin.svinsaas@gmail.com	metadata	/main	DinRutine_SuperMarket@met@cloud	8a0b14ed-ec93-414c-b-
514	11.05.2023 11:20:18	maikebre@stud.ntnu.no	rescale	/main/cleanup	DinRutine_SuperMarket@met@cloud	2a4b7f29-fd7b-4860-8-
513	11.05.2023 11:11:58	maikebre@stud.ntnu.no	Rescale	/main/cleanup	DinRutine_SuperMarket@met@cloud	79c78b26-e71a-4b17-8f
512	10.05.2023 11:05:44	Thadshajini Paramsothy	Initial commit	/main	DinRutine_SuperMarket@met@cloud	109464fd-40d3-427a-a
511	09.05.2023 14:06:05	eirin.svinsaas@gmail.com	bugfix	/main	DinRutine_SuperMarket@met@cloud	f194fd8a-ab71-4522-92
510	05.05.2023 15:06:21	eirin.svinsaas@gmail.com	done documenting scripts	/main	DinRutine_SuperMarket@met@cloud	4ca85c36-b7af-4020-b
509	05.05.2023 14:37:40	eirin.svinsaas@gmail.com	itemscollidewithbasket documented	/main	DinRutine_SuperMarket@met@cloud	b81e6be2-42f0-4dc8-9-
508	05.05.2023 14:25:52	eirin.svinsaas@gmail.com	documenting scripts	/main	DinRutine_SuperMarket@met@cloud	f01a0c9d-bdab-4053-9-
507	05.05.2023 13:42:36	eirin.svinsaas@gmail.com	documenting code	/main	DinRutine_SuperMarket@met@cloud	2dd3e4b9-c076-4574-e
506	05.05.2023 13:16:30	eirin.svinsaas@gmail.com	deleted unused scripts	/main	DinRutine_SuperMarket@met@cloud	7e9cce5ab-6f4d-458f-b3
505	05.05.2023 09:43:49	eirin.svinsaas@gmail.com	position anchors practice room	/main	DinRutine_SuperMarket@met@cloud	3a5740ac-3177-44a1-b-
504	05.05.2023 09:38:12	eirin.svinsaas@gmail.com	documenting distance scripts	/main	DinRutine_SuperMarket@met@cloud	c6e84749-e959-4611-9-
503	05.05.2023 09:17:42	eirin.svinsaas@gmail.com	documented DisableColliderTopsOnBa	/main	DinRutine_SuperMarket@met@cloud	206c2a85-a4c5-4069-f
502	05.05.2023 09:06:30	eirin.svinsaas@gmail.com	controlOutline script documented	/main	DinRutine_SuperMarket@met@cloud	c3d4848c-bbdf-44e5-b-
501	04.05.2023 14:58:54	eirin.svinsaas@gmail.com	documented checkout	/main	DinRutine_SuperMarket@met@cloud	f6dd1a35-49d8-406c-8-
500	04.05.2023 14:24:27	eirin.svinsaas@gmail.com	documentation for CanvasForCashOut	/main	DinRutine_SuperMarket@met@cloud	b07cb3ca-4ddf-439a-a
499	04.05.2023 14:15:55	eirin.svinsaas@gmail.com	removing unused imports	/main	DinRutine_SuperMarket@met@cloud	3d06f462-ebc1-407c-8-
498	04.05.2023 14:06:58	eirin.svinsaas@gmail.com	documentedand changed basket on cl	/main	DinRutine_SuperMarket@met@cloud	662540a6-2570-4b69-f
497	04.05.2023 14:00:44	thadsha1710@live.no	removed unused script	/main/walkingFinal	DinRutine_SuperMarket@met@cloud	96ae05e8-f23c-4d3e-9-
496	04.05.2023 13:59:39	thadsha1710@live.no	fixed audio on practiceroom	/main/walkingFinal	DinRutine_SuperMarket@met@cloud	38e40958-6da7-470e-f
495	04.05.2023 13:57:40	maikebre@stud.ntnu.no	Added soundclips	/main/walkingFinal	DinRutine_SuperMarket@met@cloud	4fea3927-0917-4216-9-
494	04.05.2023 13:47:19	thadsha1710@live.no	added hand layer on right hand	/main/walkingFinal	DinRutine_SuperMarket@met@cloud	3a912dd7-c67b-405e-8-
493	04.05.2023 13:43:27	thadsha1710@live.no	added hand layer on right hand	/main	DinRutine_SuperMarket@met@cloud	28ab55bd-cccc-43db-8-

Figure 7: Last Changesets



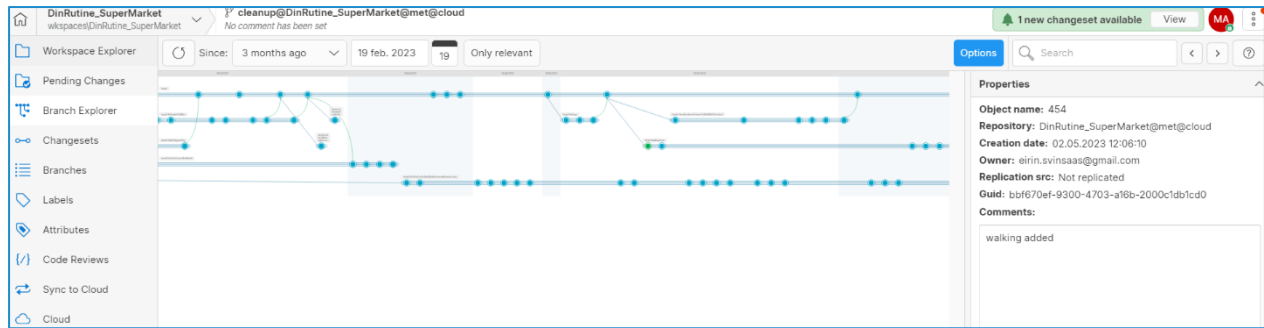


Figure 8: Branches in Repository

## 4.2 Engineering

The non-functional requirements from attachment C are listed in table 3 below.

Non-Feature Requirements	Fulfilled	Not fulfilled
The system should use a building environment.		X
The system should use version control on NTNU's GitLab.		X
The system should be runnable at deadline.	X	

Table 3: Non-Feature Requirements

The functional feature requirements are listed below in table 4.

Feature Requirements	Fulfilled	Not fulfilled
The system should contain five tasks or more, it should be a trip to the supermarket.	X	
The system should contain necessary adjustments to be user friendly for people with ID such as audio and visual support.	X	
The system should contain features that allow the user to pick some features.	X	
The system should be a trip to the supermarket, containing things like picking items, scanning them, teleporting around, and paying by card.	X	

Table 4: Feature Requirements

The development resulted in a functioning VR-game based in a supermarket, settings room, and practice room. In these scenes there were in total 9 assisting tools and features used for research.

The practice room, displayed in figure 9 below, is an independent scene that allows user to test features and buttons before starting the supermarket game. Teleportation points, arrows, canvas (UI) play bowling and audio are elements in this scene.

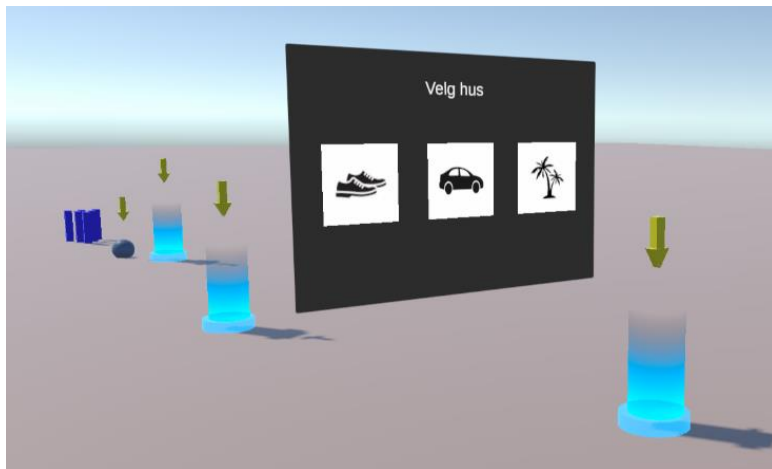


Figure 9: Practice Room Scene

A part of the Settings scene is shown in figure 10. In this scene the player can enter a chosen pin code, choose their favorite color and pick a dinner to shop for.



Figure 10: Settings Room Scene

A view of the supermarket is displayed in figure 11 below. The Grocery basket, self-checkout and paper bag were created from scratch by the team with blender.



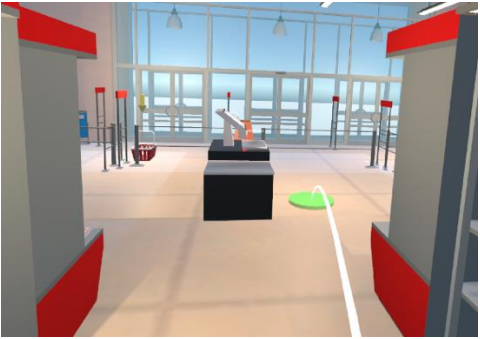



*Figure 11: Super Market Scene*

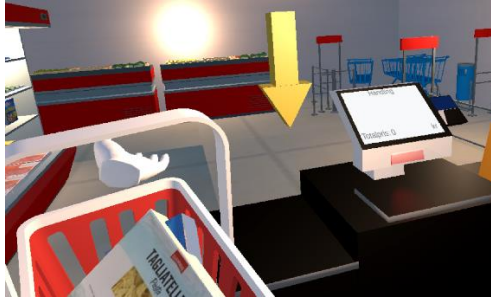
An overview of all the tasks in the supermarket game.

Task 1	canvas in settings
Task 2	grabbing and holding basket
Task 3	teleporting
Task 4	placing groceries in basket
Task 5	go to self-checkout
Task 6	place basket on checkout
Task 7	scan groceries
Task 8	put groceries in bag
Task 9	pay with card
Task 10	enter pin code

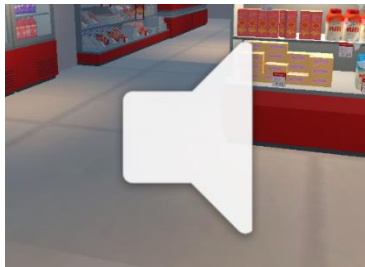
*Table 5: Description of Tasks in Grocery Shopping Game*

Table 6 below displays the tested functionalities with an image and description.

Image	Description
	<p>Free teleportation: Teleports to the green reticle when trackpad is pressed.</p>
	<p>Teleportation points: Teleport user to the blue cylinder when trigger button is pressed.</p>
	<p>Continuous Movement: Moves user the direction the trackpad is pressed. Simulates walking.</p>
	<p>Outline and particle systems: Highlights an object to indicate action.</p>



Blinking arrow:  
Highlights object or area to indicate action



Audio Clips:  
Audio was used to describe tasks, create realistic features, and reward correct actions. Examples of used audio clips are the beep sound for scanning a grocery or the feedback when the user collects correct item in the grocery basket.



UI/Canvas:  
Canvas to inform user or retrieve information. Interactive and informative canvas are displayed on the side.




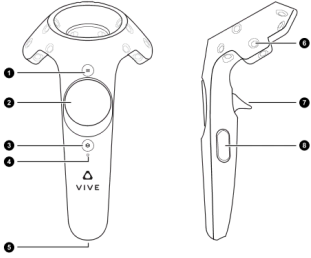
	<p>Virtual controller with highlighted buttons:</p> <p>Virtual controller that highlights which button to use appear when interaction is needed. Button for teleportation is trackpad and button for grabbing is grip.</p>
	<p>Buttons:</p> <p>Buttons for picking up objects the grab (8) and trigger (7) buttons were tested. For movement the trackpad (2) and trigger button were tested and lastly, for UI the trigger button was tested.</p>

Table 6: Assisting Tools and Feature

## 4.3 Scientific

### 4.3.1 Feasibility Study

This section will showcase the results from the feasibility study done. In addition to playing the morning routine game, participants got the opportunity to play other games available in Steam. A visualization of the need of help for each participant in the morning routine game is displayed below in figure 12 and the average is in figure 13.

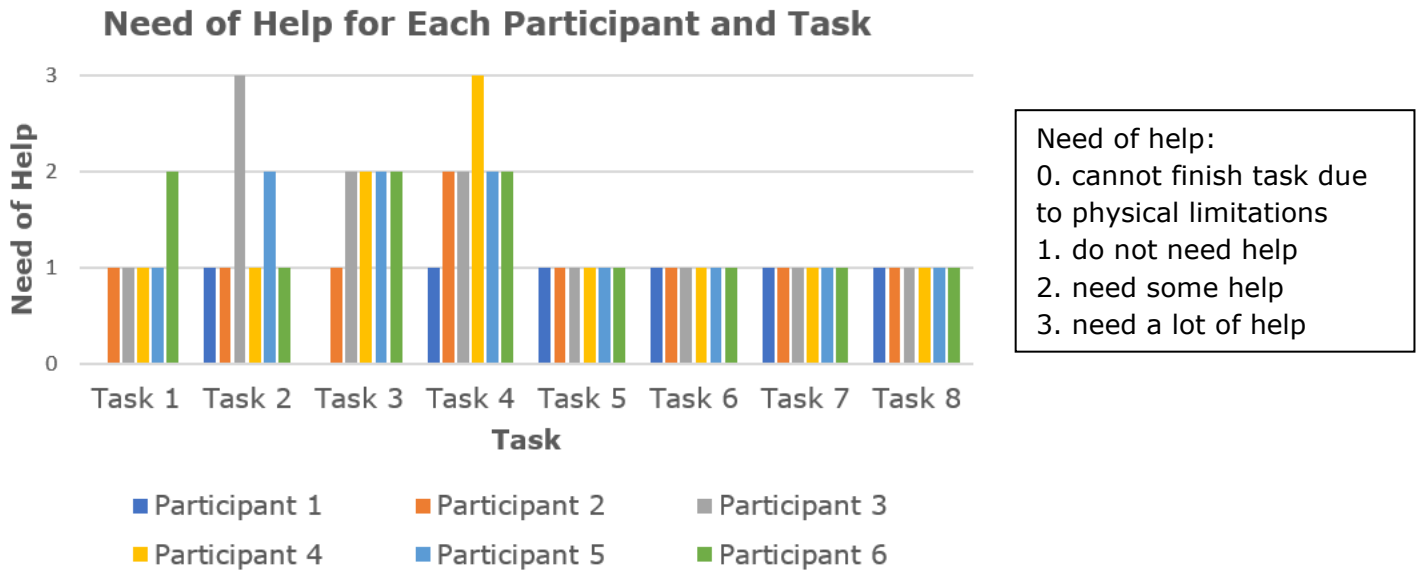


Figure 12: Results for Need of Help

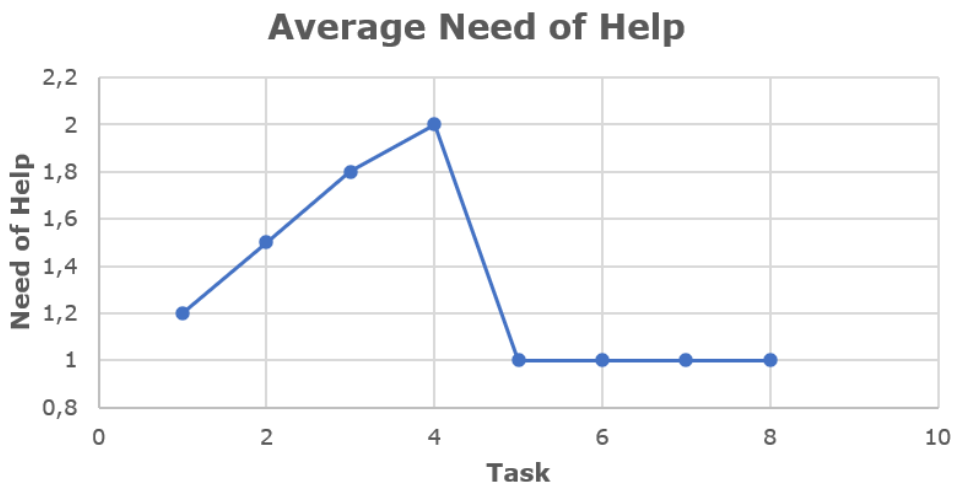
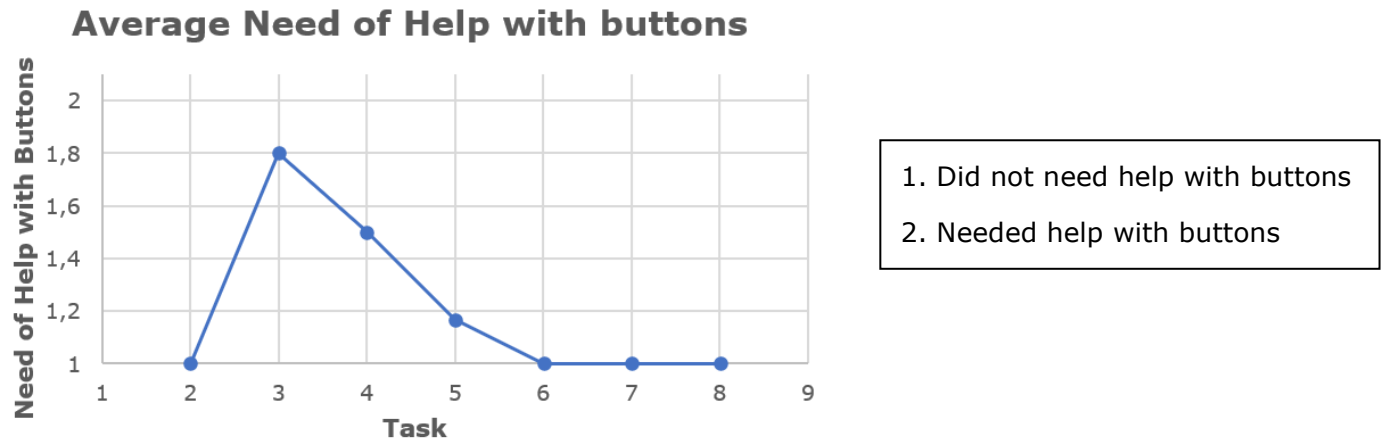


Figure 13: Average need of help for each task



*Figure 14: Average Need of Help due to Buttons*

Written observations from the feasibility study reveal that almost all the help needed was due to difficulties with the buttons. Task 3, the first task to use the grip button, had the highest need of help. Displayed in figure 14, the need for assistance in the game dropped for task 6, 7 and 8, which also uses the grab button. Other noted observations were that participants recognized the surroundings in all the games they played and had a decent understanding. When asked how they felt using VR, most of them answered that it was ok, and some said it was strange. The morning routine game used coded teleportation and no problems were observed. Short and precise audio clips seemed more successful compared to longer clips. Participants also agreed that audio was helpful. The UI pictures remained unused by all participants.



### 4.3.2 First Experiment

This section contains the results from the first experiment with the supermarket. The functionalities tested in this experiment are displayed in table 7 below.

Movement	Free teleportation
Grabbing objects	Trigger button
Interacting with UI	Trigger button
Teleportation	Trackpad button

Table 7: Tested Functionalities

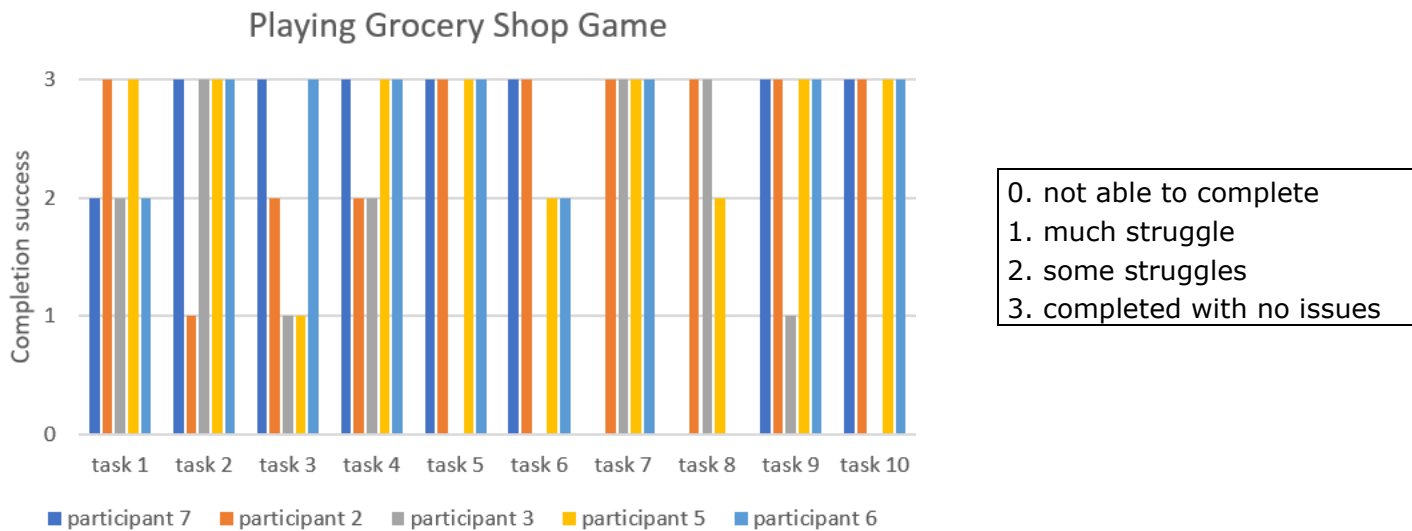


Figure 15: Visualization of Each Participants Success Rate For each task

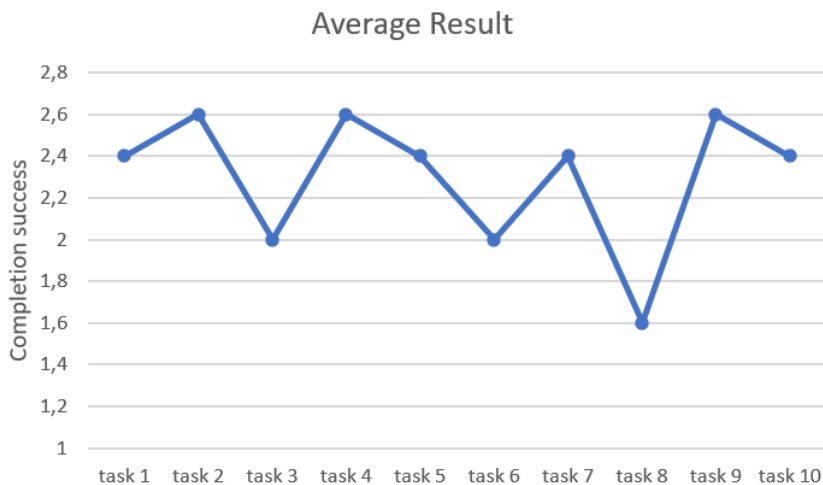


Figure 16: Average Success Rate for Each Task

Figure 16 shows calculated mastery of each task in the game. In total the average success of the tasks was 2,3.

During the first experiment the team observed the following:

- The main issue was movement. Free teleportation was oversensitive and caused spontaneous teleportation.
- Participants had issues holding the grocery basket over a longer period. Unintentionally teleporting without the basket. A lot of time was spent on teleporting between shelves to pick up the dropped basket.
- Some struggles with placing groceries in the grocery basket and them staying in there while moving around. There were also issues with coordination when placing basket on cash out, groceries tend to fall out, so participants spend time picking them up.
- It was also observed that the participants had a harder time picking objects from the floor, than higher up in the shelves.
- Practice room introduces functionality and use of buttons. There is no need for a demonstration of the game, but some explanation for teleportation was needed. The audio is understood and used to a higher degree. All participants managed to pick up the bowling ball and interact with canvas without any issues. Free teleportation caused spontaneous teleportation in practice room as well.
- Issues interacting with two or more buttons separately. The buttons were pressed simultaneously, and participants struggle to use the trackpad.
- Participants understood how to interact with UI and the meaning behind their choices. Anyhow, confusion occasionally arose when multiple questions or elements were combined in a single canvas. Choosing simple pictures had the highest success rate. The informative UI was only used by one participant.
- Visual issues with identifying outline.

### 4.3.3 Second Experiment

This section will showcase the results from the second experiment in the supermarket game. The tasks were the same as in the first experiment, but with some adjustments of the

features, see table 9. Functionalities tested in this experiment are displayed below in table 8.

Movement	Visual teleportation spots and ray appearing when needed
Grabbing objects	Trigger button
Interacting with UI	Trigger button
Teleportation	Trigger button

Table 8: Functionalities in Experiment Two

Task	Functionality	Change
Task 1	Canvas in settings	
Task 2	Grabbing and holding basket	Basket sticks to the hand from the beginning of the game
Task 3	Teleporting	Teleportation is only allowed at certain spots. These spots are highlighted with a blue cylinder. The teleportation ray and spots are only enabled and visible when they need to be used. Button is also changed to trigger.
Task 4	Placing groceries in basket	Secured grocery basket with layers and extra colliders
Task 5	Go to cashout	Teleportation spots guiding
Task 6	Place basket on cashout	Automatic position when colliding
Task 7	Scan groceries	Improved position on groceries due to automatic positioning of basket
Task 8	Put groceries in bag	Improved position on groceries due to automatic positioning of basket
Task 9	Pay with card	arrow over terminal
Task 10	Write pin code	

Table 9: Tasks with their functionalities and changes

A total of nine participants played the supermarket game in the second experiment.

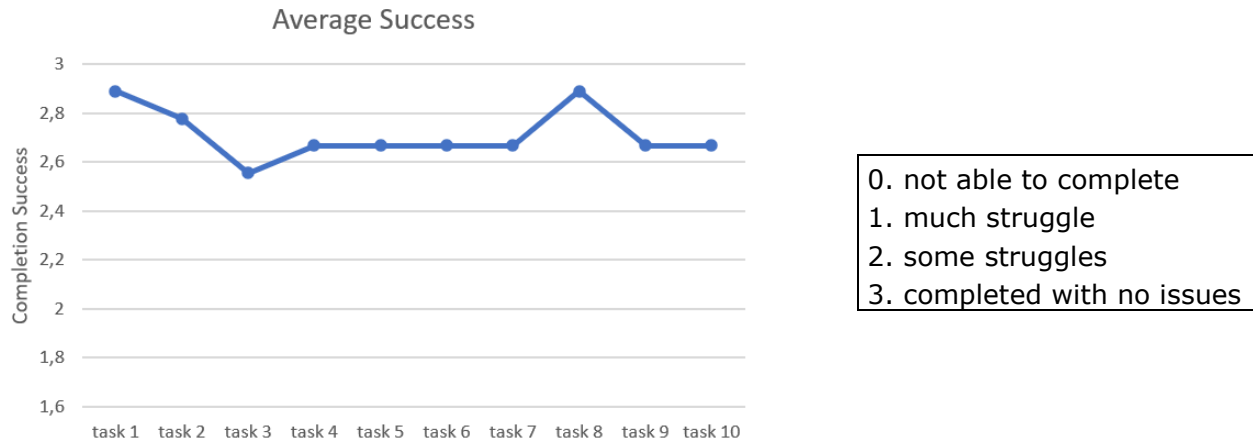


Figure 17: Average Success Experiment two

Average result for the completion success of the tasks was 2,7, which resulted in an improvement of approximately 17%.

During the second experiment the team observed the following:

- Walking: Motion-sickness was a concern, but none of the participants noticed any change in their general health. Mostly, the participants liked this feature better than teleporting. They tended to move physically instead of using continuous movement. The trackpad button was often accidentally pressed, leading to unintended movement. After some practice and assistance, a lot of the participants were able to move controlled around the store. However, they ended up skipping the tasks to explore the store. Two participants tested the walking function with an additional helping tool, yellow arrows on the ground to create a path. This slightly improved the number of tasks they were able to finish.
- Virtual hands modeled as HTC Vive Controllers with blinking button was only tested on three participants. The participants did not often hold the physical controllers high enough to see the virtual blinking buttons. Another issue was that the correct button got pressed but was released before the ray was placed on a teleportation spot.
- Issues measuring distance between hand and the objects meant to be picked.
- Informative UI was not used by any participant.
- Practice room: Overall, it seemed like the participants managed to teleport more independently and faster in the practice room compared to the supermarket. When teleporting to the bowling ball, the participants often pointed directly at the bowling ball instead of using the teleportation point besides. Apart from that, the teleportation, canvas interaction, and grab and throw interaction were successfully performed. Two out of nine participants still struggled with pressing buttons.
- Groceries rarely fell out of the basket, including at the checkout.

#### 4.3.4 Comparison of First and Second Experiment

Five participants participated in both experiments. Figure 18 below compares these results. Those five participants had in total average of improvement is approximately 23%.

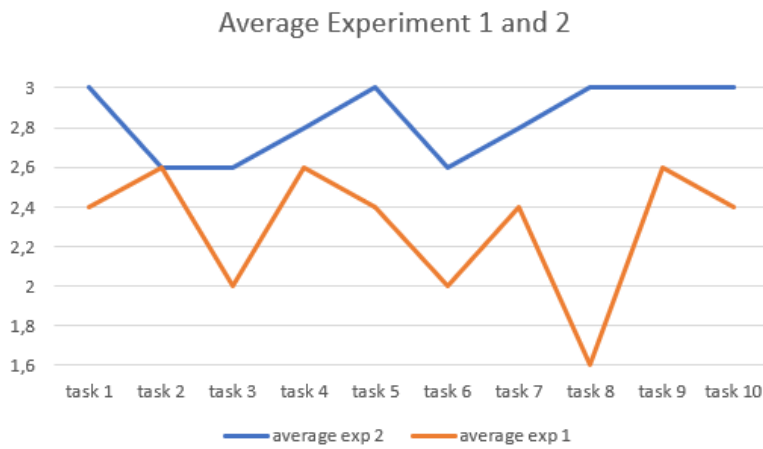


Figure 18: Completion Success Comparison of Experiment One and Two

Figure 19 below shows the time spent on completing the supermarket game in the first and second experiment for the five participants. Average time in experiment one is 11 minutes and 45 seconds. That is 6 minutes and 48 seconds more than the average time of experiment two, which is 4 minutes and 56 seconds. Overall, the time used to complete the game in experiment two had a reduction of 50,43%.

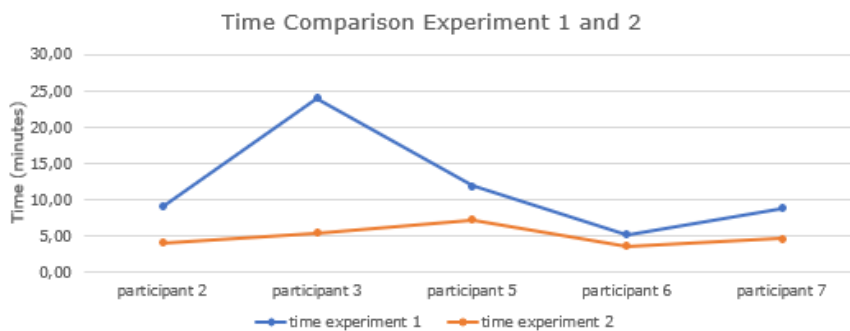


Figure 19: Time Comparison Between Experiment One and Two

#### 4.3.5 Questionnaire

Seven participants answered the questionnaire shown in appendix 2, which contains questions about the game and their personal preferences. The results from the game questions are presented in figure 20. All participants answered correct on the first question about the blinking arrow. After some guidance, all participants were able to understand the informative UI. Question three checked if participants were able to understand logic behavior, such as if they were able to determine where to tap the credit card for payment without relying on a guiding blinking arrow. Five of the participants answered correctly on

that question. All the participants except one answered correctly on the fourth question, regarding UI interaction. Few participants answered correctly on the last question, asking about what kind of guidance the outline and yellow footprints were supposed to indicate.

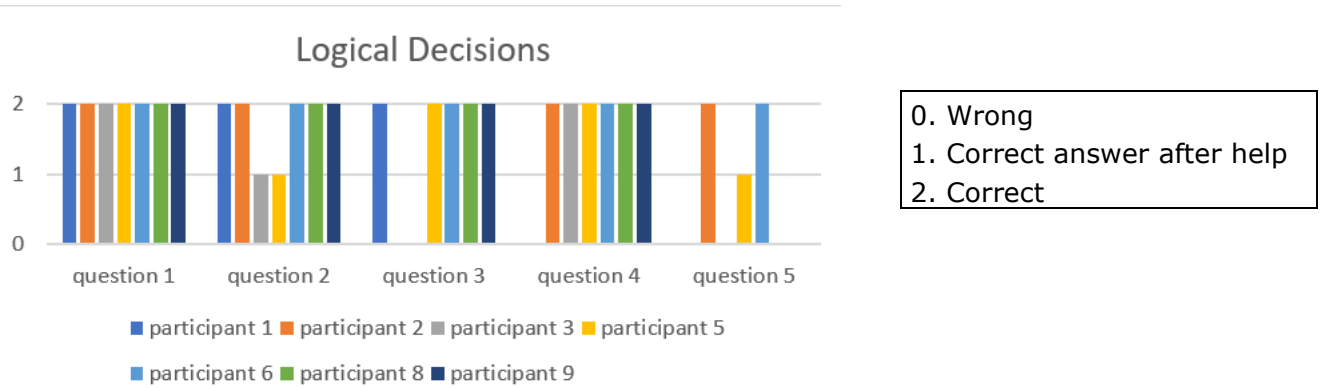


Figure 20: Results from Questionnaire of Logical Decisions

The participants were also asked about which VR game design they preferred, and the results were illustrated into the diagrams in figure 21 below. In the question about preferred hand model in the VR world, 29% of the participants did not have an opinion and 43% of them liked having virtual hands modeled as realistic hands instead of virtual HTC Vive controllers.

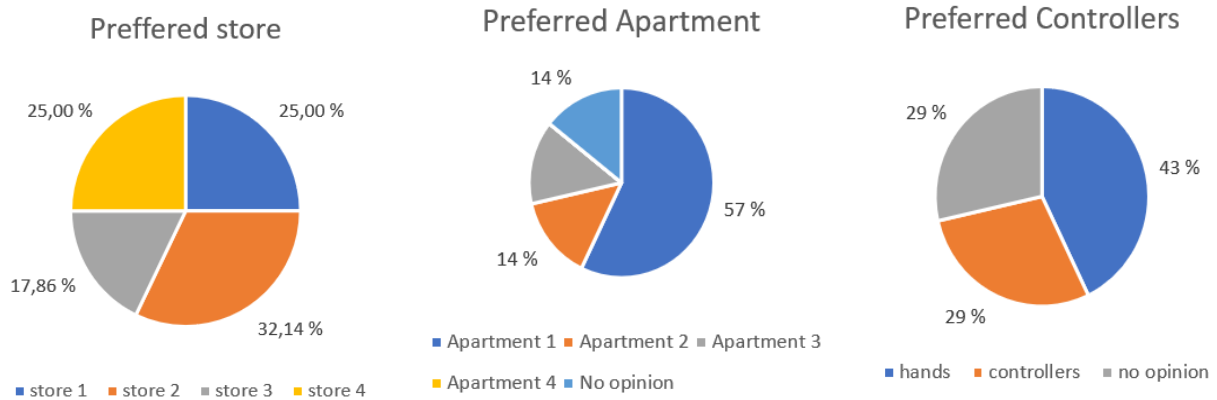


Figure 21: Results from Participant's Preferences

# 5. Discussion

The results in chapter 4 will now be discussed. Firstly, administrative results will review the work process. Secondly, the engineering results will look at the functionalities. Then, the scientific results will be discussed and finally, the validity of the research will be addressed.

## 5.1 Results

### 5.1.1 Administrative

Administrative results showed how the different elements like Gantt-diagram, timetable and kanban board were used by the team to keep track of progress. The relative success of using Gantt and kanban will be discussed in the following section.

The Gantt-diagram ended up with some inconsistencies regarding the artifacts: planned start, actual start, planned duration, actual duration, planned hours and actual hours. This is to be expected because tasks in development vary in time. Not everything can go according to plan, but what is interesting are the reasons behind the divergent in the diagram. For instance, higher time consumption than anticipated on the theory and method chapters in the main report, was caused by research. Finding correct content and relevant information took longer than expected. Considering that the research activity had much lower time consumption than anticipated, this makes sense. Therefore, some of the time allocated to theory and method should have been attributed to the research activity.

Furthermore, the activity "create and present poster" had inaccurately planned and consumed time. Creating the poster and change of research question happened at the same time, so the team had several unfinished tasks simultaneously. Which caused the time consumption on discussion of the research question to fuse into the poster activity which should be on project administration instead.

Inconsistency in duration was likely caused by initializing a task, that was temporarily paused until necessary information obtained. Differences in planned and actual start on documentation could have been caused by not having the time nor the information to solve that task. Whereas delayed start in development could be caused by discovering different needs in the experiments like solving bugs, developing new functionalities. Such issues had to be solved along the way before continuing the other commenced task.

Overall, it was challenging to anticipate the exact start and duration of tasks. One reason was that the time management of the project depended on when participants in the study were able to visit the lab. Also, this research had to take form along the way, priorities were changed as new issues emerged. Even though some of the activities did not end up exactly as planned, the team was content with the choice of Gantt-diagram. Having an overview of the time management early in the process kept the team on track with time delegation and codependent tasks. It ensured a runnable game to test for each experiment and research, with necessary fixes. Since the milestones were bigger tasks, updating around twice a month worked well and gave the team a holistic perspective throughout.

Dividing the milestones into smaller tasks in the Kanban board worked well. Kanban's focus on attaining progress by encouraging to finish a task before initializing a new one, made sure the workflow was steady and prevented bottlenecks. In addition, actively using the board kept the team informed about each other's work and prevented several members from working on the same task.

### 5.1.2 Engineering

As the preface states, this is a self-defined thesis. The team was therefore responsible for establishing the system requirements for the game. The intentions were to have general requirements for a functioning game.

The non-functional requirements, however, were not all completed. The first demand, about a building environment was not implemented. At the time of forming the requirements the direction of research and development was not fully decided yet. After the change in research question the focus shifted towards research, so the resources were dedicated to have a functioning game with assisting tools for the research. Therefore, creating a building environment and having a releasable product was not prioritized. As for the second non-functional requirement, using version control on NTNU's GitLab, was not fulfilled due to the use of Plastic SCM, described in chapter 3.1.3. The team consider this a good choice, since the collaboration became easier, and quality of the project increased.

In retrospective, there are other non-functional requirements that could be relevant. Such as implementing some universal design. However, this happened naturally because during the development, decisions were actively made to make the system fit the needs of all people. To exemplify, developing blinking effect instead of just adding yellow outline and arrow, to suit vision impairments. Another example is the contrast colors and large text on UI elements.

As seen in the results, all the functional requirements were completed. However, there could be some potential improvement regarding the priorities of the functional requirements. With the time frame, developing a game like the supermarket took an excessive amount of time. Generally, the team would prefer to spend more time on experiments investigating the assisting tools, creating even stronger empirical evidence for the findings. However, the process was affected by duration of development and when the participants were able to schedule a visit to the lab. After the feasibility study the to-do list was filled with different assisting tools to develop and such development takes a long time. By narrowing down the number of assisting tools simplifying the game there would be more time for research. Something that could have been excluded is the practice room with SteamVR's HTC Vive – model as virtual hands, considering there was not even enough time to fully research this helping tool. The team could also have saved some time having simpler design and less distractions in the supermarket. Just configuring the supermarket consumed a lot of time. The game would be completed earlier in the process and an extra experiment could be conducted. In an extra experiment the team would investigate the effect of practice room and build sufficient empirical evidence for the virtual hands modeled as HTC Vive Controllers with blinking button. On the other hand, the team perceived that the game's theme contributed to increased motivation, which could have been a possible factor for increased



completion ability. Either way, the team considers the execution and evidence base satisfactory. Meaning the results, the team will draw conclusions from are adequate and relatively accurate.

### 5.1.2 Scientific

The first performed research strategy, feasibility study, was conducted to see if researching the topic would be viable and seek an answer to the first research question, "Can people with ID master an adapted VR game?". All participants in the study were able to play the game, and the overall impression was that they enjoyed playing games in VR. The three pillars of VR described in section 2.2.2, Immersion, Presence, and Interactivity, were all present for the participants. They immersed themselves in the game, understanding the surroundings and interacting with them. This impression continued throughout the other experiments as well, validating those results.

After the feasibility study confirmed that further research was viable, the next experiments took place focusing on the second research question, "How can a game fully immersive VR game best be developed for people with ID?". Between the experiments performance was vastly improved and the need for assistance and time decreased. This indicates that the implemented changes in the games made the VR-game more accessible. To understand the modifications properly, each assisting tool is assessed below and at the end of this section some potential improvements are discussed.

**Buttons:** In all three rounds of testing, some issues with the use of buttons were observed. However, there is a big decrease in need of assistance in the last experiment. The findings here are that the grab button on the physical HTC Vive controller is located out of reach, excluding this button improved the ease of use. Then the trackpad caused issues in the second round of testing. The trackpad seems to require tactile control and abstract understanding. Since it was often pressed together with the trigger button, causing simultaneous actions. The most promising results were only using the trigger button for every action. It is important to mention that there should be only one possible action available at a time.

**Movement:** Four types of movement were tested, free teleportation, teleportation points, continuous movement, and coded teleportation. Teleportation points and coded teleportation was the least troublesome, whereas free teleportation became very challenging for the participants. The participants were unable to coordinate free teleportation and needed continuously assistance. It was poorly understood and difficult to coordinate. Teleportation points works decently, but not all participants understood its functionality right away. An audiovisual remainder could ensure proper usage or having only the next teleportation point visible can increase ease of use. This is due to each task being completed before continuing the game, narrowing down the focus to just the next step. Lastly and the most interesting discovery when researching movements, was participants liking towards continuous movement. Continuous movement open for a lot more freedom but requires better coordination. However, with some trial and error several participants managed. The freedom of using continuous movement was a distraction from the tasks, but by highlighting a path the focus was partially regained. The surprising tendency was that continuous movement

was the preferred type of movement, and that it did not cause nausea. When developing this feature, continuous movement caused nausea for the developers who are experienced VR-users. Relevant literature explained a different experience of immersion in games for people with ID. This might contribute to the absence of nausea for this target group, thinking that their lowered cognitive functioning can create a presence in VR that experience the movement differently.

**Audio:** The experiments relied heavily on audio to explain tasks and there were no issues taken note of. Audio was understood and used often. Audio is a great way to lead and motivate the player, but the audio clips should be short and precise to ensure ease of use. It is beneficial to use sounds to make the game more realistic. The participants seemed to enjoy scanning groceries with the beep sound that confirmed that the item was scanned.

**User Interface:** The UIs in the game were used and understood when it was a requirement in the game. However, the optional helping pictures in the morning routine game and the UI grocery list remained unused during the supermarket game. The questionnaire reveals an understanding of the grocery list, so it was probably unused because the participants struggled to remember it or that it required the use of another button. Other canvases in the game, which were interactive canvases, had a high success rate. Both were used and understood, the easiest was the canvas with larger images or icons along with descriptive audio.

**Highlighting:** The results show that highlighting works best with arrows. Arrows were never misunderstood or misleading, in contrast to outline. Marking more tasks with arrows created less trial and error and resulted in the desired behavior. Outline was another technique for highlighting objects, but it often blended in with the surroundings and participants struggled more to find the groceries when they were marked with just an outline. In the second experiment the items were marked with outline and a particle system. Since the particle systems have movement, it seemed like it was easier to detect the items. The result from the experiments reflects this as well. However, the arrow still created more success and less confusion. A descriptive example is that some participants could not see the terminal used to pay with before an arrow was added. This is also revealed in the questionnaire, where participants answered wrong in question 3. It is important to highlight objects in a game that should be easy to understand. Especially for this target group, that needs to be set up for success and mastery. Clear guidance towards desired behavior, such as pointing with arrows, seem to do this way better than the outline, even after adding particle system to it.

**Virtual HTC Vive controller with blinking buttons:** The results show that there is little to no effect of showing the button on the virtual controller. It is possible that this increased the difficulties of playing. Participants need to look at the hand and be able to translate that information into physically pressing correct button. Since people with ID have issues with abstraction, this logic might not be intuitive to them. However, this feature was not tested in a large scale and would need stronger empirical evidence before conclusion. Therefore, this feature is excluded from the conclusion.

To summarize the assisting tools, the participants mastered more of the game. As seen in figures 18 and 19, each participant scored higher on all tasks and the average time increased with 50,43%. This significant improvement contains strong empirical evidence because it quantifies and supports the observational results.

**Questionnaires:** The questionnaires showed that many participants like the idea of VR-games and would use them if they had access. The short investigation of design showed that realistic games with more stimuli are preferred. This matches the team's experience with the target group. However, this subject was not researched in depth but merely superficially investigated. Also, such a diverse and heterogeneous target group is expected to show great span in their preferences.

**Potential improvements:** Researchers mostly seek perfect execution of their research, but there is always some frame of time and resources limiting the execution. This thesis was adjusted to the extent of time and resources at hand, which the team intended to exploit to the best of ability. This next paragraph will discuss potential improvements and some successful achievements of the research.

To evaluate the performance of the supermarket game the three pillars of VR, physical immersion, interactivity, and presence, will be addressed. Firstly, physical immersion, as other related works showed, obtaining physical immersion with people with ID can seem easier than with other target groups. Even though ID cause issues with abstraction, the level of physical immersion in the game was surprisingly high. Some participants requested free exploration of the supermarket, merely because the immersion was satisfying. However, the use of virtual HTC Vive controllers lowered control of action with the hands in the game. So, the fully immersive headset created strong physical immersion, but the physical controllers did not. An improvement would be to use smaller physical controllers with fewer, but more evident buttons with low sensitivity. The interactivity was affected by the issues with the physical controllers since unwanted action happened occasionally. Although a low degree of interactivity might be useful because some unpredictable behavior or different understanding of the surroundings is consistent within this target group. The presence in the game, on the other hand, matched the physical immersion. Participant's interests were in completing tasks and mastering the game. Even more so in the practice room, due to few distractions and impressions.

Another aspect the team would improve is the DGMs. The procedure of data documentation during experiments focused on evaluating mastery of tasks. Shifting focus to each action during tests would open for detailed debugging of issues with the assisting tools. To exemplify, instead of writing if the participant was able to grab the grocery basket, take note of how many times the basket was dropped and how much help was needed.

There were several potential improvements in conducting the experiments. Nonetheless, the team is very content with the product, supermarket game, and conducted experiments. Despite some sources of error, the team would argue that the gathered empirical evidence creates a valid base for the conclusion.

## 5.2 Validity of the research

Throughout the research, the team opted to maintain the requirements of scientificity; critical reflection, relevance, validity and reliability, and reflexivity, to preserve the scientific nature of the work. The quality of this research increased by using these requirements as base as they were upheld in various areas of the work. This section will therefore address how the team handled the requirements and the sources of error.

Firstly, critical reflection is addressed before testing of the games, where the team ensured that each participant was provided with the same information. During testing, the team collaborated on evaluating each test and the causes behind the participants' behavior in the game. After the test, the team summarized current issues and potential solutions. Which is also associated with another requirement: reflexivity. Large scale changes were expected after the feasibility study, this directly incorporates reflexivity, since the details were to be determined in the process. The requirement regarding relevance is handled in chapter 8 Societal Impact, but it is worth mentioning that the motive behind this thesis is the relevance and the impact VR games can have on this target group. Alas, the remaining requirements of scientificity are validity and reliability.

Secondly, the validity of the research emerges from the quality of the work. One way quality was assured was the conceptual framework, triangularity, which provided several sources to confirm findings. However, some sources of error remain and working with such a complex target group can be a source of error itself. As mentioned in the method, not all people with ID are consent competent and therefore might answer inaccurately. Participants often struggled elaborating on their experience and were likely to agree to simple questions, even if it was not necessarily the case. Therefore, the questionnaires were created to avoid biases and decrease sources of error in the research. In addition to potentially inaccurate responses, it is improbable that all results from 9 participants represent the entire target group. Therefore, the responses are to be evaluated as some tendencies within the target group and that there are other tendencies outside of what is documented in this thesis. Building on this, the number of participants is a source of error itself considering the diversity and complexity of the target group. It is unlikely that the 9 participants represent the span of variety within the target group. These weaknesses negatively affect the external validity and reliability requirements. This target group is complex, and what works for some, does not work for all. Therefore, the team consider the results of this study to be generalized under that precaution.

Since the experiments investigated mastery of the tasks and features in the game, the results achieve high level of reliability due to the reproducibility of testing the mentioned features. For example, testing free teleportation on people with ID is very likely to have the same low degree of mastery with a new group of participants.

It is important to mention that working with people with ID rarely goes effortlessly, so the team had to continuously evaluate when to intervene. Each participant is different, and some needed a lot of assistance during the game. This is one source of error because interventions were tracked as they happened and not when participants requested it. It was necessary to intervene in many cases, but it was revealed in the feasibility that the team had to agree on a concrete procedure to handle this. Because participants were often unable to request assistance themselves. This source of error was corrected before the

experiments, but evaluating when to intervene is relative and can be difficult to perceive correctly. Therefore, this source of error remained to a certain degree. Though, the showcased mastery increased drastically for the last experiment and fewer interventions were necessary which partially disregards this source of error in that experiment.

To further investigate the decrease in interventions for the last experiment, a potential cause could be that for both experiments the same game was used. Which can contribute to a source of error, since participants could remember the game and therefore perform better. Yet the assisting tools, buttons and movement were different in each experiment.

Remembering the game helps in understanding tasks, but not executing them, since the buttons and movement were different. So, this source of error primarily affects the assisting tools highlighting and audio.

Lastly, external sources of errors like disturbances in the lab or the participants state on the day of testing could affect the results. Some participants expressed tiredness and stress because of other people's presence in the lab. This could contribute to lower performance. Also, technical issues like glitching and lagging caused prolonged time in the game for a few participants. However, this was continuously evaluated by the team and corrections like restart or pauses were done when necessary.

## 6. Conclusion

As stated in the effect goals, this thesis aims to gather empirical evidence and fill a void in the research of design features for fully immersive VR. This was accomplished by developing a supermarket game with various features to research design and ease of use. The target group is people with ID who can benefit from using VR games. Initially the viability of the topic was investigated which resulted in the conclusion that yes, people with ID can master an adapted fully immersive VR game. All participants were able to play VR games. Even if the success of completing tasks were of varying degree. They were still able to immerse themselves in the game and interact with objects. Later this was also reconfirmed in the experiments.

For the second research question both measurable and observational discoveries were made. These findings allow the composition of some guidelines for ease of use in design for fully immersive VR games. This target group can have spontaneous and unpredictable behavior. Therefore, it is vital to facilitate mastery even though not all actions are correct, which is what the following guidelines can help developers achieve.

The discovered features and suggested guidelines are showcased in table 10 below.

Feature	Guideline
Movement	Movement should be with teleportation points, where the teleportation ray cast and teleportation points are visible only when the user is to teleport. During other tasks the teleportation functionality should be hidden. For games taking place in smaller spaces, physical walking works fine. Another option is also to teleport the user by code. If this option is used it is important to black out the screen while teleporting, to ease the transition and prevent motion-sickness.
Button	Only use one button for all tasks, which is within reach and a natural position when holding the physical controller.
Audio	Audio clips should describe each task, reward correct actions, describe some surroundings and create realistic effects in the game. The audio clips should be concise and precise.
Highlighting	Use blinking arrows to indicate action, mark objects with outline and a particle system. The outline should be 8f thick and in a contrast color.
UI	Interaction with UI can be used to let players choose features as part of the game. Have one UI canvas for each question or task, only visible when needed. It is recommended that the content of the canvas should be mostly pictures and figures, rather than text. This works well with additional descriptive audio.

Material	Use layers on objects to avoid collisions and interaction with unnecessary objects.
Exception handling	If an object is dropped to the floor, make the object hover over ground so people with mobility issues can easily reach and grab the object.

*Table 10: Conclusive guidelines from testing*

## 7. Future Work

Since this thesis investigated 9 assisting tools there is still a lot to remaining feature before ease of use in design of fully immersive VR is complete. Firstly, the team would complete the research on virtual controller models with blinking buttons because of the unfinished results of the testing. Secondly, test VR-games with different physical controllers to see if the degree of mastery increases with other controllers. The team have a theory that smaller physical controllers with one or two obvious buttons could have better success rate. Lastly, see how people with ID manage using treadmills for movement in VR.

A very interesting area to research would be motion sickness from VR-games on this target group. This research had some interesting results regarding this topic, where the participants enjoyed movements that made the developers nauseous. As mentioned in relevant works, people with ID have high level of presence in VR-games. The combination of immersion and absence of nausea in this context might appear to hold some significance.

VR-games have many potential areas of use for people with VR. Some that should be tested are games for entertainment, examples can be games within the trending interests of people with ID such as karaoke or baking. Also, different games to practice routines like learning to do laundry, separating clothes of color and whites, selecting program etc. Another suggestion is practicing the use of public transport. Which could help increase the level of independence.



## 8. Societal Impact

The initial idea behind this thesis was to create useful technology helping people with ID practice routines to learn useful living-skills, by appealing to their way of learning with unlimited repetition and patience. This could relieve pressure of social workers and parents, but also create predictability for people with ID. The motive behind the thesis was thereof the societal impact of the technology. As mentioned in related works there are positive effects of the use of VR for people with ID, but lack in specific design features. This lack of customizability restrains the use of fully immersive VR for people with ID. This thesis aims to contribute to that gap in the research market. This chapter will supplement the report evaluating the findings in a holistic manner by first elaborating on the vitality of this research and then the potential impact of VR games for people with ID.

Creating technology accessible and usable for everyone is considered a central part of the developer profession. If the modern solutions were only available to the average user several people would be neglected societal participation. Therefore, research on designing environments accessible to everyone is necessary to include the majority in the technological shift. People with ID are underrepresented in the development of technology (Drew and Hardman, 2007). As relevant works showcase, the lack of design makes the technology unavailable, and therefore cannot be used, even if the potential and beneficial opportunities are established (Standen, 2006). Which emphasizes the importance of this research, where people with ID participate in developing ease of use for fully immersive VR-games. So, this research answers to fill that gap in the research market, contributing to include a group currently excluded from the development of this technology.

Besides from inclusion in the development of the technology, this research is a step in the right direction towards expanding the health service for people with ID. Over the past decade several complaints about cuts in budgets for people with ID and lack of resources have been published. A report by FO and NAKU established that people with ID receive health care of lower quality compared to the rest of the population. The results from the report revealed that the provided healthcare is not professionally responsible due to severe lack of competence and financing, and that resources for people with ID are unprioritized. It also stated that prejudices against, and low expectations for what people with ID can learn or achieve, prevent appropriate care and teaching (Ingen Tid å Miste, 2020). Lack of economic resources for people with ID have been registered in several cases in the past years. The Norwegian ministry of local government and regional development ordered a report on costs related to people with ID. Results showed that several municipalities lack economical resources to cover necessary care required by the law (Kommunal- og moderniseringsdepartementet, 2017). The Norwegian law states that the municipality has the responsibility for providing care for people with ID from the age 18 years. The law preserves their right to care, community participation, a place to live, self-determination and autonomy (Helse og Omsorgsdepartementet, 2016). The right to healthcare is independent from the municipalities' financing and each municipality allocates the resources given by the state individually (Helsedirektoratet, no date). Lack of both financial resources and educated people working with this target group discloses a big potential for improvement, and as seen with for instance agriculture or education, technological solutions can contribute to improved efficiency and lower costs. Hopefully an idea like this can help alleviate some of the stress on

the healthcare system while improving the service for people with ID. If the base idea of practicing routines in VR-games is achieved, it could be an expanded service for people with ID. To illustrate the thought process, imagine a young boy with moderate ID who soon will have to move to a municipal housing where social workers will help him manage the daily life. The transition from having the parents assist him to being more independent and relying on strangers is humongous for people with ID. If that boy could see his apartment and practice his routines in VR before moving in, the transition would be smoother and consume less resources. Such educational technology can enable people with ID to learn more and become more independent. The goal is to facilitate more mastery and independence for people with ID which results in better quality of life. Conducting this research is thus a progression in improving the health care for people with ID, and retrospectively improving the lives of people with ID.

To conclude, this thesis is a building block in the field of ease of use in design of full-immersive VR and a progression towards inclusion of people with ID in the development of this technology. If this field is further explored and developed, user friendly VR-games can be used to educate and supplement learning for people with ID. This can better the poor situation in healthcare for people with ID, but also provide better quality of life due to increased independence and mastery.

# Appendixes

## *Appendix 1 - Observation Questions and Questionnaire for Feasibility study*

### **Feasibility study**

#### **Observation**

How did task 1 go? (Going to the window and check weather)

How did task 2 go? (Choosing clothes for the weather)

How did task 3 go? (Put dirty clothes in the laundry basket)

How did task 4 go? (Brush the teeth)

How did task 5 go? (Intake of tablets and wash down with water)

How did task 6 go? (Eat food)

How did task 7 go? (Putting cold items in the fridge)

How did task 8 go? (Pack the bag)

How good is the user at information retrieval? (using help images to perform the game)

Is sound helpful in completing tasks?

How is the usage of the equipment? (VR headset, controls)

Number of tasks completed in the game?

Comments?

Time used?

#### **Questionnaire:**

How did you feel playing the game?

Was there anything in the game that could have been better?

What was the best part of the game?

Were there any helping aids you think helped you complete the game?

What kind of game would you like to play in VR?

Appendix 2 – Questionnaire used in experiments

1.



Kan du peke hvor du ville lagt kjøttbollene?

2.



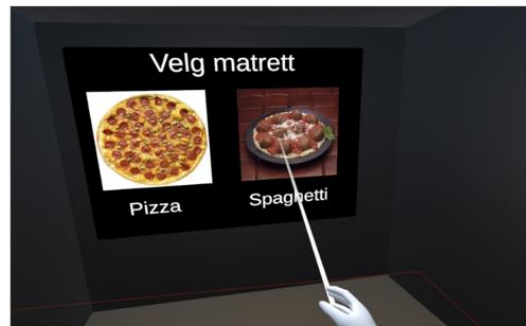
Hva tror du mangler handlelisten?

3.



Hvor ville du plassert bankkortet for å betale?

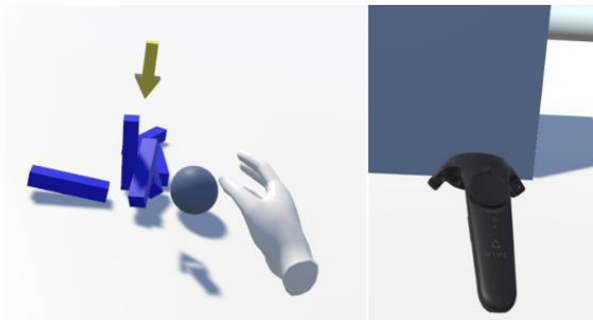
4.



Hvilken matrett velger jeg her?

5.

Vil du helst se hender eller spakene du holder i?



6.

Hva tror du man skal gjøre her?



7.



8.



1.

2.



9.

1



3

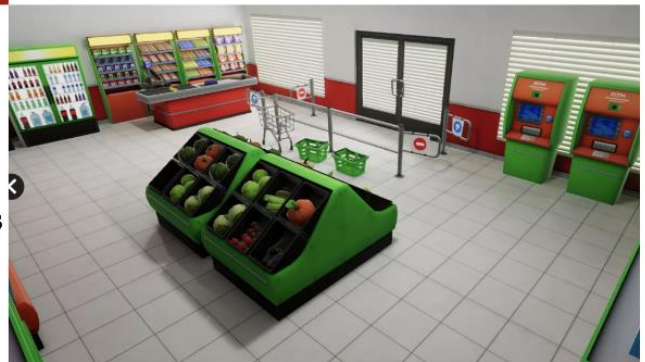


10.

4



3



11.

2



4

## Appendix 3 – Risk Assessment

Nr.	Fase i dataflyt	Uønsket hendelse/situasjon/sårbarhet (risikoelement)	Konsekvens	Eksisterende beskyttelsestiltak	Risikonivå		Tiltak som reduserer risiko (samsynlighet og/eller konsekvens)		Risikonivå etter tiltak		Ansvarelig for tiltak	Frist for gjennomføring
					S	K	S	K	S	K		
Beskrivelse		Hva kan medføre en risiko for personopplysningene i dette prosjektet? Beskriv hendelser og situasjoner som kan oppstå i løpet av prosjektperioden.	Hva er de mulige konsekvensene? Hovedfokus skal være på negative konsekvenser for de registrerte. Husk at konsekvensen (og dermed risikoen) som regel er større for særlige kategorier (sensitiv) enn for alminnelige personopplysninger (se veiledningstafane).	Finnes det allerede tiltak ved NTNUs/prosjektet som kan bidra til å hindre at det skjer?	Sansynlighet og konsekvens på en skala fra 1 til 4 (se veiledningstafane)	Sansynlighet og konsekvens på en skala fra 1 til 4 (se veiledningstafane)	De kan deles opp i organisatoriske, menneskelige og teknologiske sikringstiltak.	Sansynlighet og konsekvens på en skala fra 1 til 4 (se veiledningstafane)		Hvem er ansvarlig for at tiltaket gjennomføres?	Når skal tiltaket være gjennomført?	
	1	Innsamling	Fell notering: det kommer med personlige data	Ulovlig notering av persondata uten samtykke	NTNUs retningslinjer for behandling	1 14	14	Lage skjema basert på spillet som sikrer pløting av tall basert på oppgave og ungar personopplysninger	1 1	Dokumentansvarlig skal lage passende skjema	Før forsøk	
	2	Lagring	Noen får tilgang til driven vår hvor dataene ligger	Ulovlig deling av persondata, kan gå utover studiets deltakere	NTNUs retningslinjer for behandling	5 2	10	all data er anonymisert, slik at konsekvensene er lave	1 1	Dokumentansvarlig	Før forsøk	
	5	Behandling/analyse	det kommer fram personopplysninger via diagrammene	Ulovlig deling av persondata, kan gå utover studiets deltakere	NTNUs retningslinjer for behandling	2 3	6	Vi forholder oss til gjennomsnitt og kun interessante resultater fra all testingen samlet.	1 1	Prosjektleder	under bearbeiding av data	
	9	Deling	Fell personer ved institusjonen får tilgang til tilgangsbeskyttet datamateriale.	Ulovlig deling av persondata, kan gå utover studiets deltakere	NTNUs retningslinjer for behandling	1 2	2	Dataene våre er ikke verdtfull for andre, siden alt er anonymisert fra start	1 1	Dokumentansvarlig	Før forsøk	
10	Avslutning	Persondata blir liggende på lagringsområde etter at prosjektet er avsluttet.	Ulovlig notering av persondata uten samtykke	NTNUs retningslinjer for behandling	2 1	2	Vi ordner prosedyre for å slette all data etter vurt	1 1	Prosjektleder	Etter levert hovedrapport		



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# Attachment

Attachment A – Project Plan

Attachment B – Project Handbook

Attachment C - Vision document

Attachment D - System documentation

Attachment E – Source code

