Bachelor Thesis

Everybody has the right to play

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Abstract

People with a mild intellectual disability experience difficulties in daily life activities that require fine motor skills, such as tying shoelaces or writing with a pen. Because of this, they need help multiple times a day with performing these activities. This thesis focuses on creating an application that can stimulate people with a mild intellectual disability to train their fine motor skills in order to increase independence during daily life. The application consists of a game projected on a tabletop combined with motion tracking, causing the user to interact by moving their arms and hands in mid-air. The application has been reviewed by multiple experts and three user tests have been performed (N=4, N=2, N=3). The results showed that participants could perform all interactions on the created interactive tabletop game with satisfactorily result. From the results, a list of criteria has been established containing the elements that an interactive tabletop application should contain in order to be suitable for the target group and in order to keep the user motivated to train their fine motor skills. However, due to COVID-19 the product is not tested with people with a mild intellectual disability, so further research is necessary.

Acknowledgements

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I would like to thank the client for their feedback and creative input in all phases of the thesis.

In addition, I would like to thank the physiotherapist of Siza for participating in an interview and in the evaluation test and for giving feedback on the game concepts. Furthermore I would like to thank the game developer of the client for giving feedback about the game concepts and for participating in the evaluation test. Even though the fact that I could not test my product with my target group, thanks to them I was able to create a product that is likely to fit the needs and abilities of the target group. Lastly, I would like to thank my housemates for joining the prototype test, the pilot test and the evaluation test. Without all participants I was not able to create the end product.

Contents

List of Figures

List of Tables

1 Introduction

This thesis is done in compliance with a client, a company that creates interactive tabletop games. Due to a non-disclosure agreement, the name of this company cannot be stated in this thesis.

1.1 Intellectual disability

Intellectual disability is a common occurrence worldwide. In the Netherlands around 1 percent of the population is intellectually disabled [1]. Intellectual disability is defined as below average intellectual functioning, together with deficits or disabilities in adaptive functioning. These disabilities need to be present before the age of 18 years old [2]. In daily life, people with an intellectual disability often have difficulties in cognition, verbal expression, body movement and functioning in a social environment. Besides, they often experience troubles when performing 'activities of daily living' (from here on named ADL), like bathing, eating and walking, and therefore they are dependent on other people for performing these [3]. It is very important for people with an intellectual disability to exercise movement, since practicing motor skills can help increasing movement abilities in all fields and it can help gaining independence in their daily life while performing ADL. Because people with an intellectual disability tend to lose their independence faster, they become institutionalized sooner than people without an intellectual disability [4].

1.2 Motor skill therapy

The degree of intellectual disability can be divided into four groups: profound, severe, moderate and mild. The group with mild intellectual disability is by far the biggest group and consists of more than half of the total number of people with intellectual disability [5]. People with mild intellectual disability can usually live independently, because they can perform most ADL by themselves due to their good developed gross motor skills. This is on the contrary of people with a moderate, severe or profound intellectual disability who are often lacking gross motor skills [5] [6] [7] [8]. Despite the fact that people with a mild intellectual disability can live independently, they often live near care institutions for people with intellectual disabilities, like Siza in Arnhem, because they can need help during some ADL that require fine motor skills, like dressing or locking the door with a key [9]. They perceive these ADL as difficult, primarily because of their underdeveloped fine motor skills. Fine motor skills are the coordination between the small muscles in the hand, fingers and wrists and they are especially important when performing ADL [10]. Examples of ADL that require fine motor skills are writing with a pen, tying shoelaces or picking up small things. People with a mild intellectual disability can already receive treatment at the care institutions for their fine and gross motor impairments. The goal of these treatments is gaining some independence in performing ADL. However, Xu et al. [3] mentions that during traditional rehabilitation exercises performed in the treatments at the care institutions, people with an intellectual disability are often lacking motivation. The bottleneck exists in the unwillingness of cooperation, the tasks are perceived as boring and often the emotions are taking over. Due to these issues, their practice of motor movements is constrained. Although gaining independence in day to day life is very important, to our knowledge there are little other opportunities to practice motor movements that fit their needs. The exact needs of people with intellectual disability will be discussed in the chapter 2.

1.3 Interactive tabletops

One way of stimulating gross motor movement practice could be using an 'interactive tabletop'. An interactive tabletop is a projection on a tabletop combined with motion tracking, causing the player to interact with the table by moving their arms and hands. An example of an interactive tabletop for people with intellectual disabilities is the Tovertafel UP. The Tovertafel UP unites people with moderate to profound intellectual disabilities. It is a little box placed on the ceiling that projects games on tabletops. The colourful objects displayed on the table respond to hand and arm movements. Using the Tovertafel usually results in a lot of fun and a lively and comfortable atmosphere [11]. Besides fun, interactive tabletop games can also be used for educational purposes. The combination of 'play' and 'movement' can improve and accelerate rehabilitation [3][12]. Interactive tabletop games, like Tovertafel, have gained popularity in the last few years [13]. They stimulate collaboration, engagement and immersion [14]. Currently interactive tabletops are a strong means of practicing gross motor skills. Since they are a large success and they bypass the shortcomings of traditional exercises, interactive tabletops might also be useful for practicing fine motor skills. Given that interactive tabletops do not have applications yet that stimulate fine motor skills practice, this research will focus on how these kinds of applications should be designed.

1.4 Goal

People with a mild intellectual disability need to train fine motor skills in order to gain independence in their day to day life and to perform ADL themselves. Traditional movement exercises contain some shortcomings and to our knowledge there are few other opportunities that fit their needs in order to practice movements used during ADL. Therefore, the main objective of this research is to design an interactive tabletop experience that aims to stimulate people with an intellectual disability to practice their fine motor skills. The approach of how this objective will be achieved will be discussed in section 1.7.

1.5 Research questions

This bachelor thesis will focus on the following aim:

The aim of this thesis is to design a system to stimulate people with a mild intellectual disability to train fine motor skills by means of an interactive tabletop game.

The aim will be discussed with use of three sub research questions answered in the following phases.

Literature and State of the Art:

- What fine motor skill difficulties do people with a mild intellectual disability encounter during activities of daily living (ADL)?

Ideation, Specification, Realisation and Evaluation:

- How do people experience the elements in interactive tabletops in terms of usability?

Both Literature and State of the Art and Evaluation:

- What criteria should be contained in a game for people with a mild intellectual disability to stimulate the training of fine motor skills?

1.6 Creative Technology Design Process

In this thesis, the Creative Technology Design Process (CTDP) will be applied [15]. This design process is created for the study Creative Technology and describes four phases in which a product or application is created. The four phases of the CTDP are: ideation, specification, realisation and evaluation. Every phase exists out of two parts: a divergence part and a convergence part. In the divergence part, different solutions can be explored and in the convergence part the solutions are reduced to one or a few. The phases are intertwined and the designer can enter the phases non-chronological [15]. The design process can be found in figure 1. The phases will be explained in chapter 3.

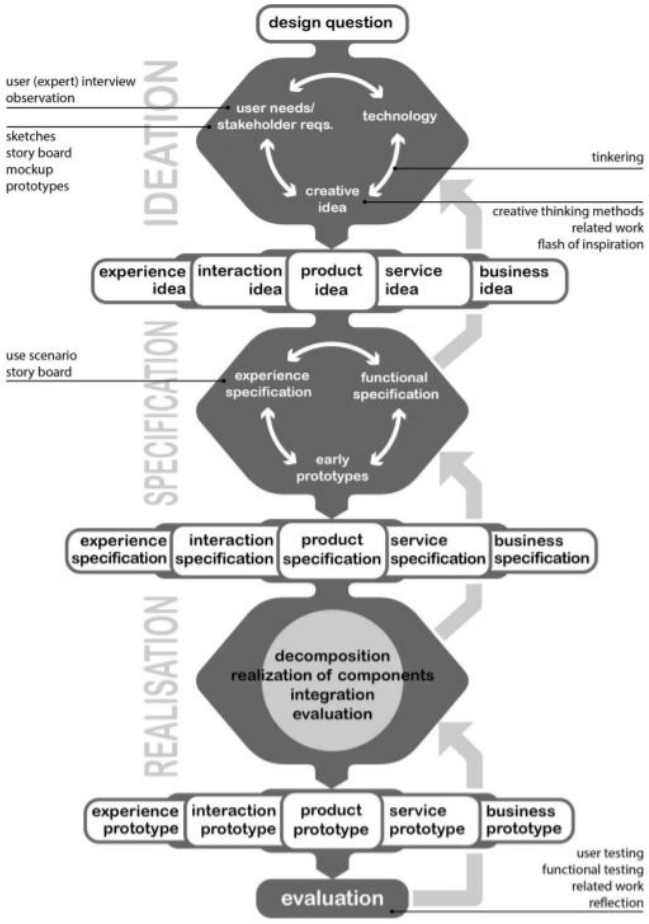


Figure 1: Overview of the Creative Technology Design Process [15]

1.7 Plan of Action

The research will be divided into the following phases:

- Literature and State of the Art
- Methods and Techniques
- Ideation
- Specification
- Realisation
- Evaluation
- Discussion and Recommendations
- Conclusion

The Literature and State of the Art phase will provide background information about the target group, interactive tabletops and games. Moreover a literature review will be written. The chapter Methods and Techniques will describe the content of the Ideation, Specification, Realisation and Evaluation phases. Lastly, the sub-research questions will be answered in the chapter Discussion and Recommendations and the main research aim will be discussed in the Conclusion.

1.8 Consequences of COVID-19

COVID-19 is a virus that is currently plaguing the world. The effect is a lock down in many countries, including the Netherlands, and people are strongly recommended to stay home during this pandemic. This affects the bachelor thesis as people are no longer permitted to meet in person. Therefore the researcher will not visit participants of the research herself. Accordingly the prototype test, the pilot test and the evaluation test will be conducted with the housemates of the researcher. The user-tests will be held in the house of the researcher and since the researcher already sees the housemates every day, there will not be additional face-to-face contact. Given that visiting experts is not feasible, interviews and user tests with experts will be held online via video calling.

1.9 Ethical procedures

Before the user-tests and the interviews, ethics requests will be proposed to the ethics committee of Creative Technology. These requests will contain a description of the task that identifies the ethical propositions encountered during the project, an ethical checklist and an informed consent. The ethics committee is an independent group of researchers that will objectively criticise all events that require people, such as user-tests or interviews. After permission of the ethics committee, the participants will receive information about the research and an informed consent which they need to sign. The informed consents can be found in Appendix C.

2 Literature and State of the Art

2.1 Introduction

In the Literate and State of the Art phase, a better context of the target group and their fine motor skills issues will be formed and it will be reviewed how interactive tabletops and games can contribute to improving these skills. First, by means of literature some background information about the target group will be provided. Additionally, existing commercial applications will be reviewed to form a context of the current usage of interactive tabletops. Then, a literature review will provide information about the target group, interactive tabletops and games. This phase will end with design recommendations that specify what elements the interactive tabletop should contain and what problems these elements should solve.

This chapter 'State of the Art' will answer the following questions

- What fine motor skill difficulties do people with a mild intellectual disability encounter during activities of daily living (ADL)?
- What criteria should be contained in a game for people with a mild intellectual disability to stimulate the training of fine motor skills?

2.2 Intellectual disability

There are four degrees of intellectual disability: profound, severe, moderate and mild. These degrees and their characteristics can be found in table 1. The table shows that the group of people with a mild intellectual disability is by far the biggest group. Besides, it shows that people with an intellectual disability have an IQ below 70, causing difficulties in cognition. Lastly, the table states that people with an intellectual disability have a developmental age of children between 0 and 12 years old, meaning that their cognition as well as their motor skills are comparable to children this age. However adults with intellectual disability do have experience of life and for this reason they should not be seen or approached as children. The degree of intellectual disability and their characteristics can be found in table 1.

Cognitive level	Profound	Severe	Moderate	Mild
Percentage of total number	1 %	7 %	17 %	75 %
Dutch term	ZEVB	EVB	MVB	LVB
Developmental age	0 - 1 yrs	1 - 3 yrs	3 - 6 yrs	6 - 12 yrs
Characteristics	Require 24-hour care and lack gross and fine motor skills.	Need daily assistance with daily activities. They lack gross and fine motor skills.	Some personal care is possible. However most people of this category do not live independently. They sometimes lack gross motor skills and almost always lack fine motor skills.	Personal care, some leisure activities and sometimes simple (factory) work is possible. Shopping or creating a planning of daily activities is not possible and they often experience problems during transport. They are often seen as 'clumsy' and can experience coordination problems. They have sufficient developed gross motor skills and often lack fine motor skills.

Table 1: Four groups of intellectual disability. Table based on Intellectual Disability Rights Service [6], Netwerk Palliatieve Zorg [7], Nederlandse vereniging van artsen voor verstandelijk gehandicapten [5] and Prinsenstichting [8].

2.3 Related work

The related work will describe currently existing commercial interactive tabletops found by searching online. The search terms used for this are 'interactive tabletop', 'fine motor skills' and 'intellectual disability'. Since there were a lot of search results, the three most promising products were chosen. This was based on the (commercial) success of the product and their relevance, besides there was a preference for interactive tabletops used for practicing motor skills or interactive tabletops used for the target group. The combination of people with an intellectual disability that can practice fine motor skills by means of an interactive tabletop was not found. When the three products were chosen, the information below about these products was primarily found on the products' websites.

2.3.1 Tovertafel - Active Cues

Active Cues is a company that creates interactive tabletops called 'Tovertafel' [16]. The Tovertafel is a small box that can be placed on the ceiling and projects games on different surfaces, like tabletops, lying mats, floors or wheelchair trays. The Tovertafels are usually placed in care homes or daytime activity centres. The colourful objects displayed on the table respond to hand and arm movements and using the Tovertafel usually results in a lot of fun and a lively and comfortable atmosphere [16]. The focus of Active Cues is to create a moment of happiness for special target groups in the health care sector [17].

Active Cues produces their games through 'co-design'. This means that the games are created together with the target group. This is a process in which designers and non-designers are involved [18]. Active Cues offers games for three different target groups: people living with dementia (Original [19]), adults with intellectual disabilities (UP [16]) and children in health care or special education (Sprout [20]). The Tovertafel UP, designed for a similar target group as this project, is designed to increase happiness, stimulate social interaction and to stimulate physical activity for people with moderate to profound disabilities [16].

Since the Tovertafel UP focuses on a similar target group as this project, these games and goals will be discussed more elaborately. To begin with, 'regular' games will not fit the needs of this target group. To adjust 'regular' games, every game of the Tovertafel UP exists of multiple layers, causing players with different degrees of intellectual disability to be able to join. Some game experiences should be present in games for people with intellectual disability, such as sensory stimulation, competition, sympathy, humour, challenge and creativity. Active Cues created game characteristics for people with an intellectual disability and these characteristics offer people with an intellectual disability to join at their own level [18]. The characteristics can be found in figure 3.

Figure 2: People with an intellectual disability playing with the Tovertafel [11].

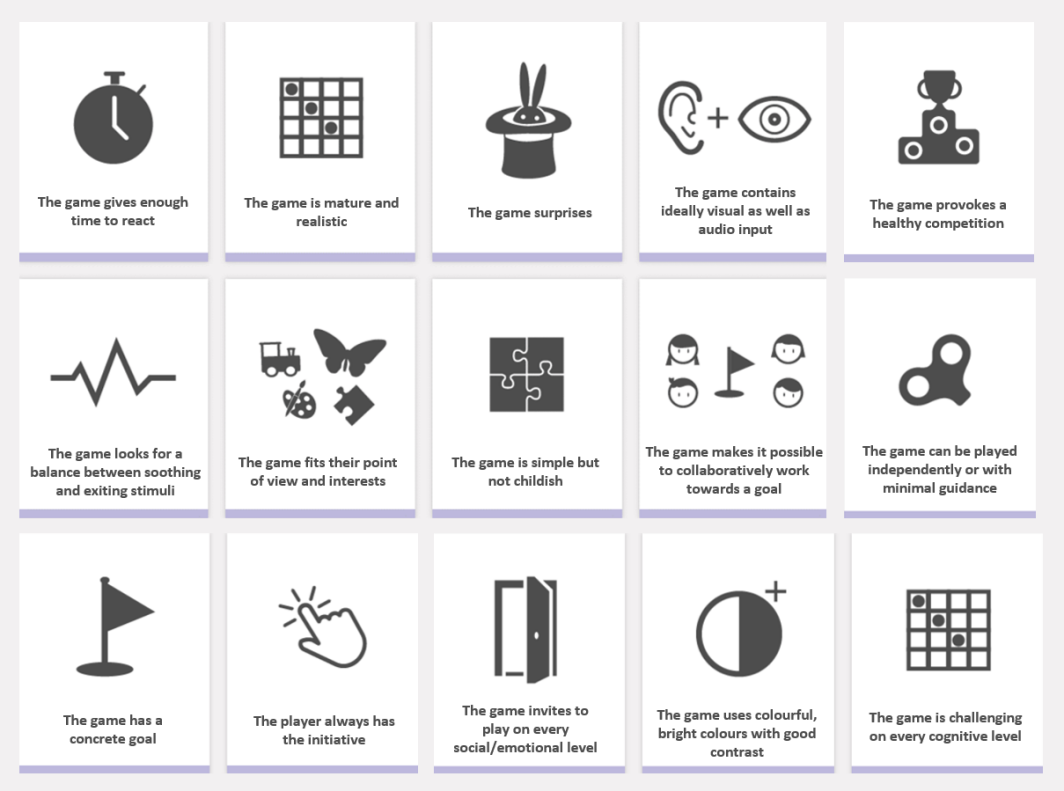


Figure 3: Game characteristics of the Tovertafel made for people with intellectual disabilities [18].

To conclude, Active Cues creates their products together with and for people in the health care sector. Besides, the Tovertafel UP is created for people with a moderate to severe intellectual disability to create moments of joy and stimulate them to move. Lastly, Active Cues makes sure that people with different degrees of intellectual disability can join and play without too much distraction of additional stimuli.

2.3.2 HandsOn - GainPlay

HandsOn is an interactive tabletop invented by Dutch students together with the rehabilitation institute Roessingh Research and Development [21]. Currently HandsOn is a product of the company GainPlay. The interactive tabletop projects a game on a tabletop created for children to stimulate rehabilitation of their fine motor skills and is often used in physiotherapy [22]. HandsOn exists out of a tripod with a projector and a Kinect. The projector projects the game on a tabletop and the Kinect detects the arm and hand movements of the player. In order to play the game, the player needs to move, rotate or slide tangible objects, like cylinders or blocks, on the interactive tabletop before the animals reach the house. These objects are sensed by Kinect and the ideal placement is visually shown by means of a projection (see projected blue and red blocks in figure 4). When moving, rotating or sliding the objects to the right places, the user can win the game [22]. Picking up or rotating blocks can be hard for users, because different hand and arm muscle groups are used. Every different type of object can be moved with different hand or wrist movements. The combination of moving and playing can be very powerful for rehabilitation and can help in building strength in the arm and hand muscles. The games can be adjusted to every

player by changing speed, block-types, colours or orientation of the play-fields [21].

Concluding, HandsOn is an interactive tabletop using Kinect to stimulate children to practice fine motor skills on their own level. HandsOn requires the use of multiple arm and hand muscles and picking up, rotating and sliding blocks can increase the muscle strength in the arms and hands of the user.

Figure 4: A person interacting with HandsOn [22].

2.3.3 Leap Motion Controller - Ultraleap

Ultraleap is a company that designs products using the Leap Motion Controller. The Leap Motion Controller is an USB device that uses an optical hand tracking module. It should be laid down on the table or placed on a VR headset and it captures the hands movements above it (see figure 5). The controller tracks palms and fingertips and displays the joints and bones inside your hand [23]. Practicing movements with the Leap Motion Controller makes interaction more natural, since the user only needs their hands instead of wearables or controllers. This describes the goal of the company well: making digital worlds feel more human [24].

The Leap Motion cameras makes it possible to tap or click in mid-air [25]. There are some movement patterns recognized by the controller:

- Circle - Single finger tracing a circle
- Swipe - Long, linear movement of finger
- Key tap - Tapping movement by finger as tapping on a keyboard key
- Screen tap - Tapping movement by finger as vertical computer screen [26].

Besides being used for games, Leap Motion Controller can also be used for rehabilitation purposes [24]. To conclude, the Leap Motion is used to make interaction with technology more natural by tracking hand movements instead of using wearables.

Figure 5: Leap Motion Controller tracking hand movements [27].

2.3.4 Conclusion

All three products show different perspectives in the field of interactive tabletops and practice of motor skills. The Tovertafel UP tries to create moments of happiness for people with a moderate to severe intellectual disability and is currently used for practicing gross motor skills, while HandsOn and Leap Motion primarily focus on rehabilitation of fine motor skills. All three interactive tabletops show that the combination of gaming and practicing motor skills can be very effective for rehabilitation. However 'regular' games need to be adjusted in order to be suitable for people with an intellectual disability. Since every user has different needs and abilities, the Tovertafel and HandsOn point out that the training of motor skills should be adjusted to every user in order to practice on a own level and pace. Therefore it is more convenient if games contain multiple layers or levels. Additionally, Tovertafel uses co-design when creating their products to make sure the application fits the needs of the target group.

Interactive tabletops seem to give a promising perspective on training fine motor skills, primarily because practicing motions on interactive tabletops could be a more natural and fun way of practicing these skills. However to our knowledge there does not exist an interactive tabletop experience yet that focuses on stimulating people with an intellectual disability to practice fine motor skills. All three products contain elements that could be used when creating such an application. Active Cues suggests game characteristics (figure 3) and experiences when creating games for people with an intellectual disability that can also be applied when creating an application for this thesis. HandsOn focuses on rehabilitation of fine motor skills of children, but the application is not user-friendly for people with an intellectual disability. For example, the time constraints give too much pressure and the game might be too childish and might contain too many distracting elements. The Leap Motion Controller makes it possible to practice fine motor skills in mid-air and is very accurate in their measurements, however the application has not been tested with people with an intellectual disability yet and therefore it is unsure whether this product will work for this target group.

2.4 Literature review

This literature review is based on a literature review written by Frederique Voskeuil for the course Academic Writing and may be used for this thesis.

2.4.1 Introduction

More background research is needed before starting this project. Especially on the specific fine motor issues of people with an intellectual disability and how interactive tabletops can contribute to practicing these. This literature review will answer the following main question: *How can we improve the practice of motor skills of people with an intellectual disability by means of projection motion sensing games?*

To give an answer to this question, the literature research will be split into three parts. First the target group and their movement problems will be discussed based on the sub-question: *What daily physical movement issues do people with an intellectual disability experience?*. Thereafter the technology used for this project will be examined. This will be divided in two parts, interactive tabletop technology and gaming. The first part will focus on the sub-question: *How can interactive tabletops influence physical movement of people with an intellectual disability?* and the second part will look at the sub-question: *How can gaming influence physical movement of people with an intellectual disability?*.

2.4.2 Motor movement issues

Besides cognitive disabilities, people with an intellectual disability often experience motor impairments as well. As a matter of fact, Rintala and Loovis [28] state that the motor skill performance of individuals with intellectual disability is significantly less developed than individuals without intellectual disability of the same age. However a good development of motor skills is important for several reasons. Motor skills in general are required throughout life for adaptation to our daily environment and activities. Moreover, they are important to obtain independence, safety, and a good quality of life. Besides, motor skills can also positively influence social skills and are needed while performing ADL. Since people with an intellectual disability are often having problems with motor skills, they experience difficulties while performing ADL, causing them to be dependent on other people. The lack of independence starts at a young age which results in deconditioning and aging prematurely [4]. Since practicing motor skills can increase movement abilities in all fields, it is important to practice these skills in order to stay independent while performing ADL [29].

Fine motor skills
When looking at the motor skills used when performing ADL, fine motor skills are in particular important. Fine motor skills are the coordination of small muscles in the hand, fingers and wrists [10]. They are required in small movements, such as writing with a pen, cutting with scissors and picking up small things between thumb and finger [30]. However people with an intellectual disability often have poorly developed fine motor skills. The biological cause of the underdeveloped fine motor skills is a delayed growth of the muscles in the hand and muscle flaccidity with increasing age [31]. Also IQ has a strong influence on manual dexterity, since the lower the IQ, the less developed the fine motor skills are [32]. When looking at the specific issues in fine motor skills, Carmeli [4] states that people with an intellectual disability often experience the inability to merge visual inputs and hand movements. Vuijk et al. [32] supports this statement by also pointing out that people with an intellectual disability experience difficulties in hand-eye coordination. Besides, he notes that people with an intellectual disability show more deficiencies in speed and accuracy of each hand separately [32]. Vimercati et al. [33] states this as well. He has shown that while drawing

with a pen, people with an intellectual disability had problems with drawing between the lines. Additionally, Stichting Rubinstein [34] states that using multiple fingers at the same time is usually difficult for people with an intellectual disability. Especially the 'tweezer grip' as shown in figure 6, grabbing something between the thumb and index finger, is perceived as hard. This is supported by Lahtinen et al. [31]. He tested the manual dexterity of people with an intellectual disability by means of a 'pearl transfer speed' test. The participants had to transfer pearls from one cup to another. People without an intellectual disability performed the test better than people of the same age with an intellectual disability.

Measuring fine motor skills

One way of measuring hand abilities of people with an intellectual disability is to use the Jebsen Test of Hand Function (JTHF). This test consists of seven small tests: writing, simulations of turning pages, lifting small objects, simulations of eating food, stacking objects, lifting large light objects and lifting large heavy objects. Zikl et al [35] performed the JTHF test with children with and without a mild intellectual disability. The tests showed a significant difference in performance between the groups of children. Tests one and three did not show significant difference, meaning that the performance of the test was significantly the same for both groups of children. In the second test, the children had to turn 5 paper cards laid on the table. The children with an intellectual disability needed 14% more time than children without an intellectual disability. In the fourth test, eating was simulated by collecting five beans on a spoon and throwing these into a can. This was significantly perceived as difficult by the children with intellectual disability and they needed 34% more time to perform this test. In the fifth test, the children had to stack 4 pieces of small figures on top of each other. The children with intellectual disability needed 19% more time when performing this test. In the sixth test, the children had to move empty cans to a predetermined location. The children with intellectual disability were 11% slower than the children without intellectual disability. In the seventh test children had to lift large heavy cans to a predetermined location and this time the children with intellectual disability were 19% slower than children without intellectual disability.

It can be concluded from the JTHF test that children with intellectual disability had the most difficulties with the fourth test. This test required the fine motor skills of holding the spoon in a straight line and rotating the hand to release the beans. This rotation movement of the hand is also used when turning pages, which was also perceived as difficult by children with intellectual disability. Thus, this research shows that the rotation movement of the hand might be difficult for people with an intellectual disability as shown in figure 7. Referring back to section 2.3.2, the HandsOn [21] also focuses on practicing the rotating movement of the hand, because this movement is difficult for people with less developed fine motor skills. Since this movement is used often during ADL, for example when unlocking a door or turning on the tap, practicing this movement is important [21]. Moreover picking up small objects and turning or stacking the objects took children with intellectual disability also longer. This could be caused by an underdeveloped hand-eye coordination and accuracy. Lastly, lifting large, light or heavy products was also perceived as a hard movement [35]. These issues in fine motor skills might lead to exclusion from vocational and recreational activities and a reducing competence of performing ADL. This leads to a daily dependence on other people [32].

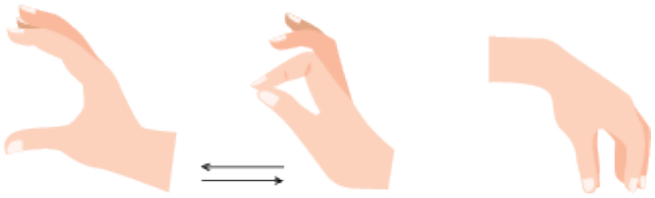


Figure 6: Using multiple fingers at the same time. The first two images show the tweezer grip. This grip can work both ways: for example when making objects smaller (left to right) or making objects bigger (right to left). The third image shows another way of using multiple fingers at the same time. Hands are downloaded from freepik [36], but they are altered.

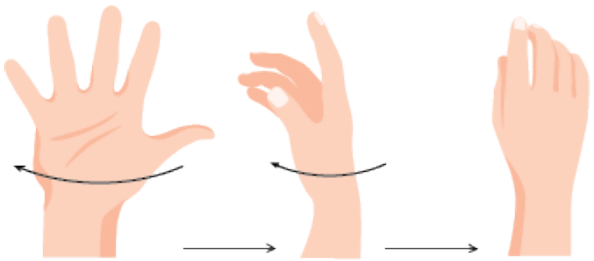


Figure 7: Rotating the hand. Hands are downloaded from freepik [36], but they are altered.

Conclusion
The sub-question for this part was: *What daily physical movement issues do people with an intellectual disability experience?*. It can be stated that people with an intellectual disability indeed experience movement difficulties and this results in dependence on other people while performing ADL. This is primarily caused due to underdeveloped fine motor skills. When looking at the specific fine motor skill issues, the biggest problems are hand-eye coordination, accuracy, speed, using multiple fingers at the same time (figure 6) and rotating the hand (figure 7). However it can be stated that the fine motor skills of someone with intellectual disability can be improved by practicing these skills [29].

2.4.3 Interactive tabletops

In this part, literature will be used to review interactive tabletops and their advantages for practicing fine motor skills. These are non-commercial products and have been created for research purposes. Therefore they are different from the products in 2.3. The literature is found by searching on Google Scholar [37], Scopus [38] and the ACM digital library [39] using the search terms: 'intellectual disability', 'interactive tabletop' 'fine motor skills' and 'practice'. The literature that best suited the objective of this research was chosen.

Treatment
People with an intellectual disability are currently dependent on rehabilitation therapists for treatment of their motor skill difficulties [4]. The goal of these treatments is gaining independence when performing ADL. However the exercises of these treatments are often perceived as boring and demotivating [3]. The bottleneck exists in the unwillingness of cooperation, the lack of motivation and often the emotions are taking over. Due to these issues, their practice of motor movements is constrained.

Games as treatment

Another way of motivating people with an intellectual disability to practice motor movement could be using an interactive tabletop. Xu et al. [3] have developed a rehabilitation game training system that could be used for rehabilitation training of children with an intellectual disability. This system uses Kinect and a projector that projects on a tabletop. The application focuses on the training of children's perception, attention, action and other abilities. The game consists of five periods: intellectual rehabilitation program, basic perceptual and cognitive rehabilitation program, upper limb rehabilitation program, lower limb rehabilitation program, leisure and health care program. Each game contains 2 to 5 game parts and has 3 levels of difficulty (easy, normal and difficult). Before testing, the measurement scale Pediatric Evaluation of Disability Inventory (PEDI) was used. This index containing 177 items measures the functional ability level of a child. The scale included three dimensions: daily activity, locomotivity and communication skills. This scale includes activities that require gross as well as fine motor skills. When this index was completed for every participant, the children had to use the application for 8 weeks, 2 times a day and 2 hours each time. They were trained at schools and institutions. After this period, the PEDI scale was completed again and the results of the scale showed that the children scored higher in all three dimensions, daily activity, locomotivity and communication skills after the intervention [3]. Furthermore, Xu et al. [3] stated that the interactive tabletop enhances attraction and can beat the shortcomings of traditional physiotherapy exercises, like boredom and the lack of motivation. Moreover, while playing with an interactive tabletop, one can just use their body and does not need a mouse or keypad. This can feel more natural to people with an intellectual disability [3].

Fu et al. [40] supports the effectiveness of using Kinect for the rehabilitation of the motor skills of children with an intellectual disability. He also states that traditional exercises cause boredom, which leads to disruptive behaviour. Therefore Fu et al. [40] have created an interactive game system for rehabilitation for children with an intellectual disability. This system uses Kinect and the game uses colourful images, vivid voice prompts and game sounds. The game contains three difficulty levels: easy, normal and hard. Before the testing, Fu et al. [40] also completed the PEDI scale for every participant. After the testing, this scale was completed again. The results showed an increase in all three domains: daily activity, locomotivity and communication skills. Additionally, Fu et al. [40] states that people with an intellectual disability are more relaxed when using an interactive tabletop, since there is no pressure in virtual situations in contrast to daily tasks. Furthermore, it is important that the environment created in these virtual situations feel natural to the user [40].

Both papers state that interactive tabletops enhance attraction and can beat the shortcomings of traditional exercises [3] [40]. Zhou et al. [41] also confirms that interactive tabletops can improve motor skills and he notes that they could even replace face to face rehabilitation therapy. However the system should contain several factors in order to be successful, like real time operation, easy manipulation, correctness of data, a friendly graphical interface and portability. He states that even if one element is missing, the positive effect of the interactive tabletop will be diminished. Another aspect that could increase the positive effect of the interactive tabletop is extending the interactive tabletop to family homes. Currently interactive tabletops are placed at care institutions for intellectual disabled people. However Zhou et al. [41], Xu et al. [3] as well as Fu et al. [40] state that extending the interactive tabletop to family homes could further improve motor skills, since it will be more convenient and efficient to practice skills at home.

Instead of using Kinect, Researcher Fernández-González et al. [42] has shown that the Leap Motion Controller (see section 2.3.3) can also be used when practicing fine motor

skills. Practicing fine motor skills by means of this controller can improve the upper limb coordination, speed of movement and fine dexterity of people with Parkinson. Additionally, because of the portability, ease of use and non-invasive nature, Leap Motion provides important advantages over other motion capture systems. In this case, visual as well as auditory feedback was given to improve the performance of the participants [42].
Foletto et al. [43] also describes how the Leap Motion Controller can be used for practicing fine motor skills. He has created serious games for people with Parkinson's Disease to train fine motor skills by using the Leap Motion Controller. The gestures that are practiced in this application have many similarities with the gestures that people with an intellectual disability are experiencing as difficult. These day-to-day gestures are picking up small things, rotating the hand and using multiple fingers at the same time or separately.
Foletto et al. [43] has created three different serious games based on observations during rehabilitation sessions. The first game consists of a lawn with eggs and baskets on it. The user has to click on the eggs, hold them, move them above the right basket and release the eggs. The movement used in this game was clicking, holding, moving and releasing. For this game one finger is required. Since people with mild intellectual disability experience difficulties in hand-eye coordination and accuracy, this game could be used by this target group as well. The second game required multiple fingers. The game layout consisted of four lanes that were linked to one of the fingers, for example the first lane corresponds to the thumb. When one lane lights up, the user has to 'press' the lane by moving the corresponding finger. Multiple fingers are trained separately. Referring back to 2.4.2, people with a mild intellectual disability experience problems with using multiple fingers separately as well. The third game consists of sheep walking in a field. The user has to place the sheep behind the fences in the field. To place them behind fences, the user has to hover over the sheep, close the hand, move the sheep over the fence and open the hand. The closing and opening of the hand was practiced in this game. This movement issue did not occur in the literature of motor movement issues of people with an intellectual disability. The results showed that the users were especially skilful in the third game. This game also had the biggest positive effect. The second game caused the most stress, due to the high perceived difficulty level. In general it appeared in the evaluation of the test done by Foletto et al. [43] that it was important that the player was not punished when practicing fine motor skills, because this could result in a reduction of motivation of the player. Additionally it was important that natural interfaces were used, since this makes the user at ease and it creates a natural environment in which the user can interact naturally and use day-to-day gestures and movements. Lastly, the example shows how the Leap Motion could be used for practicing fine motor skills in mid-air. Practicing these skills in mid-air, using horizontal as well as vertical movements, could feel more natural than practicing fine motor skills on a table or tablet while using only horizontal or vertical movements.

Technologies
Looking deeper into the type of technologies that can be used when building an interactive tabletop, it can be stated that Kinect is often used in the literature examples. Kinect is a small sensor containing a RGB camera and can track body movements [44]. Kinect works fine for measuring gross motor movements, but it cannot measure small body movements accurately and is thus not capable of measuring fine motor skills [45]. This is supported by Hosseinpour [46] as well. A technology that can measure fine motor skills is the Leap Motion Controller. This is a USB device that tracks hand and finger motions without hand contact or touching. It can be used to place on a physical desktop facing upwards with hands moving above it. The move area is approximately 1 by 1 meter and the controller captures 200 frames per second. It uses three infrared LEDs and two monochromatic IR cameras. The Leap Motion Controller is very accurate in measuring fine motor skills. It is currently used for treatment of physical injuries and hand rehabilitation [46].

Conclusion

The sub-question of this part is: *How can interactive tabletops influence physical movement of people with an intellectual disability?*

There are advantages of using interactive tabletops to stimulate movement, since they are perceived as attractive and motivating and provide a natural way to practice movements. Besides, there is no pressure when using interactive tabletops in contrast to daily tasks. Nonetheless they do need to contain some aspects in order to be successful and it would be best if they are extended to family homes.

From 2.4.2 it can be concluded that the main fine motor skill issues that people with an intellectual disability are experiencing are: hand-eye coordination, accuracy, speed, using multiple fingers at the same time or separately and rotating the hand. Interaction types that can be used when practicing these skills are clicking, tracking and releasing (figure 8), using multiple fingers separately (figure 9) and together (figure 6) or rotating the hand (figure 7). When the user has to click, track and release, the hand-eye coordination and accuracy can be trained. Using multiple fingers can be trained in different ways. Using multiple fingers at the same time can be used in the 'tweezer grip' by bringing two fingers together or moving two fingers away from each other. Using multiple fingers separately can be practiced when moving one finger at a time when holding the other fingers still. When looking at the technology to support these movements, the Leap Motion Controller would be preferred, because of its accuracy and because horizontal as well as vertical movements can be measured.

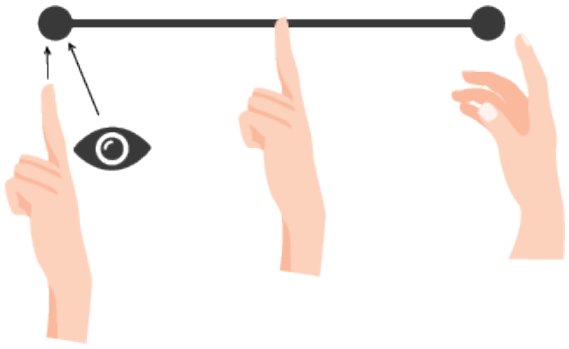


Figure 8: Clicking, tracking/dragging and releasing. This movement requires hand-eye coordination and accuracy. Hands are downloaded from freepik [36], but they are altered.

Figure 9: Using multiple fingers separately. Hands are downloaded from freepik [36], but they are altered.

2.4.4 Gaming

Gaming has become one of today's most popular media activities for people of all ages. When looking at the total entertainment market share, the game industry is already bigger than the 'Hollywood' film industry in terms of revenue [47]. Games are masterful at keeping the brain fully engaged, since players are often using a variety of different skills and techniques when playing games. Benefits of games are that they are fun, unite different players, can evoke emotions and can work as educational tool. Lanyi and Brown [48] state that learning is much more effective when the user has fun. In this particular case, games can indeed serve as educational tool, as they can be used for people with intellectual disabilities to practice motor skills. When games are used for educational purposes they can also be called 'serious games' or 'transformational games'. Transformational games can transform their player in the sense that the gaming experience has a long lasting effect on the mind instead of being just a momentary distraction [49].

There already exist serious games that provoke movement for people with an intellectual disability. Fu et al. [40] supports the idea of using games as a more attractive way for exercising motions. Games that stimulate movement could improve the practical, conceptual, cognitive and social skills of people with an intellectual disability [50]. When creating a serious game for people with intellectual disability, Lanyi and Brown [48] state that the cognitive load on the user needs to be minimised. Moreover, the game needs to be very simple and minimalistic. Besides visual output, also auditory output can promote the user to engage in games [48]. However to support accessibility, 'regular' games need to be adjusted to fit the needs of intellectual disabled. In order to do this, the applications need to have a small number of controls, rather no time constraints, no distracting elements or additional stimuli [51].

Some game aspects can contribute to practicing the following fine motor skills: hand-eye coordination, accuracy, speed, using multiple fingers at the same time or separately and rotating the hand. Ideas of how the games could look like can be found in figure 10, figure 11 and figure 12.

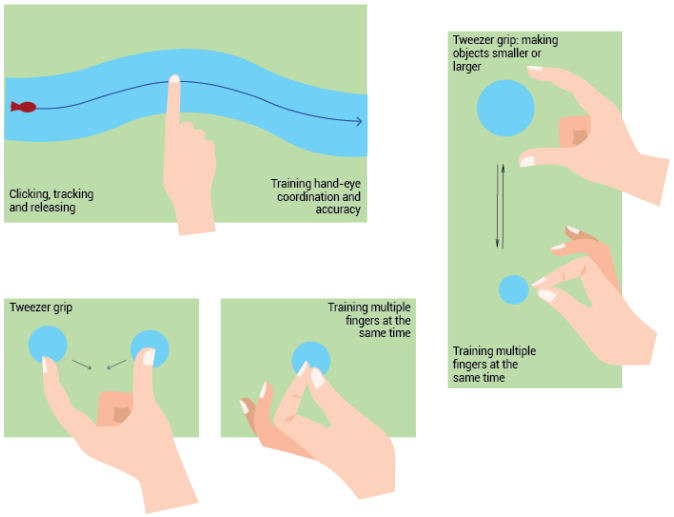


Figure 10: Game ideas of how to practice clicking, dragging and releasing and using multiple fingers at the same time. Hands are downloaded from freepik [36], but they are altered.

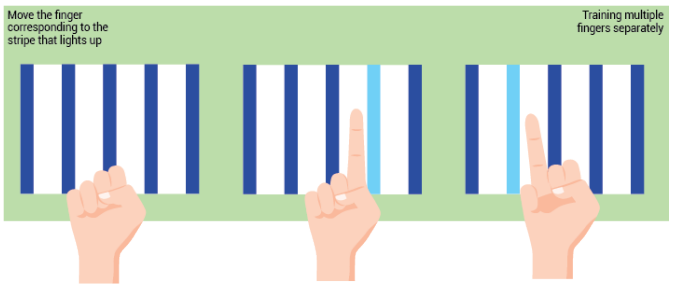


Figure 11: Game ideas of how to practice multiple fingers separately. Based on the game of Foletto et al. [43] Hands are downloaded from freepik [36], but they are altered.

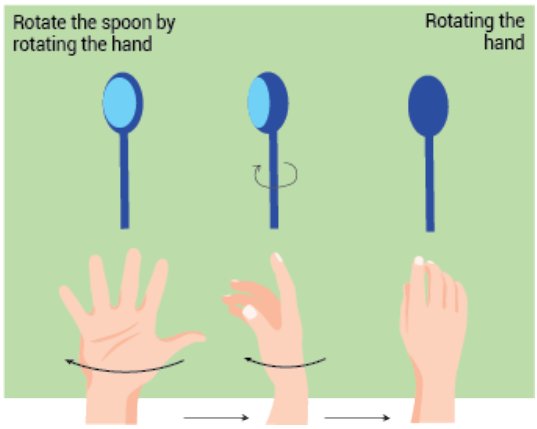


Figure 12: Game ideas how to practice hand rotation. Hands are downloaded from freepik [36], but they are altered.

Conclusion
The sub-question of this part is: *How can gaming influence physical movement of people with an intellectual disability?*. Games could be very suitable as an educational tool for practicing motor skills. Games are good at keeping the brain engaged and they could improve practical, conceptual, cognitive and social skills of people with an intellectual disability. However games have to meet some requirements in order to be successful for this group, like being minimalist, having a small number of controls and containing no distracting elements.

2.4.5 Conclusion

The main question of this literature review is: *How can we improve the practice of motor skills of people with an intellectual disability by means of interactive tabletop games?*. Before answering the question, it must be clear what motor skills are the most important to tackle. Since fine motor skills are primarily important for the performance of ADL, it would be useful to focus on improving these skills. Especially hand-eye coordination, accuracy, speed, using multiple fingers at the same time or separately and rotating the hand are perceived as difficult fine motor skills. Interactive tabletops could contribute to the practice of fine motor skills, since they can be attractive, relaxing and they can beat the shortcomings of traditional exercises, like boredom and lack of motivation. Furthermore, interacting with an interactive tabletop can feel more natural when practicing motor skills. When looking at the games projected on the interactive tabletop, it can be stated that they can function as a

motivational factor for people with an intellectual disability to move. However games need to be adapted to the needs of this group. Therefore, the games need to be minimalistic, have only a small number of controls and contain no distracting elements in order to be successful.

Concluding, the combination of practicing fine motor skills by means of an interactive tabletop might have a positive effect on the development of fine motor skills when implemented in the right way. Lastly, the PEDI scale could be very useful for measuring functional abilities of people with an intellectual disability and the JTHF test could be used for measuring the fine motor skills of people with intellectual disability.

2.5 Conclusion

Firstly, from literature it can be concluded that people with a mild intellectual disability often have underdeveloped fine motor skills and are therefore dependent on other people while performing ADL. Especially hand-eye coordination, accuracy, speed, using multiple fingers at the same time or separately and rotating the hand is difficult for people with an intellectual disability. This section will give answer to the sub-research questions posed in 1.5.

What fine motor skill difficulties do people with a mild intellectual disability encounter during activities of daily living (ADL)?
People with a mild intellectual disability perceive the following fine motor skills as difficult: clicking, tracking or dragging and releasing, using multiple fingers separately when holding the rest of the fingers still, using multiple fingers together, for example when using the tweezer grip and rotating the hand.

When looking at existing products, HandsOn [21] has shown that when picking up, rotating and sliding objects, many different muscle groups can be practiced at the same time and this can increase muscle strength. Additionally, the Leap Motion Controller makes it possible to practice fine motor skills in mid-air and this can improve upper limb coordination, speed of movement and fine dexterity. One advantage of using interactive tabletops stated by Leap Motion and supported by Xu et al. [3] is that interaction with technology can feel more natural to people with an intellectual disability instead of using a mouse or keypad. From literature it can be concluded that using an interactive tabletop can be an attractive, motivating and natural way for practicing fine motor skills. Furthermore, extending interactive tabletops to family homes could further increase the practice of fine motor skills. When comparing Kinect and the Leap Motion Controller, it can be stated that using the Leap Motion Controller to practice fine motor movements is preferred.

What criteria should be contained in a game for people with a mild intellectual disability to stimulate the training of fine motor skills?
All three existing products describe that the combination of moving and playing can be very successful. However, the games displayed on the interactive tabletops need to be adjusted to the needs of people with an intellectual disability. The Tovertafel offers a list of game characteristics (figure 3), like providing enough time to react and minimalism, that can be applied when creating a game for this target group. They further state the importance of people practicing at their own pace and difficulty level, therefore games could have different layers. Additionally, to have a better estimation of what games would fit the users, Active Cues creates their products by means of co-design, creating games together with the target group to fit their needs [18]. Furthermore, Tovertafel states that the aspect of fun needs to be present in an interactive tabletop in order to stimulate people with an intellectual disability to join [17]. This is supported by and Lanyi and Brown [48] in the literature review.

Schell [49] also supports that the aspect 'fun' needs to be present in games to stimulate people to join.
Literature has shown that games could be a good fit to practice motor skills, primarily because games are good at keeping the brain fully engaged. Furthermore, Leap Motion [42] as well as Lanyi and Brown [48] state that visual as well as auditory feedback can further increase motivation to practice fine motor skills. Lastly, Tovertafel proposed some game aspects that can increase engagement and motivation of people with an intellectual disability to use an interactive tabletop, these are sensory stimulation, competition, sympathy, humour, challenge and creativity [18].

2.5.1 Design tips

To our knowledge there does not exist a commercially application yet where people with an intellectual disability can practice fine motor skills on an interactive table. When designing such application, the following interactions should be trained:

- Hand-eye coordination
- Accuracy
- Speed
- Using multiple fingers separately
- Using multiple fingers together (f.e. in the 'tweezer-grip')
- Rotating the hand

Since clicking is more a mouse or touchscreen related activity, this activity will not be further explored in coming chapters.

3 Methods and Techniques

In this chapter, the Creative Technology Design Process (CTDP) [15] will be explained. This process exists of four phases: ideation, specification, realisation and evaluation. All phases will be used in this thesis and are explained below.

3.1 Ideation

The ideation phase will focus on creating multiple designs for the system. A user profile of a potential user will be created and mind maps will be made listing the ADL that require fine motor skills. Both are based on the findings in chapter 2 and the profile of the user will be discussed with experts. Thereafter system requirements will be composed and prioritized based on the MoSCoW analysis. This analysis decides what the product must have, should have, could have and won't have. The requirements and their prioritization will be decided based on the findings in chapter 2 and will be discussed with the client and an expert. Lastly, an individual brainstorm will be held about game concepts. Together with the client, the three most promising options will be chosen based on their connection with ADL, the suitability of the concepts for the target group and the preference of the client. These concepts will be presented to the experts and in the conclusion with the experts and the client, one game concept will be chosen based on the aspects stated above including the preference of the experts. The chosen concept will be realised in the later stages of the thesis.

3.2 Specification

The specification phase describes the interactions of the system, the game elements and objects, the course of the game, a hardware and software description and will end with creating a technology prototype. The technology prototype will be built based on the game concepts and will include the most important elements decided by the MoSCoW analysis of the ideation chapter. The goal of the technology prototype is to test the interactions between the user and the system and the product will be adjusted to the findings of the prototype testing. The chapter will end with a specified product, ready to be built in the realisation phase.

3.3 Realisation

In the realisation phase, the end product will be build based on conclusions in the specification phase. The chapter will show how the game is created and will show the software and hardware implementations. In the conclusion, a reflection on the system requirements of the ideation phase will be made. The realisation phase will make the product ready for testing.

3.4 Evaluation

The evaluation phase will exist of two user tests. First a pilot test will be conducted with the end product to check the test methods of the evaluation test. The pilot-test will be evaluated and the test procedure will be adapted to the outcomes. Then, the end product will be tested in the evaluation test. Two groups of participants will join in this test, face-to-face participants and online participants. Since the product cannot be tested with the target group, the product will be tested with the housemates of the researcher (face-to-face participants). However to get an idea of the suitability of the product for the target group, experts will be asked to provide feedback on the product via an online means. More information about the selection and procedure of evaluation test will be provided in the evaluation chapter 7.

4 Ideation

This chapter contains mind-maps, a user profile, system requirements prioritized based on the MoSCoW analysis and brainstorms about game concepts. An expert of the target group is interviewed and her answers are used for ideation. More information about this interview can be found in the section 4.1. At the end of this chapter, one game concept will be chosen based on requirements set up in this chapter and this concept will be used for the later stages of the thesis.

4.1 Methods

For this phase, an interview is held with an expert of the target group. This expert is a physiotherapist of Siza, a foundation that provides care and support for people with a physical or intellectual disability or multiple disabilities. This expert is close to the target group and has experience with the implementation of interactive tabletops for people with an intellectual disability. At Siza, they use the Tovertafel of Active Cues at daytime activities. Therefore this expert can give insight into how the target group interacts with interactive tabletops. The expert will be referred as the expert of the target group in this thesis.
Before the interview is held, an ethics request is approved by the ethics committee. This request includes an explanation of the procedure of the interview, an ethics checklist and an informed consent. The interview is a semi-structured interview which leaves space for asking follow-up questions that have not been prepared in advance. The interview is held online. The aim of this interview is to create a better context of the target group and their fine motor issues. The interview questions can be found in Appendix C.1.2.

Furthermore the game developer of the client has given feedback on a game concept that will be invented later on in this chapter (section 4.5.1). The concept is sent to him with a game explanation (figure 16 and figure 17) and feedback is sent back via email. Therefore additional face-to-face contact is avoided. The game is adjusted to the given feedback.

4.2 First ideation

The starting point of this chapter are the design tips of chapter 2. This chapter ends with stating the most important fine motor skill issues of people with a mild intellectual disability. These are:

- Hand-eye coordination
- Accuracy
- Speed
- Using multiple fingers separately
- Using multiple fingers together (f.e. in the 'tweezer-grip')
- Rotating the hand

To show the importance of these fine motor skills when performing ADL, a mind map is created that shows which fine motor skills are used for which ADL. Another mind map has been created to show the interactions, technologies and game characteristics that could be used in the end product. These mind maps are created by brainstorming about ADL. The mind maps can be found in figures 13 and 14.

Figure 13: Mind map about ADL that require fine motor skills

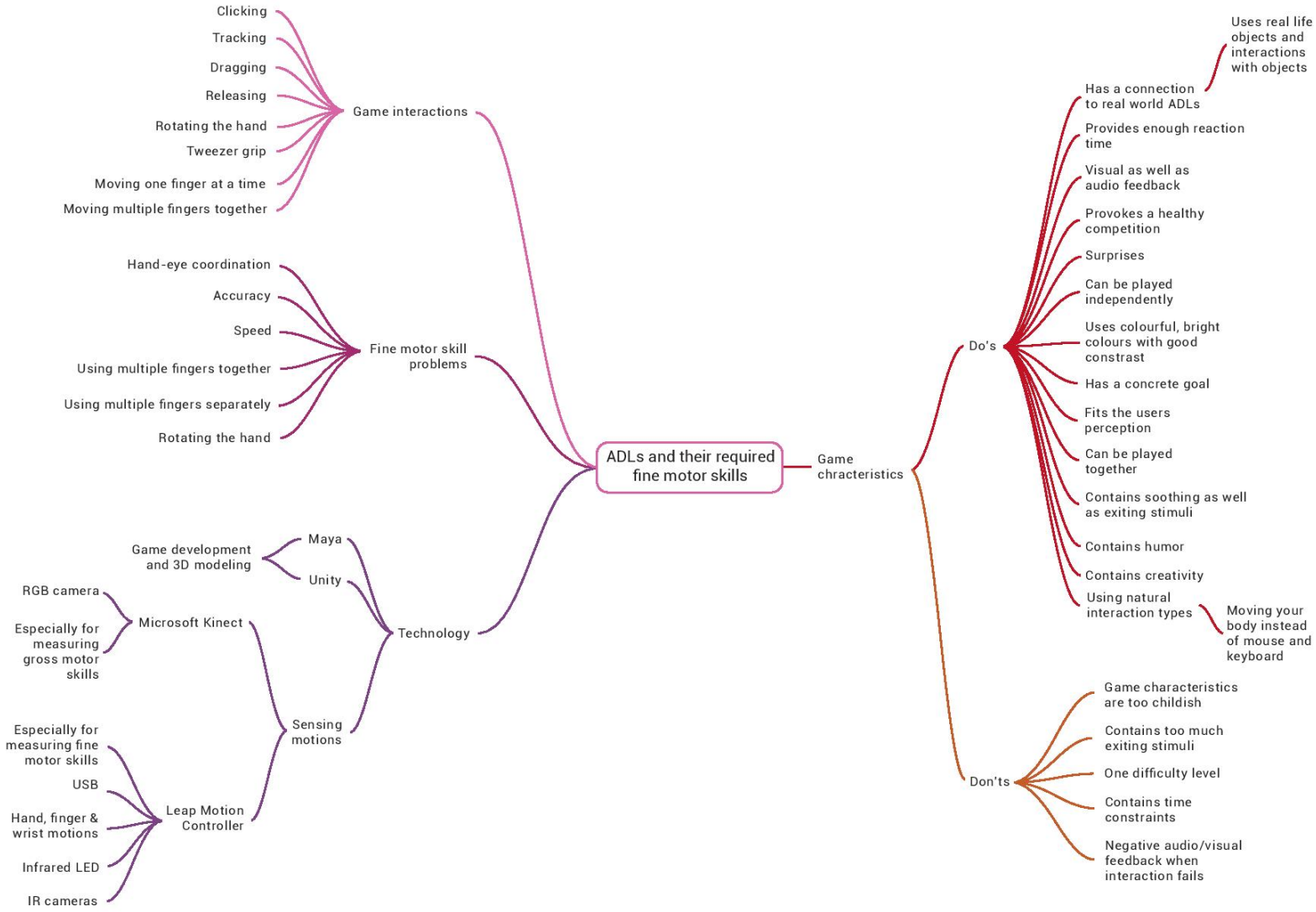


Figure 14: Mind map about game interactions, fine motor skill problems, technology that could be used for the end product and game characteristics that could be implemented in the end product

The emphasis in these mind maps is on feeding and dressing, since these ADL have the most impact on daily life. Feeding and dressing are activities that happen multiple times a day and gaining independence in these areas will lead to a large decrease in dependency on other people during the day. An example is Maarten, a man with a mild intellectual disability (see section 4.3 and figure 15). He needs help every morning with dressing himself, because sometimes he has difficulties with buttoning his shirt and pants. Every evening, he needs help again with undressing himself. If Maarten can button his own shirt and pants, he suddenly does not need someone else to help him twice a day with dressing and undressing. Additionally, when looking at food related activities, it can be stated that preparing food requires a lot of fine motor skills, such as cutting with a knife, stirring and flipping. Moreover, when looking at the specific activities related to 'feeding', it can be said that the elements that have the most impact are opening cans, trays, containers, tins and caps. Maarten has sometimes issues with opening containers and therefore he needs help with preparing these types of food. Sometimes Cor (his supervisor, see figure 15) cannot help him with cooking, subsequently the food choices of Maarten will be diminished. Therefore, it is very important to gain independence in these activities, since otherwise external help is always needed to prepare food.

When looking at the other activities of the mind map related to the food domain, it can be stated that eating with cutlery or drinking with one hand can be avoided by eating with a spoon or drinking with two hands. Therefore these activities are less important than the activities involved in preparing food.
Furthermore, another important activity showed in the mind map, is giving, counting and holding tangible money or paying with a card. However these activities might not be performed every day, therefore this aspect is has a less impact on daily life than feeding and dressing. Besides, it can also be avoided by asking someone else to do groceries. Lastly, writing and traveling with (public) transport are often the activities with the least impact on daily life, since these activities can be avoided and are often not performed frequently. However this differs per person.

Concluding, the activities: 'feeding' and 'dressing' will be elaborated in this thesis.

4.3 User profile

The brainstorm has listed all ADL and their required fine motor skills, however the target group and their issues can still feel a bit abstract and vague. Therefore a user persona, a person of the target group, is created (figure 15). This persona shows Maarten, a person with a mild intellectual disability and a potential client for the product created in this thesis. The name and age are randomly chosen, since gender and age are not relevant for this thesis. The residence of the user is based on the living situation of people with a mild intellectual disability at Siza in Arnhem, the Netherlands. The physical skills of the user are deduced from chapter 2. The day schedule is based on the day schedules of the people with a mild intellectual disability in the documentary called 'Net ff anders' [52]. Additionally, the user persona is discussed with the expert of the target group and therefore his characteristics are representative for someone with a mild intellectual disability.

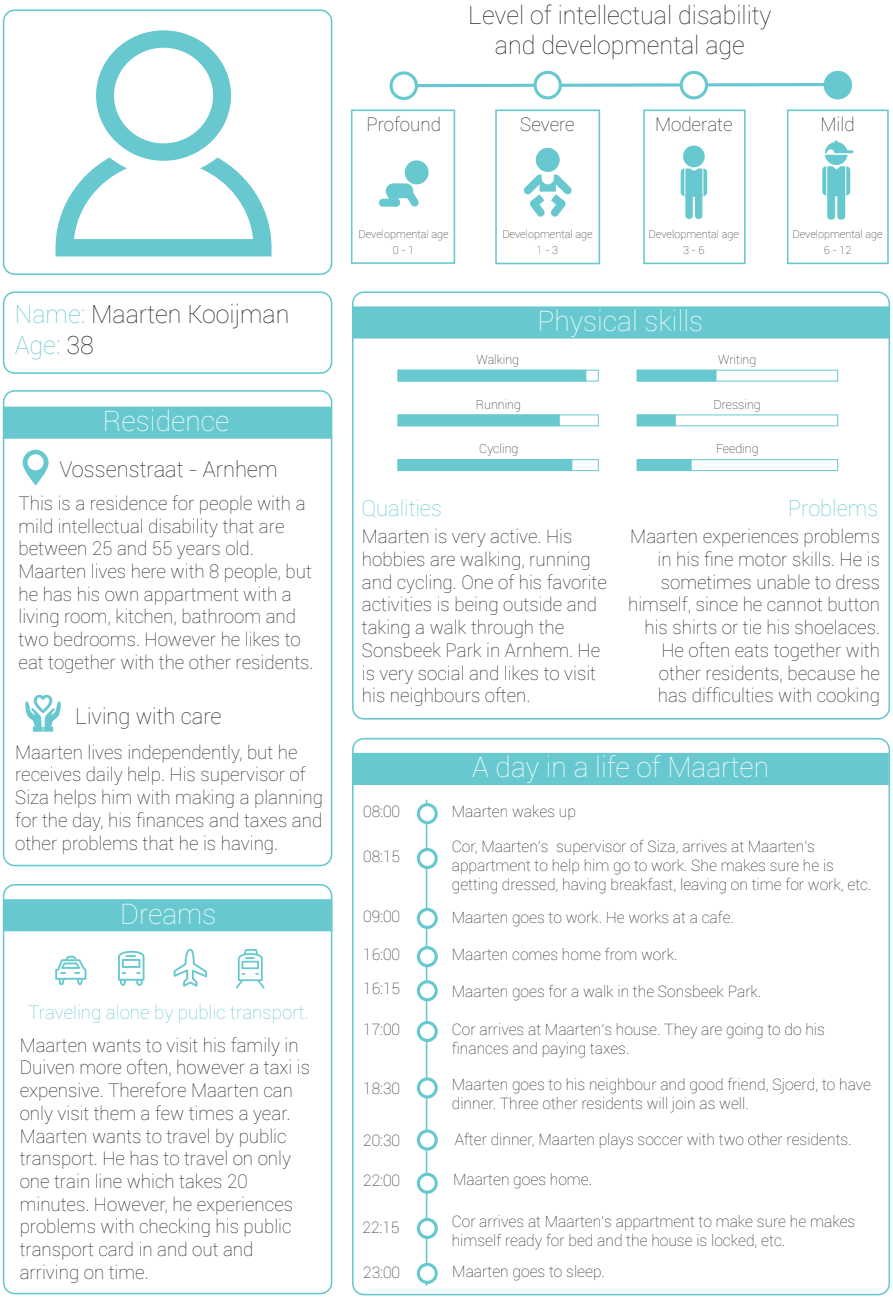


Figure 15: User persona representative for the target group and made in consultation with the expert of the target group. Figures retrieved from Vecteezy and freepik [53][54][55][56][57].

4.4 Requirements

This chapter will provide the requirements for the system. These requirements are based on the findings in chapter 2, the interview with the expert of the target group and have been discussed with the client. The layout of the requirements is based on the layout used in a lecture about requirements engineering of the University of Twente and Roessingh Research and Development [58].
Within these requirements a distinction is made between functional and non-functional requirements. The functional requirements will describe *what* the system will do and the non-functional requirements will describe *how* the system will do this. Furthermore, the 'rationale' will provide a short statement that explains the importance of the requirements. Finally, the MoSCoW analysis will prioritize each requirement. The priority of the requirement is based on multiple sources: the findings in Chapter2, the feedback of the client and the feedback of the expert of the target group. The feedback is very important for the prioritization of the requirements, since both experts contain insight into the usage of interactive tabletops for the target group of this thesis. Most requirements have been presented to the client and their priority have been discussed based on experience with interactive tabletops. The expert of the target group has emphasized the importance of some requirements during the interview. The other requirements are composed on the basis of the findings of chapter 2 and 4.

4.4.1 Functional Requirements

Requirement ID #1	**Hardware**
Requirement	The system is able to track hand movements: horizontal and vertical
Rationale	The goal of the system is to practice hand movements. In order to have interaction with the system, the system measures hand movements. Different hand movements will affect the game differently.
Source	Conclusion of chapters 2 and 4
Priority	Must have

Table 2: Requirement ID #1

Requirement ID #2	**Hardware**
Requirement	The system works with a gaming engine
Rationale	Games are a good fit for practicing motor skills, because they are, for example, good at keeping the brain fully engaged. In order to create a game in which fine motor skills can be practiced, a gaming engine is needed.
Source	Conclusion of chapters 2 and 4 and stated by Lanyi and Brown [48] and Schell [49]
Importance	Must have

Table 3: Requirement ID #2

Requirement ID #3	**Hardware**
Requirement	The system is stable and measures what it should measure
Rationale	The system should measure different hand-movements in order to practice different hand-movements. The most important hand-movements the system should measure are: • Tracking • Releasing • Rotating the hand • Closing the hand • Opening the hand • Using fingers separately • The combination of fingers together
Source	Conclusion of chapter 2 and Carmeli et al. [4], Lahtinen et al. [31], Vuijk et al. [32], Vimercati et al. [33] and Stichting Rubinstein [34]
Importance	Must have

Table 4: Requirement ID #3

Requirement ID #4	**Hardware**
Requirement	The system gives audio and visual feedback to the user
Rationale	Audio and visual feedback can increase motivation and can provoke engagement. Further, audio and visual feedback can inform the player about specific actions and whether they are for example, good or neutral actions.
Source	Fernández-González et al. [42] and Lanyi and Brown [48]
Importance	Must have

Table 5: Requirement ID #4

Requirement ID #5	**Hardware**
Requirement	The system contains a trigger to pause or stop the game.
Rationale	Sometimes the games might be too overwhelming for people with a mild intellectual disability. Also the player must be able to stop the game at any point for whatsoever reason.
Source	Expert of the target group
Importance	Must have

Table 6: Requirement ID #5

Requirement ID #6	**Software**
Requirement	The game can be played with multiple people
Rationale	Playing games with multiple people can provoke a healthy competition wherein people are more motivated to try their best. Moreover, multiplayer games can raise good discussions about the game and can help in developing social skills.
Source	Active Cues [18] and expert of the target group
Importance	Should have

Table 7: Requirement ID #6

Requirement ID #7	**Software**
Requirement	The game consists out of multiple 'mini'-games that each practice other fine motor skills
Rationale	More variety may lead to a decrease in boredom. Additionally, different games with only a few different hand-movements might be easier to understand instead of having a lot of interactions in just one game.
Source	Conclusion of chapter 4
Importance	Could have

Table 8: Requirement ID #7

4.4.2 Non-Functional Requirements

Requirement ID #8	**Software**
Requirement	The game is easy to understand, but the content should not be too simple or childish
Rationale	People with a mild intellectual disability have a slower understanding, because of their lower developmental age and IQ. However they are adults and they contain experience of life and thus they should not be approached as children.
Source	Expert of the target group and Nederlandse vereniging van artsen voor verstandelijke gehandicapten [5], Intellectual Disability Rights Service [6], Netwerk Palliatieve Zorg [7], Prinsenstichting [8], Active Cues [18], Vuijk et al. [32]
Importance	Must have

Table 9: Requirement ID #8

Requirement ID #9	**Software**
Requirement	The game provides sufficient time to react
Rationale	People with a mild intellectual disability can react slower due to their slower understanding. Therefore 'regular' games might be too fast.
Source	Expert of the target group a and Active Cues [18]
Importance	Must have

Table 10: Requirement ID #9

Requirement ID #10	**Software**
Requirement	The game has a connection with activities of daily living (ADL)
Rationale	The goal of the system is to train fine motor skills that are required when performing ADL. When the connection between the goal and the game is clearly visible, the user might have a better recognition of the movements performed in the game are also used during the day and understands why it is important to practice the skills.
Source	Expert of the target group and Active Cues [18]
Importance	Should have

Table 11: Requirement ID #10

Requirement ID #11	**Software**
Requirement	The game can be played without assistance of a supervisor
Rationale	When a supervisor is not around or busy, the user should be able to play the game independently.
Source	Active Cues [18]]
Importance	Could have

Table 12: Requirement ID #11

Requirement ID #12	**Software**
Requirement	The game does not give negative feedback (visual or audio)
Rationale	When the user fails to perform an action, the system should not give negative feedback. People with an intellectual disability often need more time or 'tries' to perform a task than people without a intellectual disability. Therefore negative audio or visual feedback can decrease their motivation and self-confidence.
Source	Expert of the target group
Importance	Must not have

Table 13: Requirement ID #12

4.5 First game concepts

After the system requirements have been set up, the first game concepts are created. These concepts are created during a brainstorm with the system requirements in mind. This brainstorm was performed individually and sketched on paper (see Appendix A.1). Later, the brainstorm has been written down (see Appendix A.2). The concept ideas were discussed with the client and together with the client, the three most promising concepts were chosen. These concepts were chosen based on their connection with ADL, suitability for the target group, feasibility, creativity and humour. The three ideas that have been chosen are called: mice, meatballs and pancakes in the subsections below.

4.5.1 Mice

In this game, the player has to protect his food against mice. The game starts with open containers and jars on the table and every container has his own lid. The player has to find the right lid that fits the right container. After a few moments, a mouse will enter the table. The mouse smells the food inside the containers and he will try to eat it. When the mouse is eating the food, the food inside the container diminishes. However the mouse will not eat all the food at once, when he has eaten a certain amount of food, the mouse will fall asleep. The player has now more time to close the container. The player can also remove the mouse from the table by using the 'tweezer grip'.
The interactions of this game are as follows:

- Closing containers: the player can close the containers before the mouse eats the food inside of it. There are different types of containers: round containers, square containers and rectangular containers. Every type of container has to be closed differently. The round containers require a rotation of the hand, while the square and rectangular containers require the usage of multiple fingers together.
- Removing the mouse from the table: the mouse can be removed from the table by using the 'tweezer grip'. The player has to place thumb and index finger on top of each other in order to grab the mouse. Then the player has to move the mouse upwards (vertical movement), thereafter the player can move the mouse to the end of the playing field (horizontal movement). Lastly the player has to open his hand.

It is important that enough reaction time is provided for this target group. Therefore the mice in the game are slow, inattentive and they will fall asleep when they have eaten food. However when the game is too simple, the difficulty can be increased by adding more mice and decreasing the time until the mice start eating the food inside the containers. Moreover, the difficulty can be increased by increasing the amount of food eaten by the mice.
The game could become boring after a while, therefore, the colour and size of the containers can be changed. The speed and amount of the mice can be adapted as well, since everyone is different and everyone must be able to play at his own speed. The game will start with a predefined starting speed and a certain amount of mice, but if the game is too difficult or too simple, the player can adjust the speed themselves by for example, a menu.

The game contains a connection with activities of daily living. In daily life, people with a mild intellectual disability can experience problems with opening and closing contains, jars and cans. When practicing this movement in a virtual world, the pressure on doing it correctly is low in comparison to the real world. The game will contain real life looking containers and mice, so that the visual connection between the game and real life can be seen by the users as well. This might increase the awareness of the importance of practicing these skills.

The movements used in this game are:

- Rotating the hand
- Using multiple fingers together in the 'tweezer grip' and when grabbing lids

The first sketches of this game concept can be found in the figures below (figures 16 and 17).

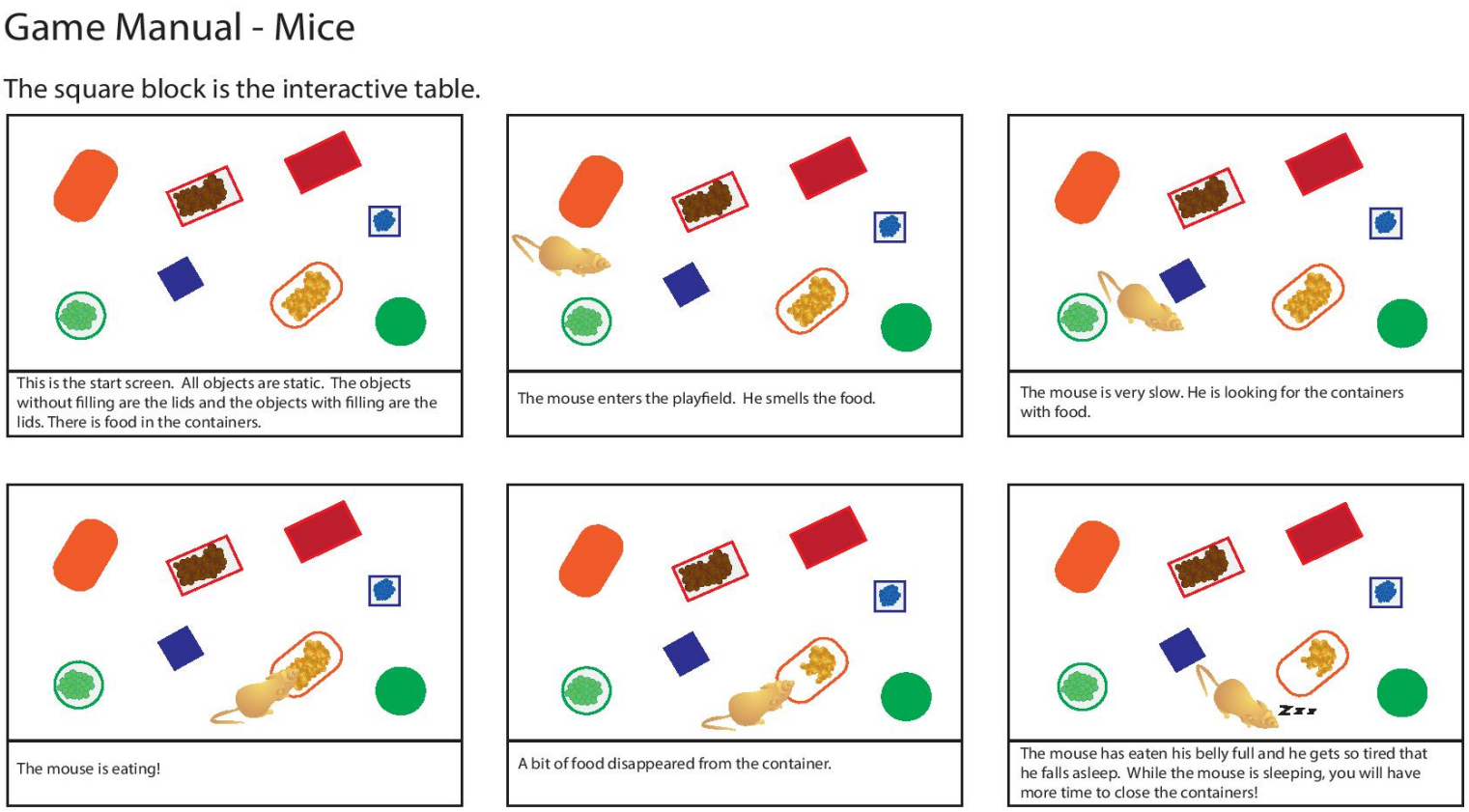


Figure 16: Game concept: mice

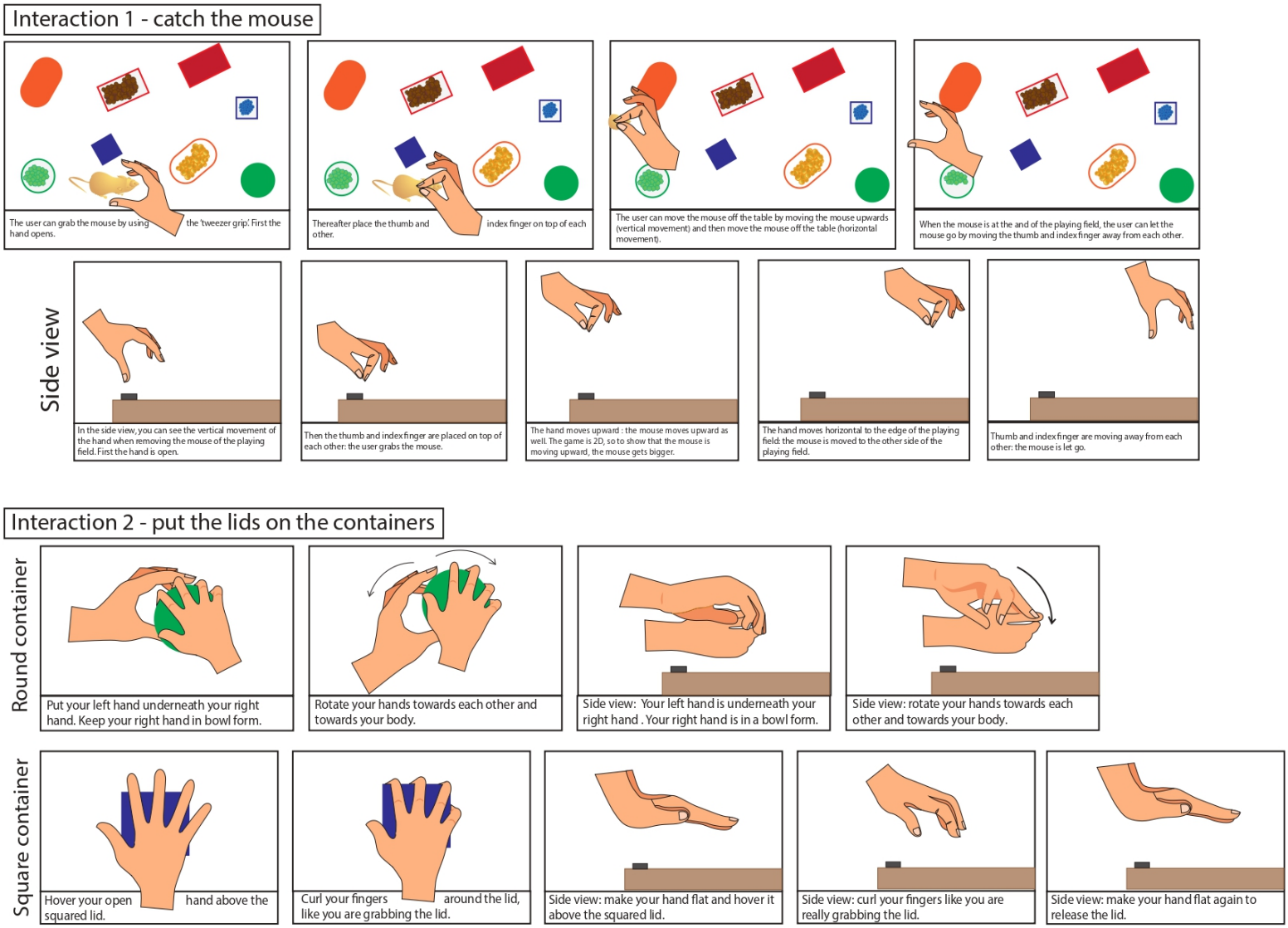


Figure 17: Game concept: mice

4.5.2 Meatballs

The game starts with meatballs wearing blouses and they are walking over the table. They are very fat and their blouses become tighter and tighter and they are about to snap. The user has to release the buttons by using the 'tweezer grip' before the blouses snap. If the blouse snaps open, the button will fly away and fall somewhere on the play field. The meatball is dazed and falls on his back. This must look very funny. The user can collect the buttons by using the 'tweezer grip' to pick them up and dragging them to a can with the same colour as the button.
The interactions of the game are as follows:

- Open the blouses: the user can open the blouses by using the 'tweezer grip'. The user has to place his thumb and index finger on the button and then move the fingers away from each other.
- Collect the buttons: when the blouse snaps open, the buttons falls somewhere on the field. The user can collect the buttons by using the 'tweezer grip'. To grab the button the user can place his thumb and index finger on the button. Thereafter the button can be moved to the corresponding can, this is the can with the same colour as the button. The button can be released by moving thumb and index finger away from each other.

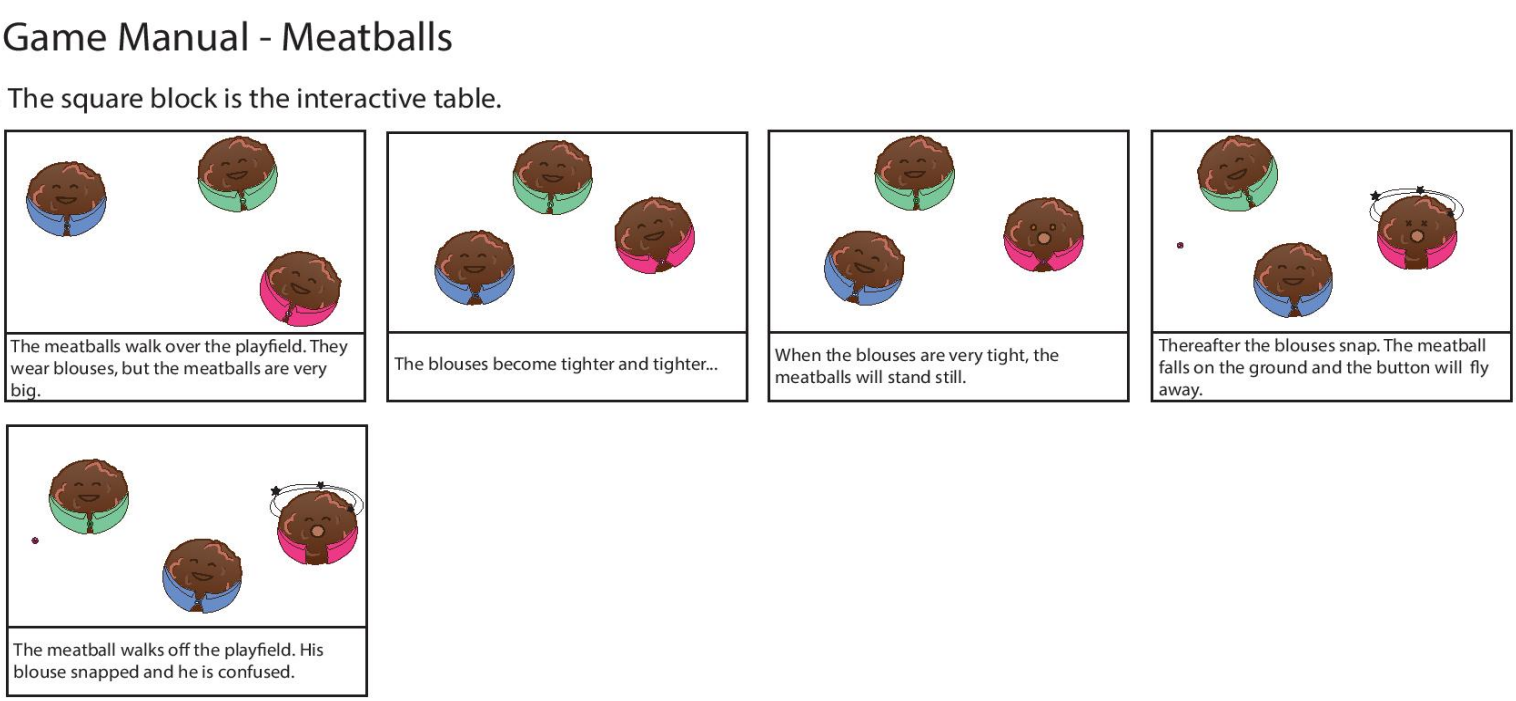
The game can be adjusted to the target group by increasing the 'time to snap' of the blouses and decreasing the amount of meatballs on the table in order to reduce the stimuli. Moreover the meatballs will stand still when their blouses are about to snap, because it might be easier for the user to use the tweezer grip on a still object instead of a moving object.
The game might become boring after playing for a while, therefore the blouses can change colour and the time to snap of the blouses can change. Another idea to decrease the risk of boredom is changing the meatballs into balloons or footballs.

The game practices the tweezer grip and this movement is used often in ADL. However this movement is usually perceived as difficult by the target group. Besides, hand-eye coordination and accuracy is practiced in this game as well.

The movements used in this game are:

- Using multiple fingers together in the 'tweezer grip'

The first sketches of this game concept can be found in the figures below (figures 18 and 19).



The interactions are explained on the next slide. The interactions are:

- Opening the blouses
- Picking up the buttons and sorting them

To make the game more challenging or for multiple people, more meatballs can be added at the same time or the time till the blouse snaps can be diminished.

Source meatballs: https://www.vecteezy.com/vector-art/90110-free-meatball-vector-set

Figure 18: Game concept: meatballs

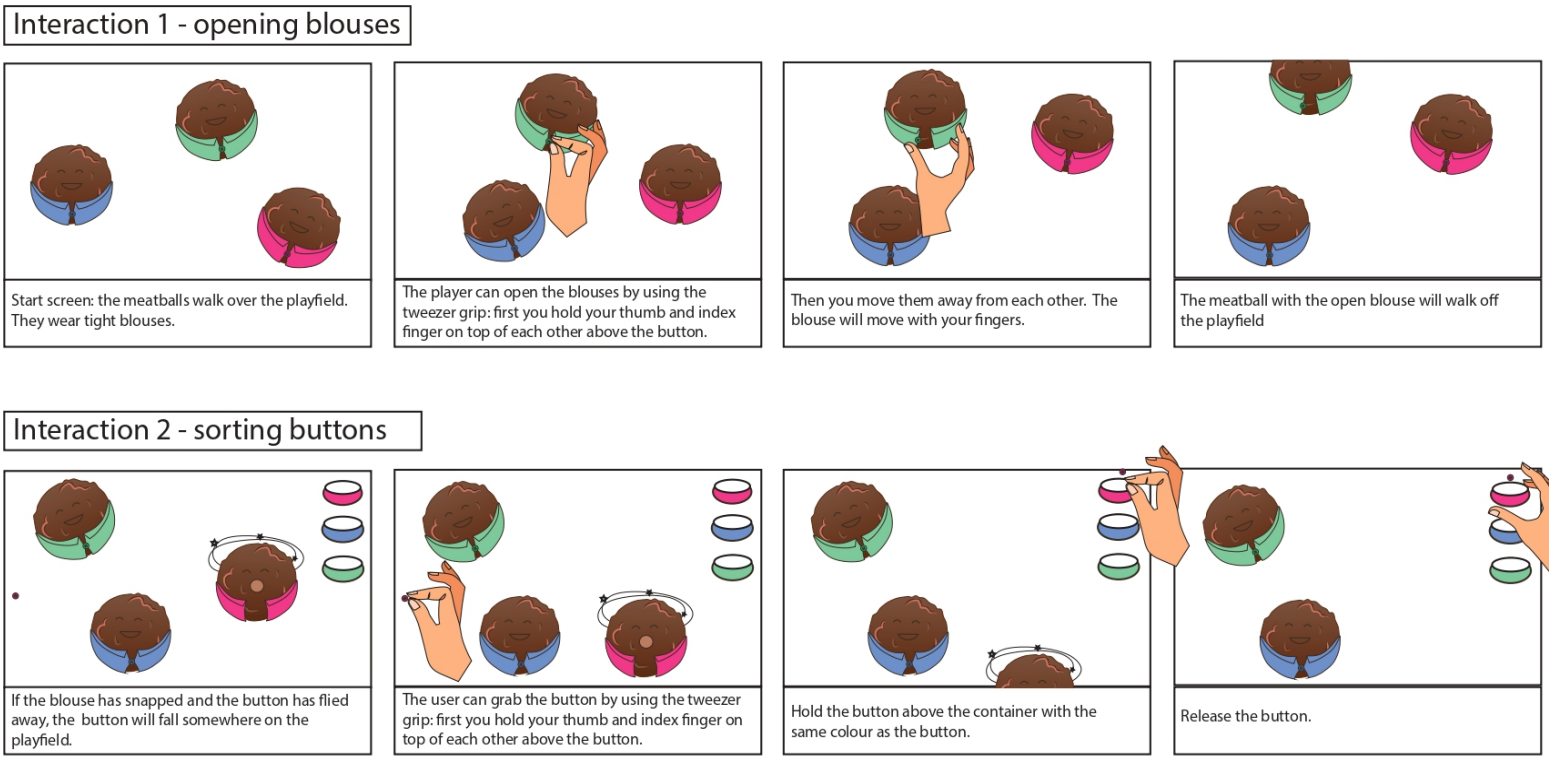


Figure 19: Game concept: meatballs

4.5.3 Pancakes

In this game, the user is going to make pancakes. First the ingredients need to be chosen. All kinds of foods are floating over the table: eggs, tomatoes, flour, hamburgers, pasta, etc. The user has to click on the ingredients that are needed for pancakes: eggs, flour and milk. Thereafter the ingredients need to be mixed and this can be done by rotating the hand clockwise above the container with the pancake mixture. Then the user has to put a pan on the stove and has to pour one scoop of pancake mix inside the pan. When the pancake turns brown, the user can flip it. When the other side is brown as well, the user can shove the pancake on their plate.
The interactions of the game are:

- Selecting the right ingredients: the user has to select the ingredients that are needed for the pancake mix. The game provides a grocery list containing these ingredients. The user can select the ingredients by clicking.
- Mixing the ingredients: the ingredients can be mixed by rotating the hand horizontal and clockwise above the container containing the pancake mixture.
- Pan on the stove: the user can put the pan on the stove by closing the hand above the pan and opening the hand above the stove.
- Scooping the pancake mixture: the pancake mixture can be scooped by closing the hand above the mix and opening the hand above the pan.
- Flipping the pancake: the user can flip the pancake by rotating the hand above the pancake.
- Shoving the pancake on the plate: the user can shove the pancake on the plate by closing the hand above the pan and rotating the hand above the plate.

The game does not have a timer and therefore the user can practice at their own pace. Besides, the risk of over-stimulation should be prevented and therefore the game should focus on practicing one movement at a time.

The game could become boring after playing it a few times. Therefore some extra ideas can be added. One idea is that the user can throw over with the pancakes by shoving the pancake from their plate. The pancake will bounce against the walls. This can be played with multiple people. Another idea is that the user can make a pancake pie. The user can make this pancake pie by first baking a pancake and placing it on a plate. Then a layer of jam, cheese or another topping of choosing can be added. Thereafter another pancake can be baked to put on top of the topping layer. Then another topping layer is placed on the pie. The result is a pile of pancakes with toppings in between.

The game contains a connection with activities of daily living, since in daily life people bake pancakes as well. Learning how to cook is very important, since a lot of independence could be gained in this field. Even when a person with an intellectual disability already knows how to cook, it is very important to keep practicing in order to avoid deconditioning or unlearning the knowledge. Lastly, hand-eye coordination and accuracy is trained since the user has to select small objects when selecting the ingredients.

The movements used in this game are:

- Clicking
- Rotating the hand in different ways

- Using multiple fingers together
- Using multiple fingers separately

The first sketches of this game concept can be found in the figures below (figures 20, 21 and 22).

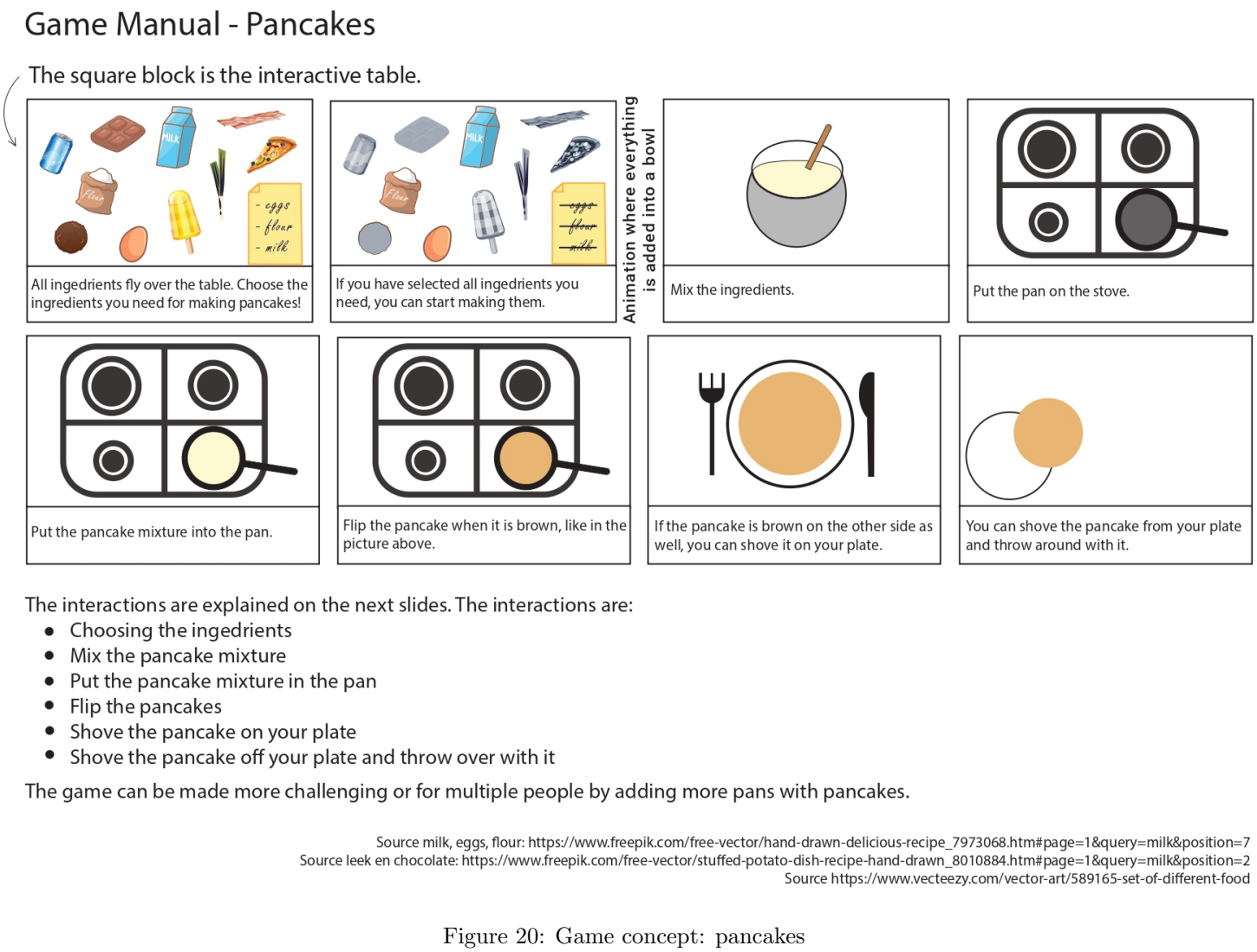


Figure 20: Game concept: pancakes

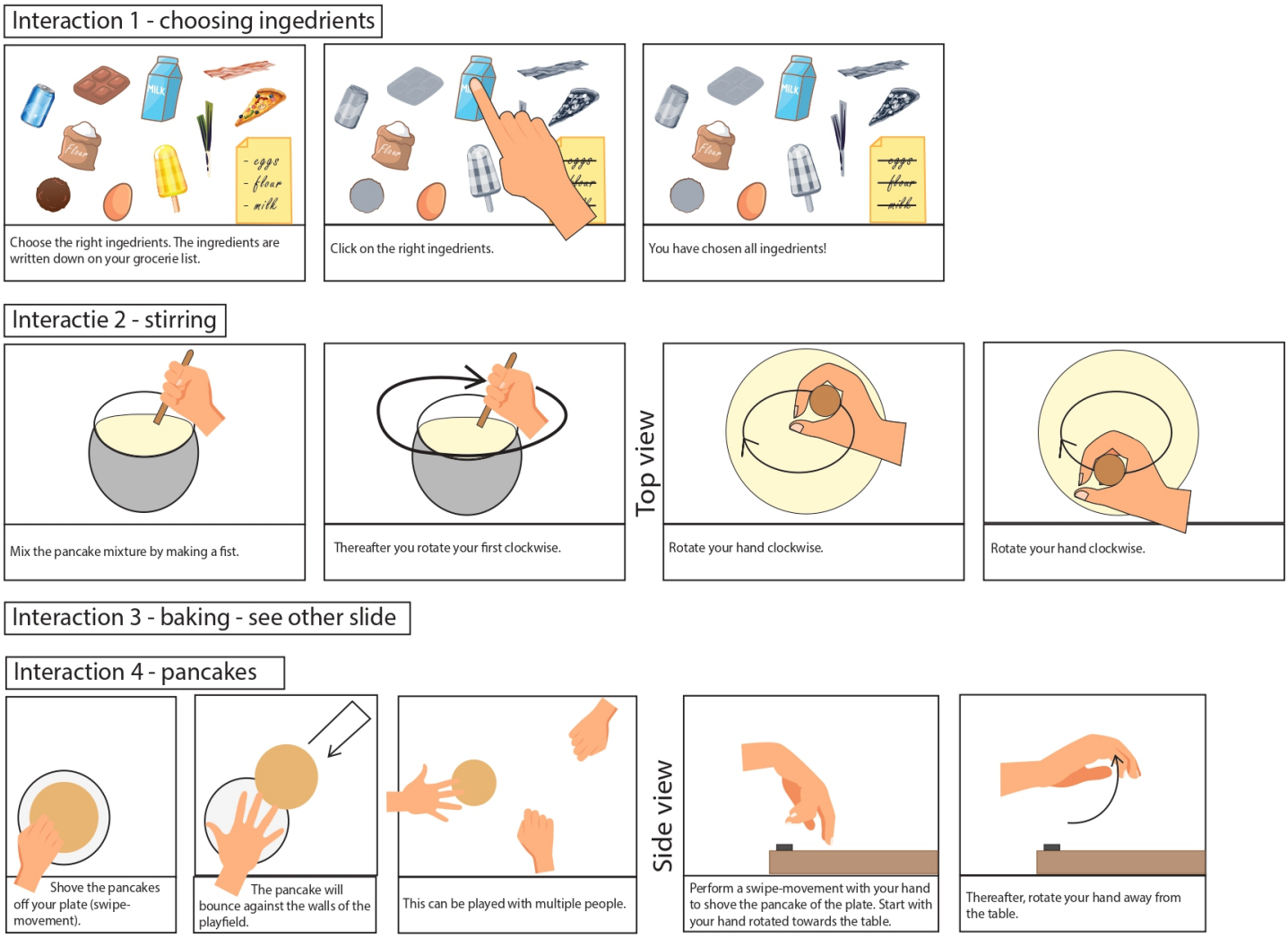


Figure 21: Game concept: pancakes

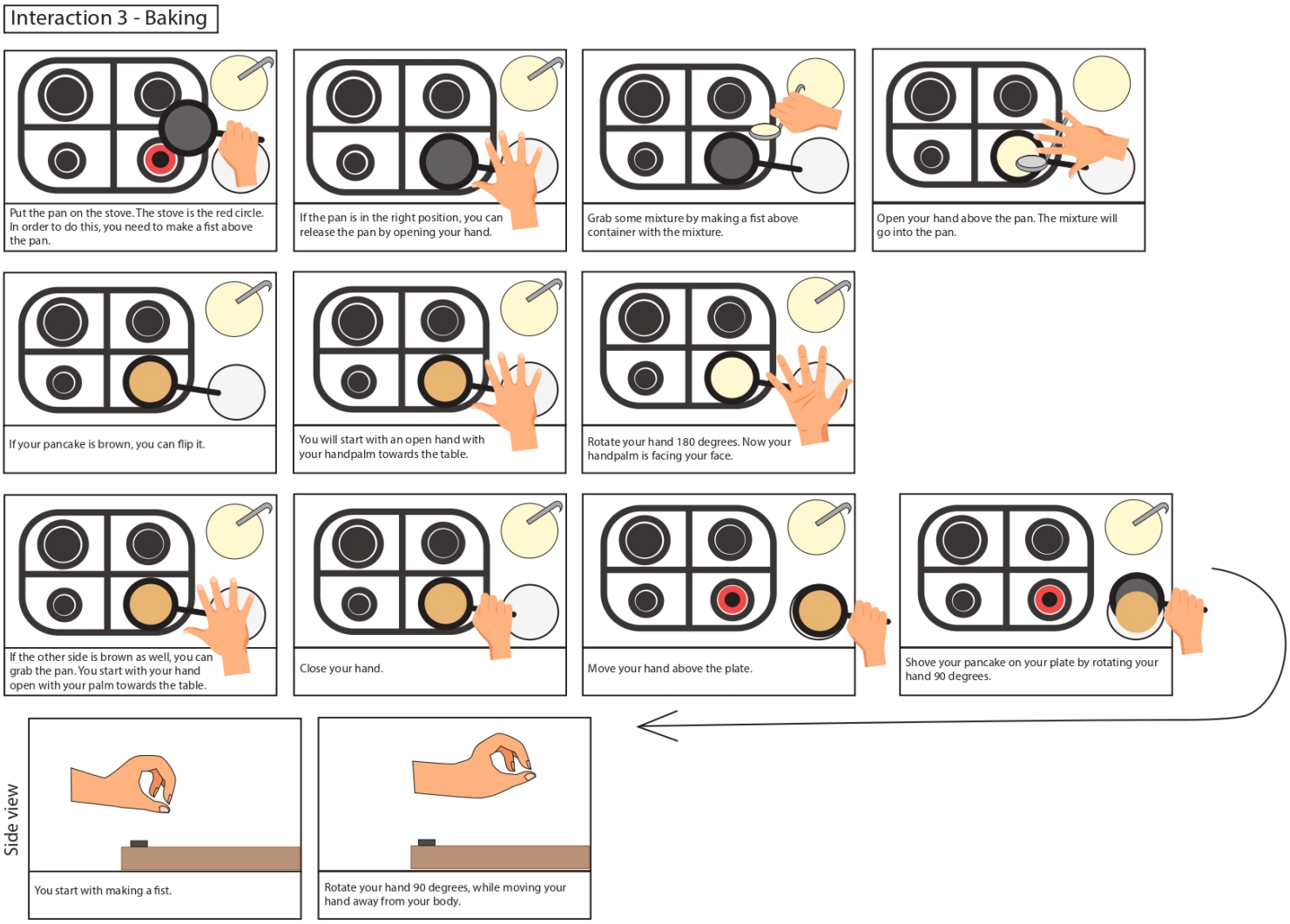


Figure 22: Game concept: pancakes

4.6 Final game concept

In the previous section, three concepts have been chosen of all game concepts invented in the individual brainstorm. For the specification phase it is important to choose one game concept, since creating three games is too ambitious for this thesis. In order to choose one game concept, the game concepts have been discussed with the client and with the expert of the target group. During the discussion, it became clear that the most important elements of the game are: the connection to activities of daily living, the amount of different hand movements trained, the suitability of the game for the target group and the possibility to play the game with multiple people. To make an easier choice, a table is created containing the most important aspects of the game (table 4.6). The scores that can be assigned to the elements are '1', '2' and '3'. The scores have been assigned based on the game concepts and based on the discussion with the client and the expert. Since all games can be adjusted to a multiplayer game, this aspect will not be taken into account in the table.

The game concept with the highest score will be chosen for the coming phases and the end product.

		Mice	**Meatballs**	**Pancakes**
Connection to ADL	Explanation	Closing containers and mice are real, but the context is fiction	Walking meatballs in blouses is fiction, however meatballs itself and opening blouses is non-fiction	The process of baking pancakes is made virtual and non-fiction
	Score	2	1	3
Hand movement types	Explanation	• Rotating the hand • Using multiple fingers together	• Using multiple fingers together (tweezer grip)	• Clicking • Hand eye coordination • Rotating the hand in different ways • Using multiple fingers together
	Score	2	1	3
Suitability for target group	Explanation	The game has gaming elements and non-fiction aspects	The game is a bit too childish	The game has almost no gaming elements, but the movements and cognitive aspects are very useful to practice
	Score	3	1	2
Client	Score	3	2	1
Expert of the target group	Score	3	1	2
	Total score	**13**	**6**	**11**

Table 14: Table considering the three most promising game concepts.

This table shows that there is a preference for the game concept 'Mice'. The game has a connection to activities of daily living (ADL) and practices multiple types of hand-movements. Additionally, the preference of the client and the expert of the target group is considered as very important and they both have a preference for the game concept: 'Mice'. Therefore this game will be chosen as final game concept. The specification of the game concept will be elaborated in chapter 5.

4.7 Conclusion and recommendations

The ideation chapter contained mind-maps, a user persona, system requirements and a brainstorm. Lastly three game concepts have been reviewed and one game concept has been chosen.

The game will be a serious game focusing on improving the fine motor skills of people with an intellectual disability. The most important elements that the game should contain will be discussed now. Chapter 2 states that people with a mild intellectual disability often have a slower understanding, therefore the game should be simple and should not contain too much stimuli. Likewise, the user should be given enough reaction time. Also every person has different needs and abilities and therefore the user should be able to change the difficulty level. This is supported by the expert of the target group as well. Therefore it is decided that the game contains multiple difficulty levels and these levels should be changeable while playing the game. Further, as already mentioned in chapter 2, audio and visual feedback is important to keep users engaged in playing a game. Hence visual as well as audio feedback will be present in the game. Moreover, the game should contain a pause and stop button, because the player needs to be able to stop the game at any point for whatsoever reason. Finally, the game must be playable with multiple people. The expert of the target group emphasised that the games on the Tovertafel are created to serve a social role as well, since solving games together can be very binding and can cause a better understanding of the game in general.

The specific interactions and game elements will be elaborated in the specification phase (chapter 5).

5 Specification

The ideation chapter (chapter 4) ended with design recommendations for this chapter. The game 'Mice' is chosen to be implemented and focuses on practicing opening and closing containers. The goal of this chapter is to specify the game and make it ready for building. When reflecting on the previous chapter, it is important that all system requirements with the priority of 'must have' are guaranteed in the end product. Therefore this chapter will make sure that all 'must haves' are assured in the end product. Moreover, this chapter will show the interaction elements and the game elements of the system. Furthermore, the chapter will provide a system description showing which hardware and software will be used in the end product and it illustrates the setup of the system. Finally in this chapter, a technology prototype will be built and tested. The chapter will end with a conclusion and design recommendations for the next chapter 'Realisation' (chapter 6).

5.1 Methods

At the end of the specification phase, a technology prototype will be tested. Due to COVID-19 it is not possible to test the prototype with the target group, therefore the prototype will be tested with two housemates of the researcher in the house of the researcher. Before the prototype testing, an ethics request is approved by the ethics committee including an ethics checklist and an informed consent. The section 5.5 will discuss the methods, results and conclusion of the test.

5.2 Interaction elements

Multiple different hand movements are involved in fine motor skills and practicing these hand movements is important to gain independence in daily life. In order to practice the hand movements, different container types will be used and every container trains his own hand movements. The containers and their hand movement will be discussed below.
From the conclusions of chapters 2 and 4 it could be stated that people with a mild intellectual disability often have difficulties with rotating the hand. Besides, this movement is used often in ADL, for example when unlocking the door with a key or pouring drinks, and therefore this hand movement will be practiced in the game when closing round containers. Moreover, from chapters 2 and 4 it could be concluded that people with a mild intellectual disability experience difficulties when using multiple fingers at the same time. This movement is used often in ADL, for example when putting a (safety) belt on or when grabbing large things, like apples or laptops. This movement will be practiced when closing square or rectangular containers in the game. Lastly, from chapters 2 and 4 it could be said that using multiple fingers together is experienced as difficult by people with a mild intellectual disability. Since fingers are trained together in the tweezer grip, this movement will be trained in the game by adding mice to the game. The user can grab the mice by using this tweezer grip. The tweezer grip is also used in ADL when opening cans, zipping or buttoning clothes or paying with a card.
The different hand movements are discussed below. The images illustrate the translation of hand movements used in real life and how they are practiced in the game.
Lastly it is important that no one is left out in the game, thus the game should also be playable by people that are left handed.

Round containers

For closing round containers, the user has to rotate their hands. This rotation movement can be a big or small movement. An example for when the big movement is used, is when opening sandwich spreads, like jam or peanut butter. The big rotation movement is also used when opening jarred vegetables. The small rotation movement is often used when opening bottles. The movements can be found in figure 23.

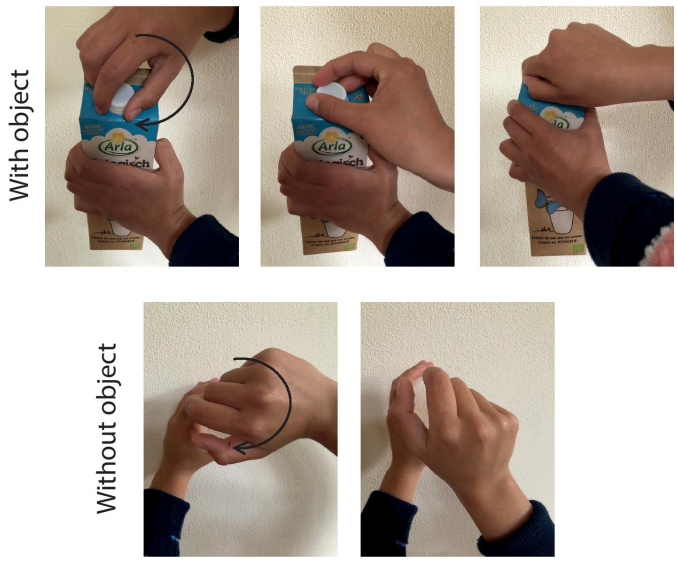


Figure 23: Movement used for round containers. The upper three images show the movement with the container and the lower two images show the movement without the container.

Square containers

When closing square containers, multiple fingers will be used at the same time. First the fingers will grab the lid and when the hand hovers over the container, the lid is let go by opening the hand. This movement is used when opening and closing containers, like for example containers with butter or cheeses and food storage containers. The exact movement can be found in figure 24.

Figure 24: Movement used for square containers. The upper three images show the movement with the container and the lower three images show the movement without the container.

Rectangular containers

The rectangular containers in this thesis will have clickable sides that need to be clicked in order to close the container. This movement requires the use of multiple fingers at the same time and the rotating of the hand. This movement is used when closing food storage containers or lunch boxes. The exact movement can be found in figure 25.

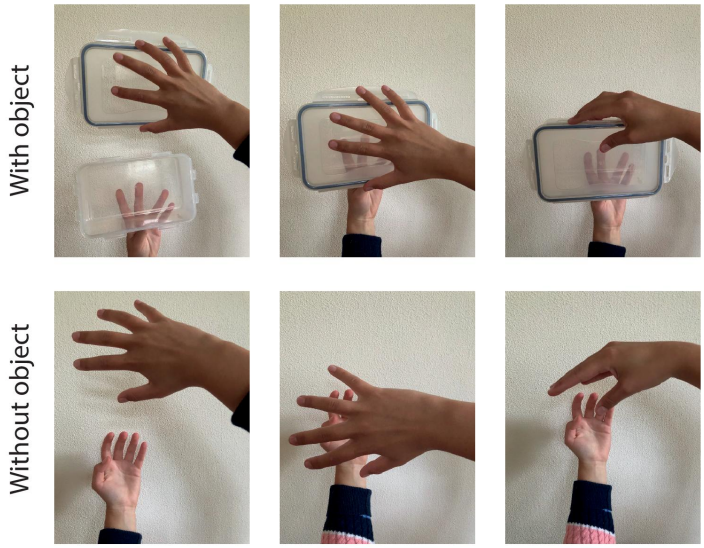


Figure 25: Movement used for rectangular containers. The upper three images show the movement with the container and the lower three images show the movement without the container.

Mice in container

In order to move the mice into the mouse container, the tweezer grip is used. This grip is used often in daily life, for example for opening cans, activities that involve physical money, using zippers or tying shoelaces. The exact movement can be found in figure 26.

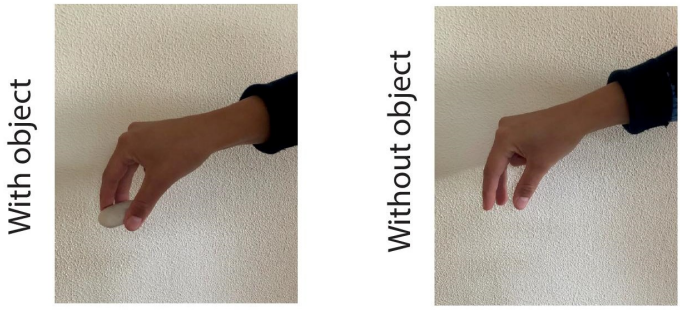


Figure 26: Movement used for the mouse. The left image shows the movement with a real object and the right image shows the movement without the object.

Container over mice

The mouse can also be locked inside the mouse container. The user can put the mouse inside the container by grabbing the container with all fingers and then rotating the hand 180 degrees in order to place the container on top of the mouse. This movement can be found in figure 27.

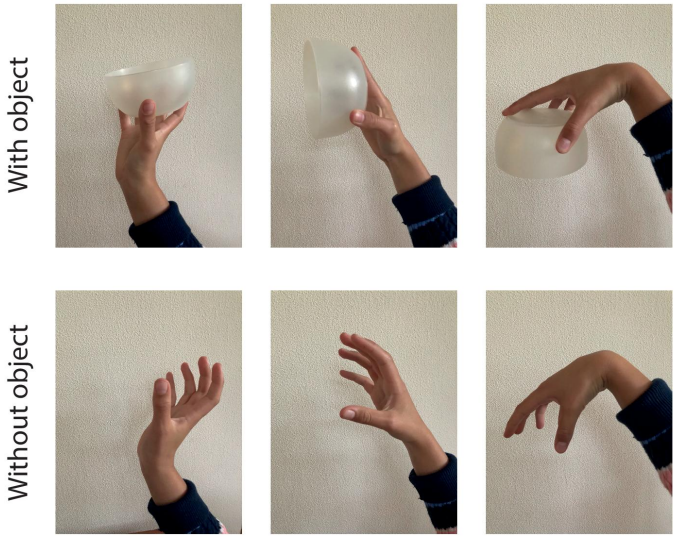


Figure 27: Movement used for the mouse. The upper three images show the movement with the container and the lower three images show the movement without the container.

5.3 Game elements

5.3.1 General game elements

Playing field

The playing field is the place on a tabletop on which the game is projected and the area in which the user can interact with the system. If the game can fit on any standard table, the user is not forced to purchase a new table for this game. The average 6 person table size in the Netherlands is roughly 160 cm till 180 cm long and 90 cm till 100 cm wide and the average 4 person table size in the Netherlands is roughly 130 cm till 140 cm long and 90 cm till 100 cm wide [59] [60] [61] [62].

The company UltraLeap states on their website that the Leap Motion Controller can measure an area of 60 cm x 60 cm. However this interaction area depends on specific situations and the area can be extended till 120 cm x 120 cm [63]. Because of the big difference in interaction area, the Leap Motion Controller was tested for this thesis to see what the controller can measure in this specific situation. The testing was done by linking the Leap Motion Controller to Unity and measuring the distance in which the hands where still noticed by the controller. Since Unity will be used for the end product, the results of this test are representative for the interaction area of the end product. After the test, it can be stated that the Leap Motion Controller measures roughly a length of 85 cm and width of 67 cm in this specific situation.

It can be concluded that the interaction area of the Leap Motion Controller can easily fit on a 4 to 6 person table. Besides, the game measures from the top of the Leap Motion Controller vertically up to roughly 80 cm all around the controller [63]. This means that the game can also be played while standing. The interaction area of the Leap Motion Controller can be found in figure 28.

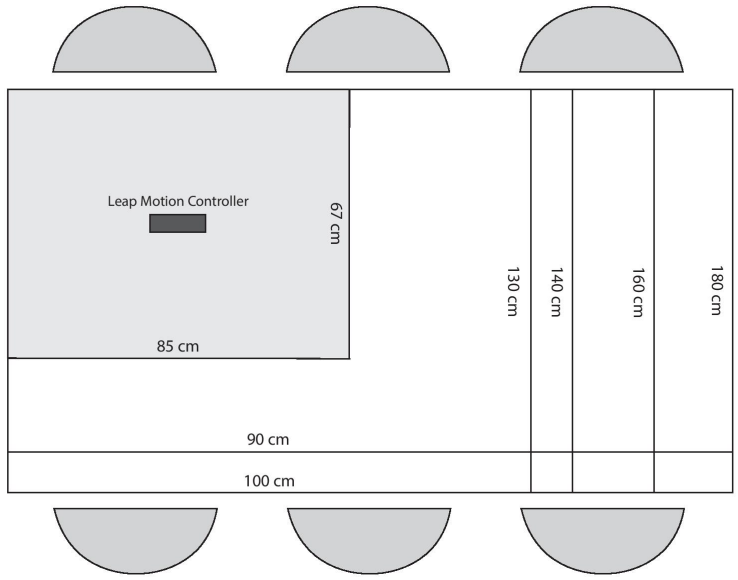


Figure 28: Table sizes of an average 4 and 6 person table [59] [60] [61] [62]. The light grey area is the interaction area of the Leap Motion Controller and the dark grey area is the Leap Motion Controller itself.

Dimension
The projection of the game on the table will be a 2 dimensional projection. However the game itself will be 3 dimensional. The reason for this choice is that the system should measure horizontal as well as vertical movements and the game would feel more natural to the user when the game uses both axis as well. One of the system requirements of chapter 4 with the priority 'must have', was that the system should measure horizontal as well as vertical movements. Whether using 3 dimensions in the game feels natural to the user, will be tested in the test of the prototypes. Concluding, most movements use the vertical as well as the horizontal axis.

Stop/pause button
One of the 'must have' system requirements of chapter 4, was a stop or pause button, because the user needs to be able to stop the game at any point for whatsoever reason.
The button could be build inside the game or the button could be a tangible button. As discussed with the client as well, the stop or pause button should not distract the user from the game. Besides, the user must be able to easily or quickly press the button. However when the button is built inside the game, it might be too easy to press the button accidentally or it might be very hard to perform the right hand movement in order to press the button. Therefore this button will not be built inside the game, but the button will be a tangible button.

Feedback
When the user is interacting with the system, the system should provide feedback to inform the user about the status of that action. Audio and visual feedback is one of the system requirements of chapter 4 with a priority of 'must have'. The types of feedback have been split into two: visual and audio feedback, and these will be discussed below.

Visual feedback

- The lid and mouse move with the hand of the user
  - When the user makes the grabbing movement, the lid/mouse moves a bit up. You can see that the lid/mouse moves towards the user, because the lid/mouse becomes larger and therefore it seems like the lid/mouse is grabbed.
  - When you have grabbed the lid/mouse, the lid/mouse moves with your hand. This means that the lid/mouse will hover underneath your hand.
  - The lid or mouse is 'let go' when you open your hand. The user can see that the lid/mouse is let go, because the lid/mouse becomes smaller and seems farther away from the user. This happens when the user opens his hand above a container or somewhere above the play-field.
  - When the user places the lid on the container, the lid snaps on the container. Otherwise it is very hard to place the lid exactly on the container and it is very difficult for the system to measure the position of the lid when it is not placed correctly on the container.

Audio feedback

- The mouse will make sounds. These sounds will be obtained from the internet. There will be four kinds of mouse sounds for the four states in which the mouse can be:
  - Normal state: in this state the mouse makes mouse sounds, like sniffing.
  - Eating state: the mouse will make eating noises in this state, like crunching.
  - Sleeping state: the mouse will make snoring sounds in this state.
  - Grab state: when the mouse is grabbed by the user, the mouse will squeak. This must not be too dramatic or scary, but the sound will be implemented to inform the user about their actions.
- Sound of closing containers: closing containers is a positive action, therefore this action will contain a positive audio sound. This might be the sound of real containers closing or a positive tone so that the user knows closing containers is something positive.

The specific visual aspects and sounds can be found in chapter 6.

Multiplayer
The system requirements that have been set up in chapter 4 have stated that the game should be playable with multiple people. The reason for this is that playing together causes a healthy competition. Another reason for this, supported by the expert of the target group, is that playing the game together can provoke a conversation in which users will try to find out how the game works. When someone understands how the game must be played, this person can explain it to other people. Furthermore, the game adjusts to the speed of playing and therefore if there are more people playing the game at the same time, the playing-speed will automatically increase. This means that if the containers are closed quickly, new and more containers will arise on the table quicker. Accordingly, the difficulty level depends on the playing-speed and is adjustable on the player, because every player is different.

Game explanation
Before playing the game, a game explanation might be necessary. Otherwise the user would not know how the game works. However when discussing this point with the expert of the target group, it was decided to not provide a game explanation at the start of the game. The reason for this is that playing a game without explanation, causes a conversation at the table in which the users will try to solve how to play the game together. Besides, winning the game is not the goal, considering the goal of the game is to practice hand movements. How much information is needed beforehand will be tested in the user-tests. During user-tests it will also be tested whether it is necessary to tell the users that they cannot touch the table and that they should play the game in mid-air, because the Leap Motion Controller cannot measure movements underneath the controller.
It might be necessary to explain that some containers need an extra interaction, like rotating the hand (round container) or clicking the sides (rectangular containers). This will be made clear by means of an animation. Whether users understand an animation that explains an action that they need to take, will also be tested during the user-tests. Lastly, when the user takes very long before interacting with the system (this time will be specified during testing), there should be a trigger that makes the user interact with the system. This can be in the form of an animation or a sound.

5.3.2 Containers

The main interaction of the game is closing the containers in order to prevent the mice from eating the food. Every container has a lid and the user has to find the right lid of the right

containers. Too see the difference in containers, the containers are different in colour, size and form. Another reason for different forms of containers, is to practice different hand movements. Lastly, the containers will look like real life containers.

Colours

The containers will be given a colour in order to see a significant difference between the containers. The client and the expert of the target group have emphasized that the colours need to be bright and have good contrast. This way, the difference can be seen more easily. Besides, intellectual disability can influence the eye sight of people, so people with intellectual disability can experience colour-blindness [64]. Therefore the colours are also tested on colour-blindness.

For inspiration of the colours, two colour-wheels that have been found on the internet will be used. These colour-wheels can be found in figure 29. The colours of these wheels are: purple, blue, green, yellow, orange, pink and red and within these colour groups there are multiple shades and colour combinations, for example light-green, dark-green and yellow-green. For this project, the colour yellow will not be used, since the colour might have a low contrast with the table and might easily fade in the projection. The colour purple will be chosen, because pink and red lack contrast, purple and pink lack contrast and purple and red do contrast each other. There are now five colours left: purple, blue, green, orange and red. Since light-blue and dark-blue contrast as well, two colours blue will be used. To finalize, six colours are chosen for the containers: purple, dark-blue, light-blue, green, orange and red. The reason behind having six different colours is that more different colours help in distinguishing containers. When having more than these six colours, the colours can lack contrast and the user might not see the difference between the colours. Furthermore, the colours are a combination of bright and darker colours, since this gives good contrast as well. Concluding, the chosen colours for the containers can be found in figure 30. The colours will also be reviewed when they are projected on the table. Some colours might look different when projected due to the lighting or the colour of the table.

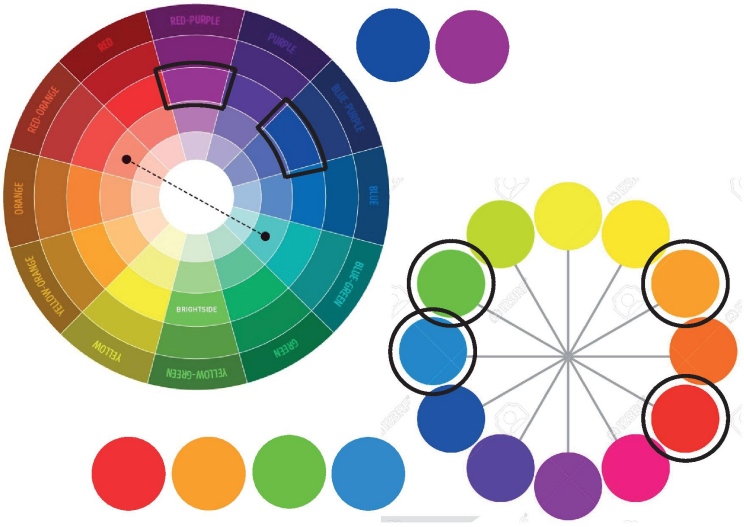


Figure 29: Colour-wheels as inspiration for the colours of the containers. Left:[65] and right:[66]

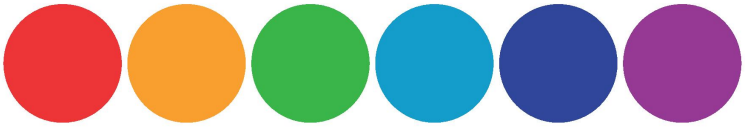


Figure 30: Colours of the containers

Forms
The containers can each differ in form and size. However a connection with real life containers must be made here, because the goal of the project is to train skills that are used when opening containers and jars in real life. As inspiration of real life containers, examples of containers from supermarkets and food storage containers are used, like jars containing vegetables, juices and bottled drinks, different kinds of sandwich spreads, like peanut butter and jam, and different types of food storage containers. The examples can be found in figure 31.

Figure 31: Inspiration of supermarket containers for the forms of the containers

The figure shows different types of containers. When looking at the form of the containers and bottles it can be stated that there are three forms: round, square and rectangular. Therefore this thesis will focus on imitating these forms of containers. These forms can be found in figure 71. This might seem like a small amount of different container types, however as you can see in figure 31, the containers differ in size as well. Likewise, the containers in this project will differ in size too. The size of the containers will be discussed in section 5.3.2.

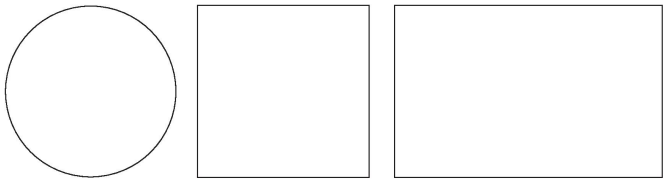


Figure 32: Forms of the containers

Patterns
The containers already differ in colour and form, but to increase the variety of containers, the containers can also differ in pattern. The patterns have been made up by brainstorming about patterns. They can be found in figure 33. Every container has one of these four patterns. Besides having more options of containers, users can distinguish the containers better when having patterns. Despite that the colours have been checked on colour-blindness, the containers might be hard to distinguish and the patterns can help in distinguishing the containers. Lastly, it should be made sure that there does not exist a container on the table with the same colour, form and pattern at the same time, since this would be confusing for the user.

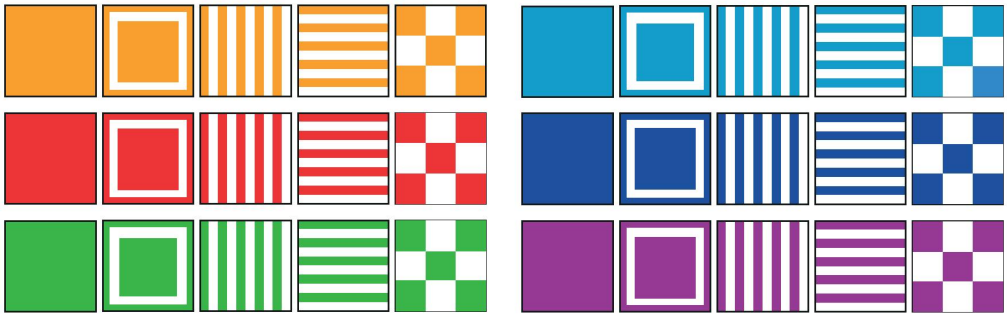


Figure 33: Patterns of the containers

Size
The containers in the game can differ in size, because real life containers differ in size too. For example, a bottle has a small round cap and a jar has a big round lid, however the hand movement to close the lids is for both the same. The interaction area of the table will be around 85 cm long and 67 cm wide (see section 5.3.1) and the the containers must fit on the table. When deciding how big the containers should be, different containers have been collected and measured and the average will be used. The average sizes of the containers are shown in the table below (table 15). These sizes are based on measurements done for this thesis.

Container type	**Items**	**Range**	**Average**
Round container small	7	2.8 cm - 3.4 cm	3 cm diameter
Round container large	14	5.6 cm - 13.5 cm	7.5 cm diameter
Square container	8	10 cm - 14.5 cm	12 cm width and length
Rectangular container	3	width: 11 cm - 14.5 cm length: 12.5 cm - 20 cm	width: 17.5 cm and length: 13 cm

Table 15: Sizes of containers

The containers and their lids should fit on the table. The size of the containers is dependent on the interaction range of The Leap Motion Controller. From experience, it appeared in section 5.3.1 that the Leap Motion Controller can measure roughly 85 cm long and 67 cm wide. However in specific situations this is not guaranteed. Additionally, hands can move beyond the interaction borders when interacting with the system. Therefore some distance is subtracted from this area. The interaction field will now be settled between 75 cm long and 60 cm wide. If this area is bigger than the Leap Motion Controller can measure, this area

will be down scaled in the realisation phase. This will be determined during the user-tests.

If the containers have the average sizes that are stated in the table (table 15), then the maximum capacity on the table is 6 containers (figure 34). This happens when all three types of containers are on the table and the other containers are the largest containers possible (rectangular containers). In this situation, the minimum distance between the containers is 7 cm. Therefore the mouse can be a maximum 7 cm long and wide. However, this situation is not likely to occur often, since there should not be too many containers on the table at the same time, because the target group is easily over-stimulated. Therefore the game should adjust to the playing-speed, so that only if the user can handle a larger amount of containers, more containers will appear on the table.

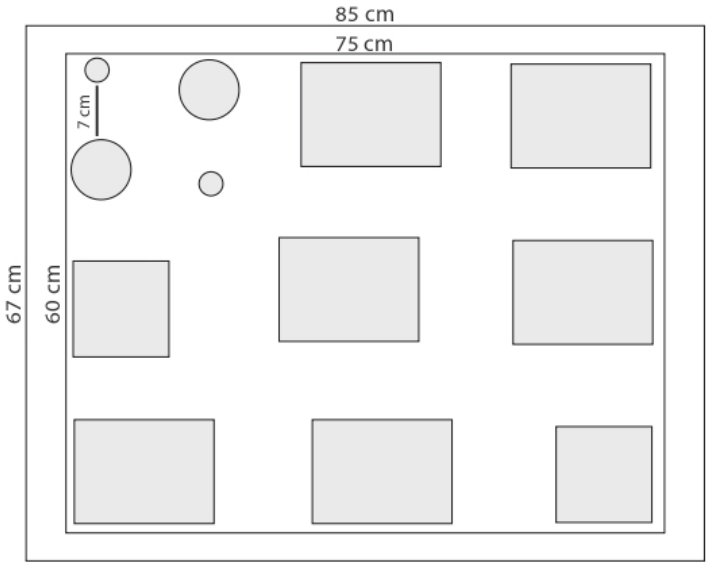


Figure 34: Table with maximum capacity of containers

Inside the containers
There is food inside the containers. The reason for this is to show the similarities between daily life and the game. Besides it would be easier for the user to distinguish the container and the lid. The kind of food is chosen based on colour, size, simplicity and healthiness. The colour of the food matters, because the user must be able to see the difference between the container and the food. Therefore the colour of the food is chosen so that they contrast with the container. Moreover, unhealthy food should not be stimulated. Accordingly, the chosen food that will be placed inside the containers are carrots, bananas and strawberries. The food can be found in chapter 6.

5.3.3 Mouse

Colour and form
The mouse in figure 35 is created by tracing an image of a real mouse. The colour of the mouse is determined by searching for colours of real mice. The common colours of mice are white, brown and grey [67]. The colours white and grey are not convenient in this project, because these colours are too light. The chance of not seeing the mouse on the projection

would be too big, especially if the projection is underexposed due to lighting. Thus, a brown colour will be chosen for the mouse. This brown colour must contrast with the container colours, hence a dark brown colour is chosen. The mouse, the mouse colour and colours of the containers can be found in figure 35.

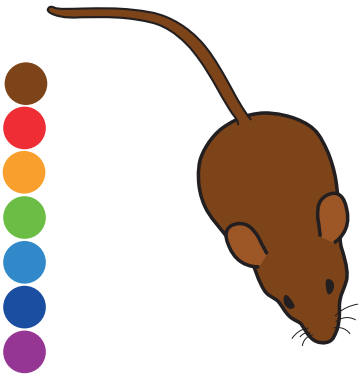


Figure 35: The mouse, mouse colour and container colours

The size of the mouse is dependent on the size of the play-field and the container sizes. As concluded in the section 5.3.2, the minimum distance between the containers is 7 cm, therefore the mouse must be 7 cm long or smaller than 7 cm long. However the mouse should not be too small, because the user should be able to grab the mouse easily. If the mouse is 7 cm long, the play-field would look like figure 36. The optimal size of the mouse will be tested in the user-tests.

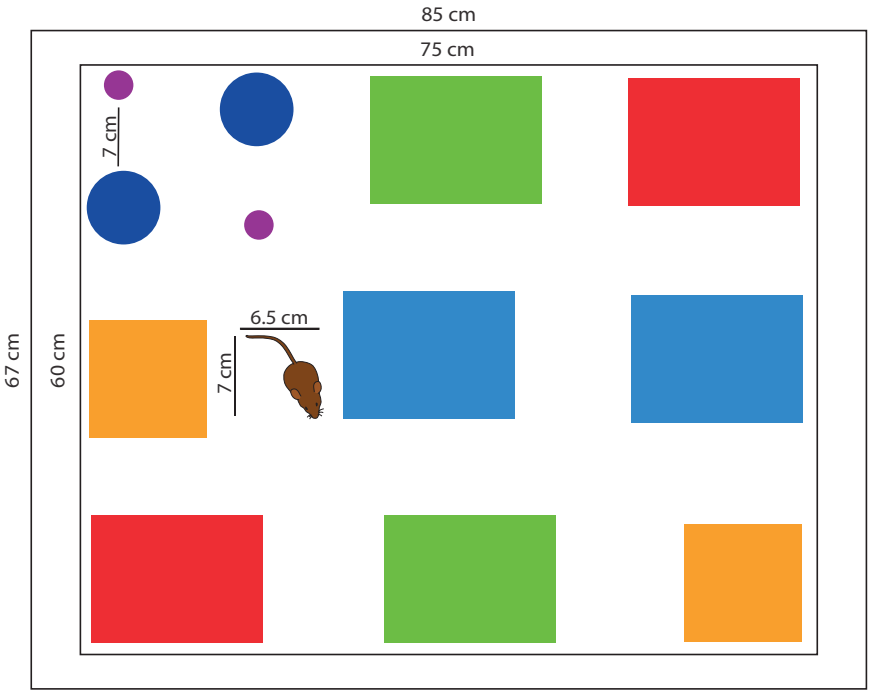


Figure 36: Table with containers and mouse

Mouse elements
It is very important that enough reaction time is provided for this target group. Providing enough reaction time was one of the most important system requirements of chapter 4. How much reaction time is needed differs per person. Therefore the game adjusts to the playing speed of the player. The game will start with presenting only a few containers and when the player has closed these containers, new containers will appear. If this takes a long time, the mouse will wait longer until it eats and he will eat more slowly. The mouse can fall asleep when he has eaten a certain amount of food. The mouse will sleep for a certain amount of time. This amount will be specified during user-tests.
Lastly a mouse container will be placed on the table which the player can use to catch the mouse. This container can be placed on top of the mouse.

5.3.4 Course of the game

The game starts with two containers and two lids on the table, see figure 37 step 1. The two containers have the same form and contain food. The reason why the game starts with one type of container is that the user can adjust to practicing only one type of hand movement and therefore too much stimuli is prevented. Besides the containers, a mouse container and a placing area for the Leap Motion Controller are visible on the table as well. The steps 2 to 6 show that the user can close the containers by performing certain hand movements (figure 37). The container is closed in the last step.

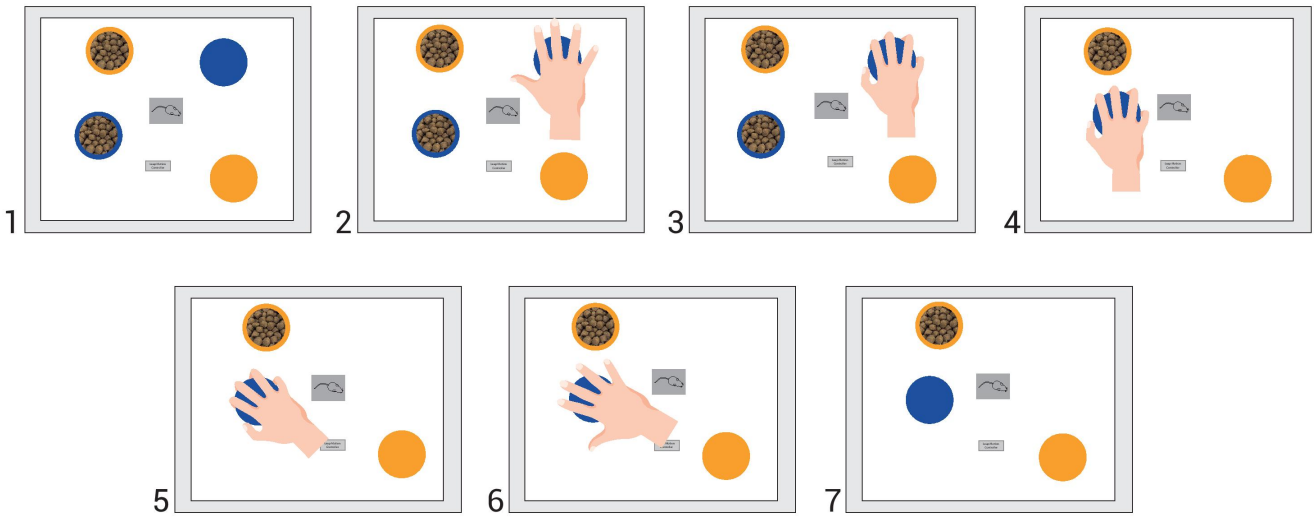


Figure 37: First step of the game

When the player has closed one of the two containers, a mouse enters the field. Figure 38 shows that if the player does nothing, the mouse will eat the food inside the container. Step 4 of this figure shows that the food is diminished in the container.

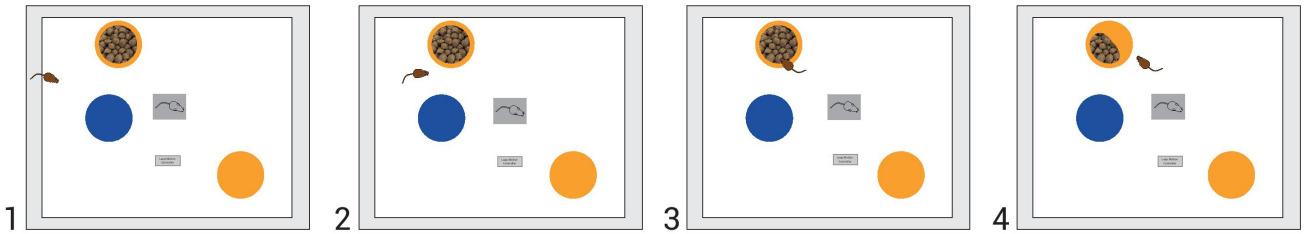


Figure 38: The mouse eats the food

The player can also choose to react on the mouse entering the play field. One option is grabbing the mouse and putting it inside the mouse container (see figure 39). If the mouse is inside the mouse container, the mouse cannot eat the food inside the containers. The mouse will stay in the mouse container for a certain amount of time. This amount will be specified during user-tests.

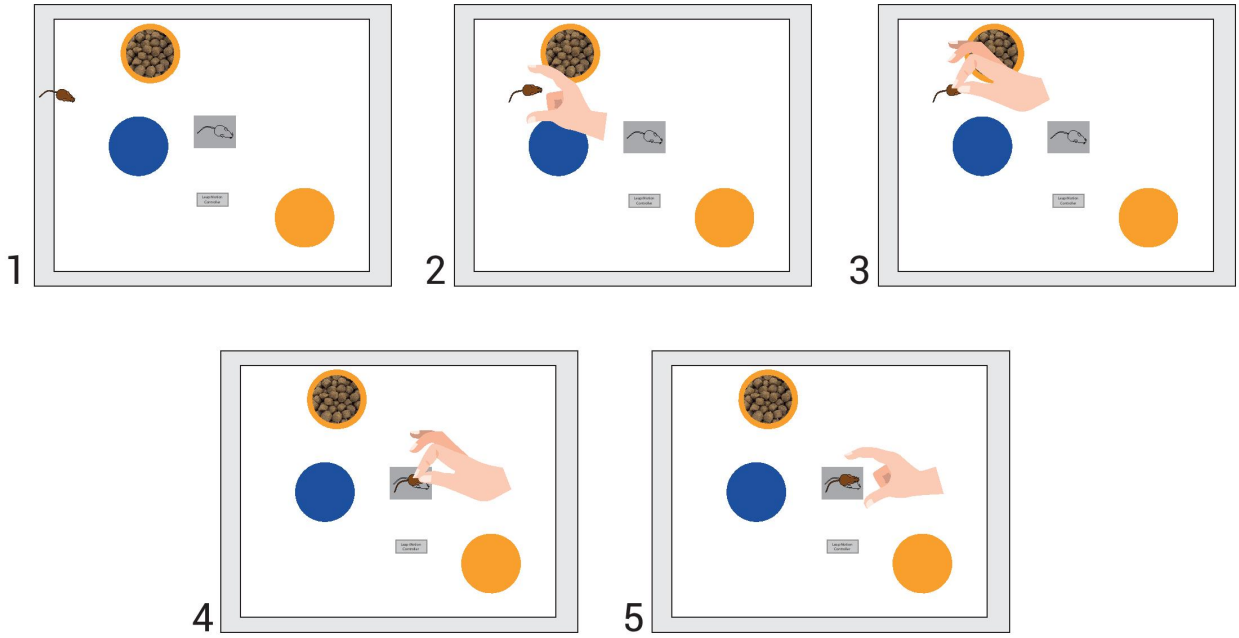


Figure 39: The mouse is put inside the mouse container

Instead of putting the mouse in the mouse container, the player can also choose to pick up the mouse container and put it over the mouse (see figure 40). The mouse will stay inside the container for a certain amount of time. This time will also be specified during user-tests.

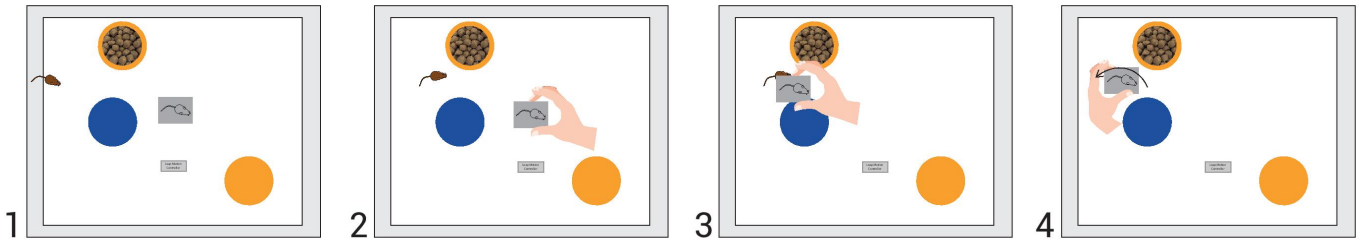


Figure 40: The container is put over the mouse

Besides interacting with the mouse, the player can also choose to close the containers before the mouse eats the food (see figure 41).

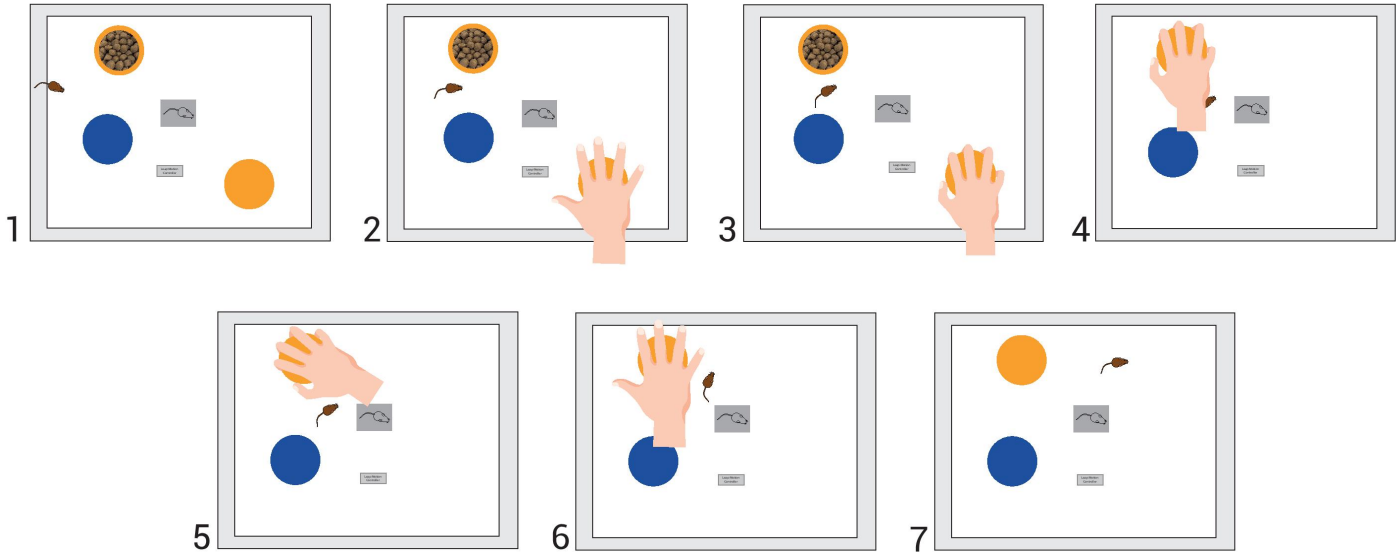


Figure 41: The containers are closed by the user

After closing the two containers, the closed containers will disappear and two new containers with new interactions will appear on the play-field. The old containers will disappear by fading out and the new containers will enter the playing field by fading in. Whether this is the right way to disappear and appear containers, will be tested during the user-tests.

5.4 System description

5.4.1 Hardware

The hardware used for the system consist of the Leap Motion Controller, the projector and a computer. The projector projects the game on the tabletop and the Leap Motion Controller is used to measure the hand movements of the player. The computer will run the program with the game. The sections bellow will describe the hardware per item.

Leap Motion Controller
Measuring horizontal as well as vertical hand movements was one of the system requirements in chapter 4 with a priority of 'must have'. A device that can measure this, is the Leap Motion Controller. The Leap Motion Controller is a device that can be placed on the table or on a VR headset (see figure 42). It is a small device of 80 mm long, 30 mm wide and has a height of 13 mm. Because of this height, the Leap Motion Controller cannot measure hands on the table, thus the user has to hold his hands higher than roughly 13 mm above the table. Because the controller is primarily used to place on VR headsets, the range is quite small: 60 cm from the device all around (see figure 42) [63].
The controller contains two near-infrared cameras and three LEDs. The hands of the user are illuminated by the LEDs with infrared light. The sensors send this back to the computer where the images are used to generate a virtual model of the hand movements. They have chosen to model the joints and bones inside your hands too, besides your palm and fingertips [63].
Examples of applications in which the Leap Motion Controller can be used are: healthcare, like stroke rehabilitation, therapy and education, like anatomic visualisations and robotics, like robotic controls.

Figure 42: Range of the Leap Motion Controller when placing the controller on a VR headset [63]

Projector
The games will be projected on the table with the PicoPix Projector of Philips (see figure 43) [68]. The PicoPix is a small, portable projector that works with Wi-Fi or Bluetooth or with a USB or HDMI cable. The projector has built-in speakers [68].

During feedback sessions with the client, the question arose whether the shadow of the hands will form a problem when playing the game, because the projection could be blocked by the hands. Due to the shadow, the user would not able to see what is happening underneath the hand when the hand is hovering over the table. This issue will be explored during building the setup and performing the user tests for the prototype. If the shadow forms a big issue, alternatives will be explored. Alternatives could be

- Audio feedback instead of visual feedback. For example, instead of showing that a container is closed, a positive sound when you have placed the lid on top of the container can inform the player of his actions.
- Attach the Leap Motion Controller to the ceiling. Because the Leap Motion Controller lays on the table, the controller cannot measure what happens below the height of the controller. When placing the controller on the ceiling, the user can perform their actions closer to the table or even while touching the table. The closer the hands are to the table, the less shadow that is present.

- Rotating the projector. The shadow will be diminished when the projector is not placed right above the table. However, this might cause a deformation of the projection.
- Present the game from below by using of a screen instead of a projector. No shadow will be present when having the light coming from below instead of from above.

Figure 43: The projector PicoPix of Philips [68].

Computer
A computer or laptop is needed to run the program on which the game is located. This computer needs to be able to run the software: Unity and Maya and needs to be able to connect to the PicoPix projector and Leap Motion Controller.

5.4.2 Software

The software that will be used are Unity and Maya. Both programs will run on the computer and they will be discussed in the sections below.

Unity
The gaming engine used for this thesis is Unity [69]. The system requirements of chapter 4 stated that the system should be able to work with a gaming engine and that the system should be able to measure different hand-movements. Both requirements had a priority of 'must have'. Unity is a real-time development platform that allows 2D, 3D, VR and AR visualizations for games, animations, films and more. During the study Creative Technology, Unity is often used for game development and animations. Besides that, UltraLeap offers packages for Unity in order to use the Leap Motion Controller with Unity. Therefore there is a preference for using Unity above other gaming engines, like Unreal.

Autodesk Maya
The 3D objects used in the game will be modelled with the 3D modelling program Maya [70]. Maya offers a wide range of tools and features and works easy together with Unity. Besides modelling, Maya is great at texturing, lighting and rendering. The objects used in the game are simple and are low in polygon's which can easily be made with Maya. Since this 3D modelling program offers what is needed for this thesis and has been used before in the study Creative Technology, also together with Unity, the program has a preference over other 3D modelling programs, like Blender or Cinema 4D.

5.4.3 Scripts and packages

Before the Leap Motion Controller can measure hand movements and before the player can interact with objects, some packages need to be installed. UltraLeap, the company that creates the Leap Motion Controller, offers a wide range of packages. For this thesis Unity is used, so the packages that are being installed work with Unity.

Setup
After the Leap Motion Controller is connected to the computer, the controller software needs to be installed. UltraLeap offers a variety of software packages, but for this thesis the standard V4 SDK for Windows is used [71]. This package supports the usage of the newest versions of game engines, like Unity.

Unity Core Assets
Before Unity can use the Leap Motion Controller and can measure and visualize hands, the Unity Core Assets need to be downloaded [71]. These Unity Core Assets are also offered by UltraLeap and entail Unity Modules that make it possible to sense your hands and display your hands within Unity.

Interaction Engine
The Interaction Engine of UltraLeap is needed to make it possible to interact with virtual objects. A movement that is used often in this thesis is 'grasping'. The Interaction Engine makes it possible to grasp small objects and the user can even give objects from one hand to the other [71].

5.4.4 System setup

The system consists of the Leap Motion Controller, the projector and the laptop or computer. The computer will run the Unity file with the game and will be connected to the projector, that projects the game, and the Leap Motion Controller, that is measuring the hand movements. The setup can be found in figure 44.

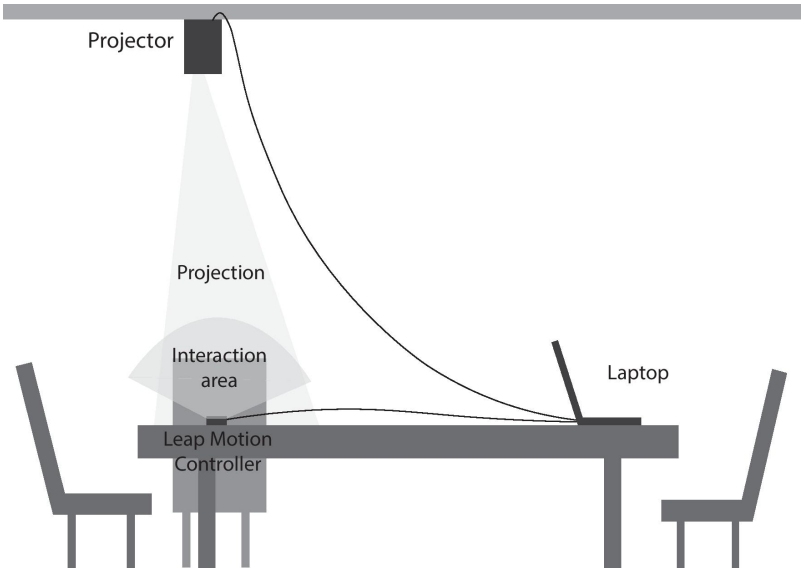


Figure 44: Setup of the system

5.5 Technology prototype

Before the real product is made, a prototype will be built. The goal of this prototype is to check whether the interactions feel natural to the user and to see whether users understand how to play the game. For the testing, a combination between a formative and summative test will be used. The user-test tests a more formal prototype, however qualitative data will be collected, since this is the first prototype tested. The user-tests will be performed at the

home of the researcher and the researcher will be present when the test takes place.
This subsection will show the building process of the prototype, the test setup and the prototype testing and evaluation. This chapter ends with a conclusion with design recommendations for chapter 6.

5.5.1 Methods

Participants
Four participants participate in the prototype testing. Since it is not possible to test with the target group itself, housemates of the researcher will asked to join the testing. For pilot test and the user-testing of the end product other housemates will be asked, because otherwise the participants would already know the system and therefore they might be biased. All participants will test the same game in this prototype testing.

Before the prototype testing takes place, an ethical approval was needed from the ethics committee of Creative Technology. In order to receive the approval, an ethical checklist, informed consent (see Appendix C.2.1) and explanation of the test procedure has been submitted. This ethics request has been approved before the testing. The participants have received the informed consent a few days before the prototype testing in order to have time to consider participation.

Materials
The hardware materials used for the prototype testing included the projector, the Leap Motion Controller and the laptop. The software materials used for the prototype testing included the Unity file with the game.
In the game, three types of containers will be showed: square, round and rectangular with side-closing. The three containers will be showed at the same time and the user has to close all three. The square container can be closed by grabbing the lid, moving the lid above the container and releasing the lid (see figure 24). The round container can be closed by grabbing the lid, moving the lid above the container, releasing the lid and rotating the hand above the lid (see figure 23). Finally, the rectangular container can be closed by grabbing the lid, moving the lid above the container, releasing the lid and closing the sides by rotating the hand (see figure 25). The prototype can be found below in figure 45.

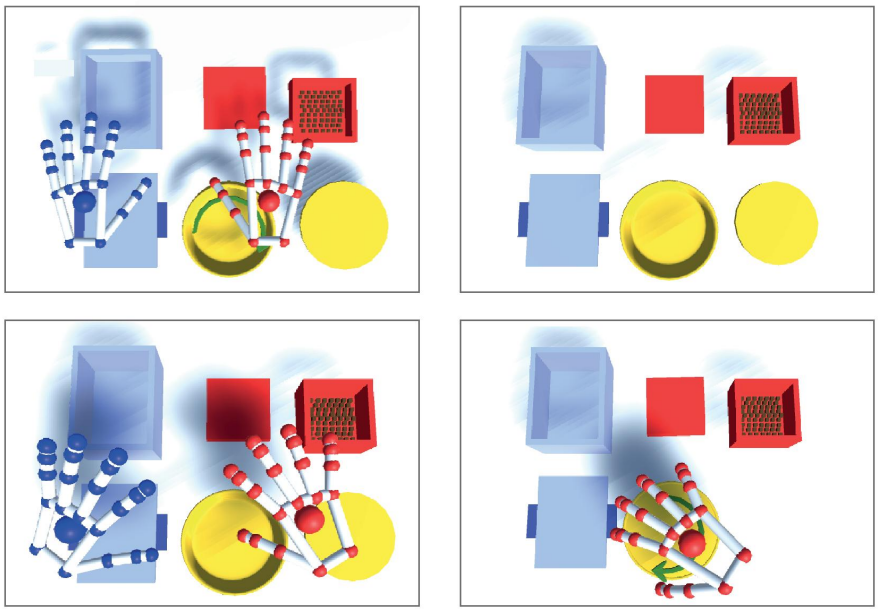


Figure 45: Some stills of the technology prototype in Unity

Procedures
The users are informed about the testing a week in advance and the informed consent form will be sent to them. When they arrive at the testing, they are asked a few questions regarding their health status, due to COVID-19, and they are asked to wash their hands. Then they have to sign the informed consent form. Thereafter they are asked about whether they have used the Leap Motion Controller before, because they might be biased when they have already used this technology before and therefore it should be taken into account when evaluating the test. They might know their way around the system better if they have used the controller before.

Then, the Leap Motion Controller and the projector are activated and the user plays the game. When the user has closed both containers, the user-test stops. While the participants are interacting with the system, they are being observed and sometimes filmed, so that the researcher could watch the user-test again to see if something was missed. After the user-testing, their opinion about the interaction is asked. These questions can be found in Appendix C.2.2. The questions are regarding the shadow of the hand, whether this forms a problem or not, the interactions, if they feel natural, and whether they enjoy playing the game or whether it frustrates them. Concluding, they are asked to wash their hands again.

5.5.2 Results

While observing the participants, it became clear that shadows can really form a problem. All users experienced problems with their shadow and were not able to see what was happening underneath their hands.
Besides, after they had to get used to the interaction, they understood what they had to do. However there was some confusion about which object was the container and which object was the lid. After a few seconds of confusion, the users understood which container matched which lid.
Additionally, during the testing there were some problems observed with the rectangular container. Every participant tried to close the container differently and this frustrated the user.

Lastly, while observing it became clear that the play field of game was bigger than the Leap Motion Controller could measure. When a lid was moved outside the interaction range by the user, it was very frustrating, because the user could do nothing to get the lid back.

In the questions after the prototype testing it became clear that none of the users had used the Leap Motion Controller before. One user has seen the controller in videos before, but has not used it himself. This user did interact with the prototype most easily, understood what he had to do the fastest and was first finished with all actions. The other users indicated that they had to get used to the interaction, but within half a minute, everyone understood what to do and how the interactions worked. The participants thought that animated arrows made it very clear what extra movement was required: rotating the hand for the yellow lid. Lastly, the users stated that the game became frustrating when the they were not able to close the containers, because they dropped the lid too soon. This happened often in the beginning of the testing.

Some stills of the prototype user-test can be found in figure 46.

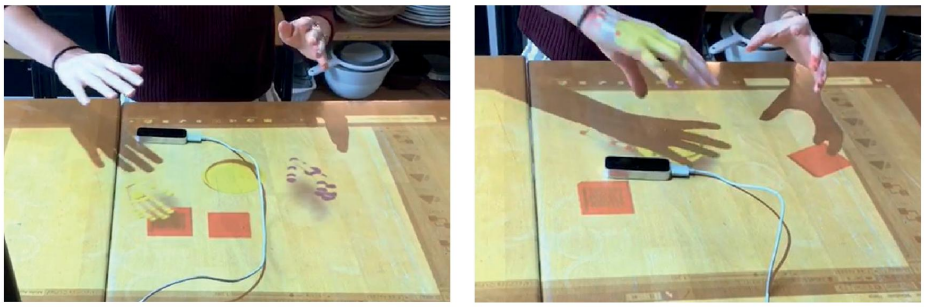


Figure 46: Some stills of the prototype test. A participant is interacting with the system

5.5.3 Conclusion

Firstly, the shadow formed a problem during the testing. Therefore the other options that can bypass the shadow-effect stated in section 5.4.1 will be explored in the realisation phase.
Secondly, it should be made clear to the user what the container is and what the lid is. The containers in the prototype did not contain food yet, therefore the containers must contain real looking foods in the end product.
Thirdly, there were issues with closing the rectangular container, since users did not know how to close these. This container should be adjusted or left out in the end product. These options will be discussed with the client as well.
Lastly, the play area of the Leap Motion needs to be diminished, since the lid was sometimes out of range and this frustrated the users. Besides, walls could be placed at the sides of the play field and can help preventing the lids 'falling off the table', where they are not visible anymore to the users.

5.6 Conclusion

The game has been specified in this chapter. First the interaction elements are specified, then the 3D models of the containers and mouse are made, thereafter the course of the game is determined and a description of the system is given. Lastly a technology prototype is created.
The design recommendations for next chapter include adjusting the containers in order that the users can distinguish the containers and lids. Furthermore, a solution for the problem of the shadow of the hands should be explored as stated in the section 5.4.1. Lastly, the play-field needs to be reduced, because the objects where sometimes out of range. How much smaller the play-field needs to be, should be specified during the coming user-tests.

6 Realisation

Previous chapter ended with a recommendation for this chapter. The realisation chapter focuses on building the end product according to these recommendations. First the implementation of the elements in Maya will be discussed, thereafter these elements will be added to Unity and the needed scripts will be written. Then the course of the game will be shown and lastly a conclusion will be made based on the MoSCoW analysis of the system requirements.

6.1 Maya

The 3D objects are created in the programs Unity and Maya. Unity has been used for more simple objects, like a cube, sphere or cylinder. Anything that required more alterations was created with Maya. The created objects will be discussed below.

6.1.1 Containers

Chapter 4 proposes three kinds of containers: a round container, a square container and a rectangular container. In chapter 5 these three containers were built and tested in the prototype testing, however during the testing there occurred some problems with the rectangular container. Every participant tried to close the container differently. Since this movement was very unclear, the container is left out. During a feedback session with the client, it was chosen to implement a container with a zipper that needs to be closed by performing the tweezer grip, because this movement is used often as well, for example when zipping your pants and coat or zipping small and large bags and suitcases. The new container and the movement of this container can be found in figure 47.

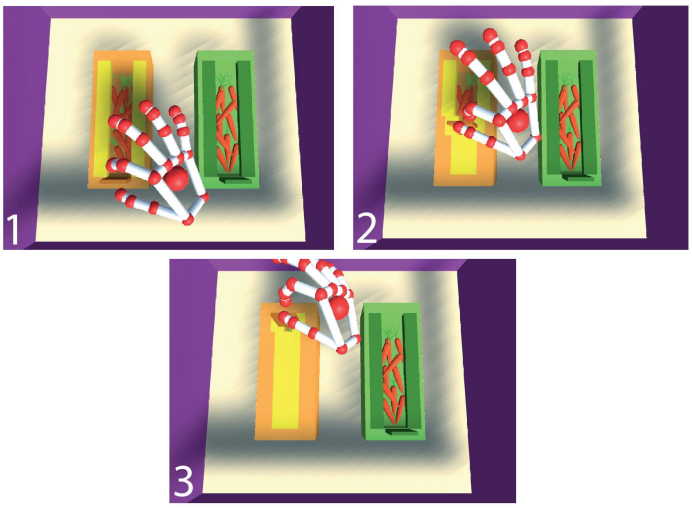


Figure 47: Stills from the game in Unity showing two zipper containers. The hand is closing the zipping the container by using the tweezer grip.

The round container and square container are built as well. All containers contain a small amount of polygons. The colours of the containers are the colours chosen in chapter 5 (figure 30). All containers of the game can be found in figure 48.

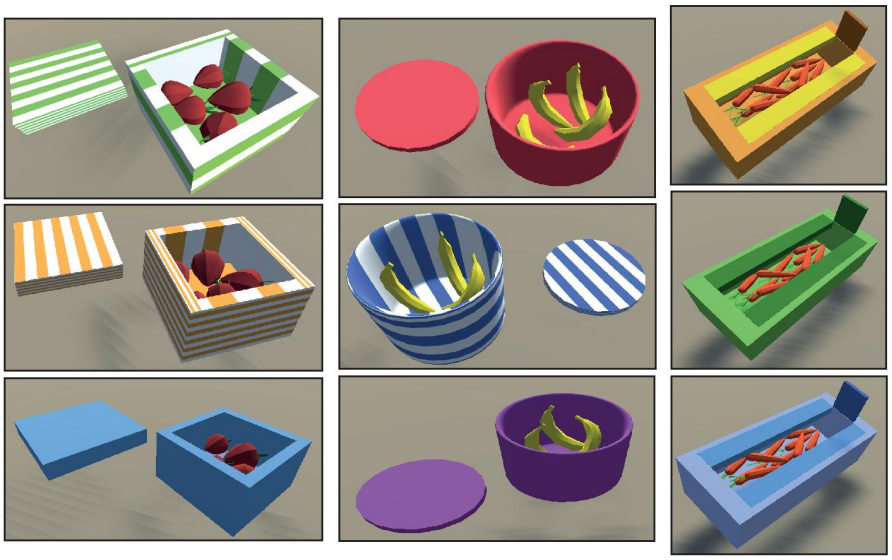


Figure 48: 3D models of containers used in the game. From left to right: the square containers, the round containers and the zipper containers.

6.1.2 Food in containers

The food inside the containers have a low polygon amount, which means that they are very simple. The food is created by tracing images of real food. The food inside the containers can be found in figure 49.

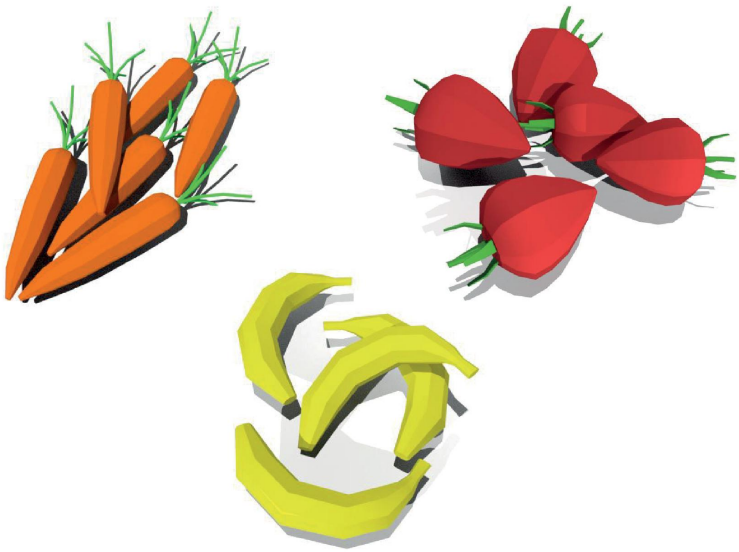


Figure 49: 3D models of the food inside the containers: carrots, bananas and strawberries.

6.1.3 Mouse

The mouse is a very simple 3D object and consists of the following components: a body, two ears, two eyes and four whiskers. The mouse is made by outlining a picture of a real mouse. The mouse does not have feet, but since the user can only see the top of the mouse, feet are unnecessary. The mouse has the same colour of the mouse in chapter 5 (see figure 35). The mouse can be found in figure 50.

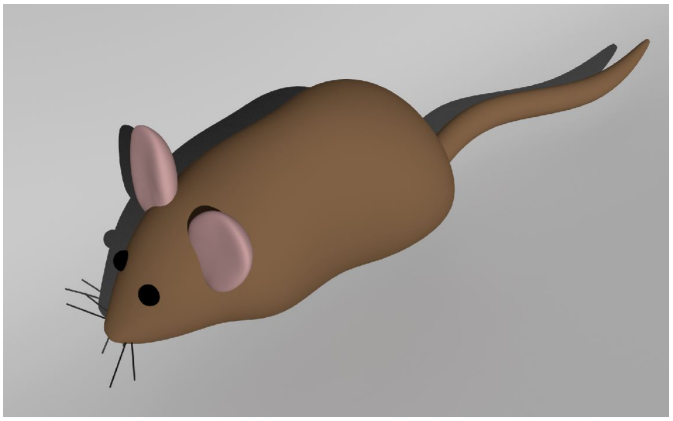


Figure 50: The 3D model of the mouse.

6.1.4 Other objects

Besides containers, food and a mouse, some additional objects are added to the game. The round containers have arrows that indicate that the lid needs to be rotated in order to close the container. These arrows rotate in the direction in which the container needs to be closed. Secondly, the check mark appears when a 'round' has ended. This happens when all containers in this 'round' are closed. Lastly, the transparent lids are used in an animation that shows the user that he has to close the containers with the lids. When the user does not know how to close the containers and does not interact with the system for 30 seconds, a transparent lid will appear and will animate the motion the user has to perform. The round container contains a stripe and the reason for this is that the user can see that the lid is rotated. The transparent lids, the arrows and the check mark can be found in figure 51.

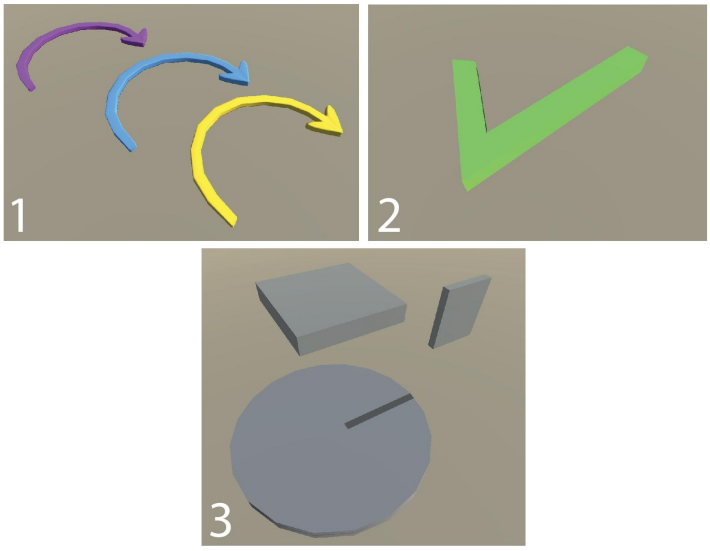


Figure 51: Other 3D objects. 1: The arrows of the round containers, 2: the check mark when a 'round' is completed, 3: the transparent lids that show what the user has to do.

6.2 Unity

6.2.1 System setup

The game is created in Unity. First, the ground and the walls have been created. These objects are made within Unity with as goal to keep everything on its place. The walls indicate the play-field of the Leap Motion Controller.

6.2.2 Mouse

The mouse aspects were harder to implement than calculated. In the original idea created in chapter 4, the mouse walks on the table between the containers and lids. In order to program the mouse in a way that it recognizes the walls, containers and lids, a NavMesh can be created. A NavMesh is a pre-calculated path in which the NavAgent, in this case the mouse, can walk. It recognizes objects, the NavObjects, and it does not walk over them. The objects in this game are the walls, containers and lids. However, the lids contain an Interaction Behaviour script, a script provided in the package 'Interaction Engine' (see section 5.4.3) that makes sure that the user can interact with objects. When adding the NavObject component to the lids as well, the game crashes, because the two components cannot be added to the same object. It is possible to let the mouse walk between the walls and containers, but since the lids cannot contain the NavObject component, the mouse will walk over the lids.
Other possibilities have been explored as well, for example coding a field in which the mouse can move. However, since the objects move, this does not work. For example, if the lids are moved, the mouse will not walk over the old position of the lid and the mouse will walk over the lids new position.

Therefore it is decided that the mouse is left out in the game. The impact of this choice will be explained in the evaluation.

6.2.3 Scripts

All scripts are written by the researcher herself and their description and structure can be found in figure 52. The title in the darker blue boxes is the name of the script and the lighter blue boxes below explain what the script does. The arrows between the scripts mean that the script that points at another script uses that script. For example, if a variable is created in the script 'ContainerRound', the script 'ContainerRotation' uses this variable. The scripts itself can be found in Appendix B.1.

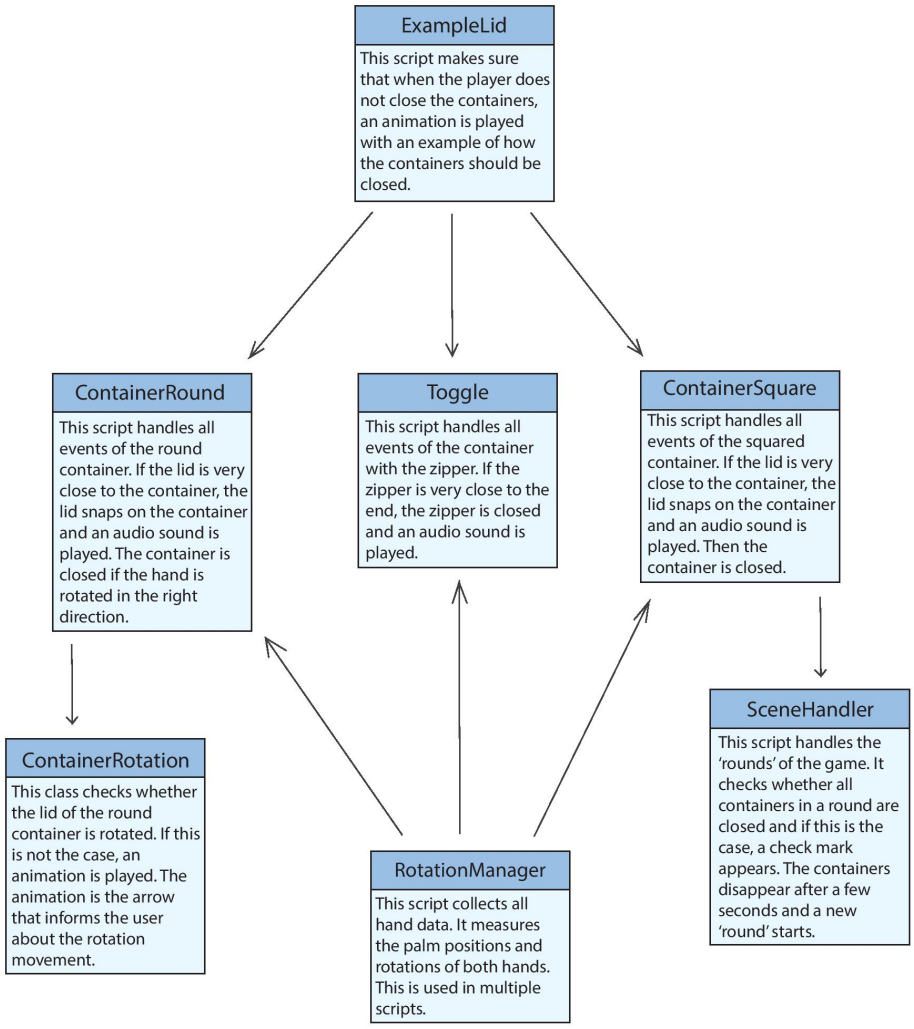


Figure 52: The scripts written in Unity for the game.

6.3 Audio

Chapter 4 states that around five audio sounds should be present in the game: the standard sound of the mouse, the eating sound of the mouse, the sleeping sound of the mouse, the sound of the mouse when it is grabbed and the sound of the containers being closed. Since all mouse elements have been left out, these sounds will not be used anymore. The sound of the containers being closed will still be implemented in the end product. The sounds are being reviewed in the evaluation test.

6.3.1 Container

The sound of the container is a positive sound, because closing a container is a positive action. The sound is retrieved from the site 'freesound.com' [72].

6.4 Game course

The course of the game can be found in figure 53. In round 1 the user will be confronted with two square containers. These are the containers that require the least interaction, in order that the user can adjust to the system. The left image shows the containers before they are closed. The second round shows two round containers and the third round shows two containers with a zipper. The last round contains all types of containers: square, round and the container with the zipper. After the fourth round, more rounds can be added containing different types of containers. Since the user has seen all types of containers, it is assumed that the user is a bit familiar with the interactions. However, how many rounds of each container are necessary in order to get used to the interaction, will be tested in the evaluation phase.

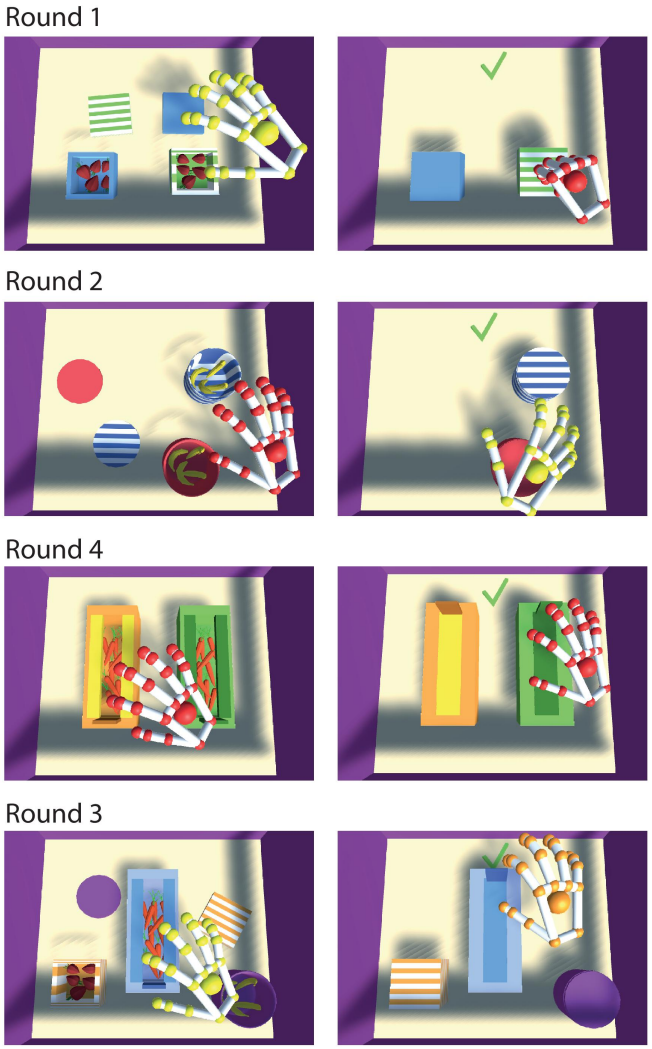


Figure 53: The course of the game with different rounds.

6.5 Stop or pause button

The stop or pause button will not be created for this thesis, because of time constraints. Due to this choice, the best options for a stop or pause button cannot be explored. However in the evaluation phase it will be analysed how such button should be created by interviewing experts.
Despite the fact that the button is not created for this thesis, it can be stated from the interview with the expert of the target group in chapter 4 that a stop or pause button is strongly advised for the end product, because the user must be able to stop the game at any point for whatsoever reason, for example if the user is over-stimulated.

6.6 Shadow

The shadow formed a problem during the prototype test in chapter 5. Therefore, during the evaluation tests, the projector will be secured diagonally to the ceiling. If the shadow still forms a problem during the evaluation tests, other options will be explored (see section 5.4.1).

6.7 Conclusion

Most elements stated in chapter 5 have been implemented in this chapter. One of the main changes of the game is that the mouse is not implemented in the game anymore. This is due to time and knowledge constraints as explained in the section 6.2.2. Another big change is the replacement of the rectangular container for the container with the zipper. The reason for this is that the rectangular container was very unclear for the participants, besides a zipper is used often in ADL.
Lastly, to check whether all system requirements composed in chapter 4 are implemented in the final product, a table is created (table 16). The requirements with the green columns are implemented in the end product. The requirements with the orange columns are partially implemented, because most of the requirements have not been tested with users yet. Therefore it cannot be stated that they are already fully implemented in the end product. The requirements with the red columns are not implemented. The stop or pause button will not be implemented in this thesis, due to time constraints. However a stop or pause button is strongly advised when further developing this product. Furthermore, the game does not exist out of small mini-games. One of the biggest reasons for creating multiple mini-games was that multiple hand movements can be practiced and to offer a wider range of variety. However the current game does contain 'rounds' in which different hand-movements are practiced and therefore offers some variety.

Requirement ID	Priority	Fulfilled
#1 The system is able to track hand movements: horizontal and vertical	Must have	Yes
#2 The system works with a gaming engine	Must have	Yes
#3 The system is stable and measures what it should measure	Must have	Yes
#4 The system gives audio and visual feedback to the user	Must have	Yes
#5 The system contains a trigger to pause or stop the game	Must have	No
#6 The game can be played with multiple people	Should have	Partially
#7 The game consists out of multiple 'mini'-games that each practice other fine motor skills	Could have	No
#8 The game is easy to understand, but the content should not be too simple or childish	Must have	Partially
#9 The game provides sufficient time to react	Must have	Partially
#10 The game has a connection with activities of daily living (ADL)	Should have	Yes
#11 The game can be played without assistance of a supervisor	Could have	Partially
#12 The game does not give negative feedback (visual or audio)	Must not have	Yes

Table 16: Requirements created in the ideation phase (tables 2 till 13) with their prioritization and whether they have been fulfilled in the realisation phase.

7 Evaluation

This chapter will focus on evaluating the product realised in chapter 6. This chapter consists out of two user-tests: a pilot test and an evaluation test. First the methods of the tests will be discussed, than the results and lastly the conclusion.

The sub research questions that will be answered in this phase are:

- How do people experience the elements in interactive tabletops in terms of usability?
- What criteria should be contained in a game for people with a mild intellectual disability to stimulate the training of fine motor skills?

7.1 Methods

In the evaluation phase, two professionals are contacted: the expert of the target group and the game developer of the client. The expert of target group knows the target group very well and can therefore indicate whether some aspects do or do not fit the needs of the target group. The game developer of the client can give feedback about the game elements of the product.
Normally the pilot test and the evaluation test are performed with representative users of the product, however due to COVID-19 this is not possible. Therefore two housemates will join the pilot test and three housemates will join the evaluation test.
Before the pilot and evaluation test take place, an ethics request is approved by the ethics committee. This request included ethics checklists and informed consents that can be found in Appendices C.2.1 and C.2.4. The methods used in the tests will be explained in the method section of the tests.

7.2 Pilot test

A pilot test will be performed to check the methods of the evaluation test. This test is performed to filter flaws in the procedure of the test and potential biases. Therefore the pilot test should be taken seriously.

7.2.1 Methods

Participants
The participants that participate in the pilot test are two housemates of the researcher. These participants are not representative for the target group and the participants have not seen the system before to diminish potential biases. They are informed about the pilot test in advance and the informed consent have been sent to them in advance as well (see Appendix C.2.1).

Materials
The materials used for the pilot test are the projector, Leap Motion Controller and a laptop containing the Unity game. The game is the end product as showed in chapter 6. Besides, the informed consents will be printed and the participants can fill these in on paper. Lastly, the survey will be conducted on the same laptop on which the game is running.

Procedures
Since the pilot test tests the evaluation test, it is important to check whether the procedure of the testing is correct.
The participants are notified about the pilot test in advance and the informed consent has been sent to them. When they arrive at the test location (the house of the researcher), they

have to sign the informed consent. Besides, they are asked whether they have used the Leap Motion Controller before. Thereafter they are given an introduction about the procedure of the testing and the game. This introduction entails the following:

Welcome to the pilot test of my bachelor thesis. I have created a game for people with a mild intellectual disability to practice their fine motor skills. On the table, there lies a Leap Motion Controller and this controller will measure hand movements. The game will be projected on the table and you can interact with the game by moving your hands. The procedure of this test will go as follows: I will ask you to play the game once. After you have played the game, I will ask you if you want to play the game again to see if things were missed. After the play-sessions, I will ask you to fill in a survey about the game experience. After the survey has been completed, the pilot test has ended. Before we start, I will record audio and video in order to observe the performed test again. However faces will not be present on the video. I will use stills of the videos for my report. Lastly, I want to emphasize that you as participant can stop at any point without consequences and on request all previous given answers can be deleted. I hope I have informed you right, are there any questions? I will now start the recording.

If there are no questions, the players will be asked to play the game. They will play the game together. If things are unclear, the players have the possibility to play the game again. Thereafter the participants are asked to fill in a survey about the game experience and after this survey has been submitted, the pilot test has ended. The participants are thanked for their contribution.

Analysis
The observations will be used to check whether there are confusions. At the end of the pilot test a survey will be filled in by the participants. The answers of this survey will be taken into account when adjusting the game, however the main focus of this test is to test the evaluation test. Therefore the main focus is to spot flaws in the test and procedure.

7.2.2 Results

Both of the users have never used the Leap Motion Controller before. While observing the participants they said that they had to get used to the mechanics and interactions of the game. Moreover it occurred that there was some confusion at the beginning about which object is the lid and which object is the container. Both participants tried to move the container, but when they saw that the container did not move and the lid did moved, they knew which was the lid. Besides, both users did not close the containers within 30 seconds, so they saw the transparent lids that showed the interaction. These transparent lids helped the users to close the containers. Moreover, both users did not know that they had to rotate the round container, but when they saw the arrow they immediately rotated their hands above the containers. Additionally, both users did not see that the rectangular container was a container with a zipper. One participant needed the animation of the transparent zipper in order to close the container and the other participant needed hints of the researcher how to close this container. When they knew it was a zipper, they closed the container very easily. Lastly, it appeared that both users formed a fist very often and did not often use their fingers separately.

The results of the survey will be discussed below.

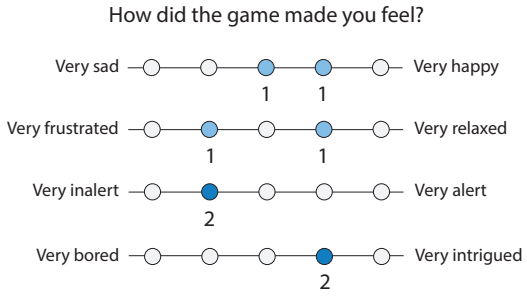


Figure 54: Answers of the first part of the survey

It can be said that the game did not really evoke emotions or it made the participants slightly happy. Besides, the game made the participants feel a bit in-alert and a bit intrigued. Lastly, because there was no time limit, one participant thought the game was relaxing. See the results in figure 54.

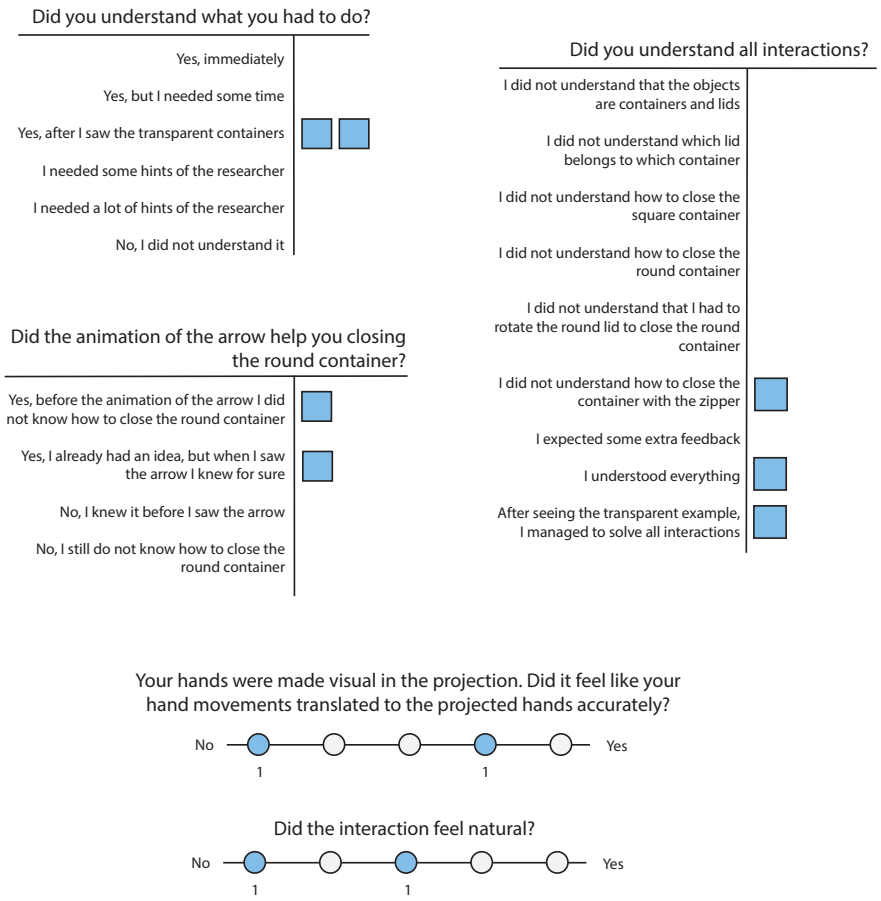


Figure 55: Answers of the second part of the survey

The participants did understand what to do after seeing the transparent containers and the arrow of the round container. They knew they were doing the right thing, because of the positive audio sound after closing the containers. However one participant had difficulties with closing the container with the zipper. This participant had also difficulties with the translation of his hand into a virtual hand and noticed that the interaction did not feel very natural. See the results in figure 55.

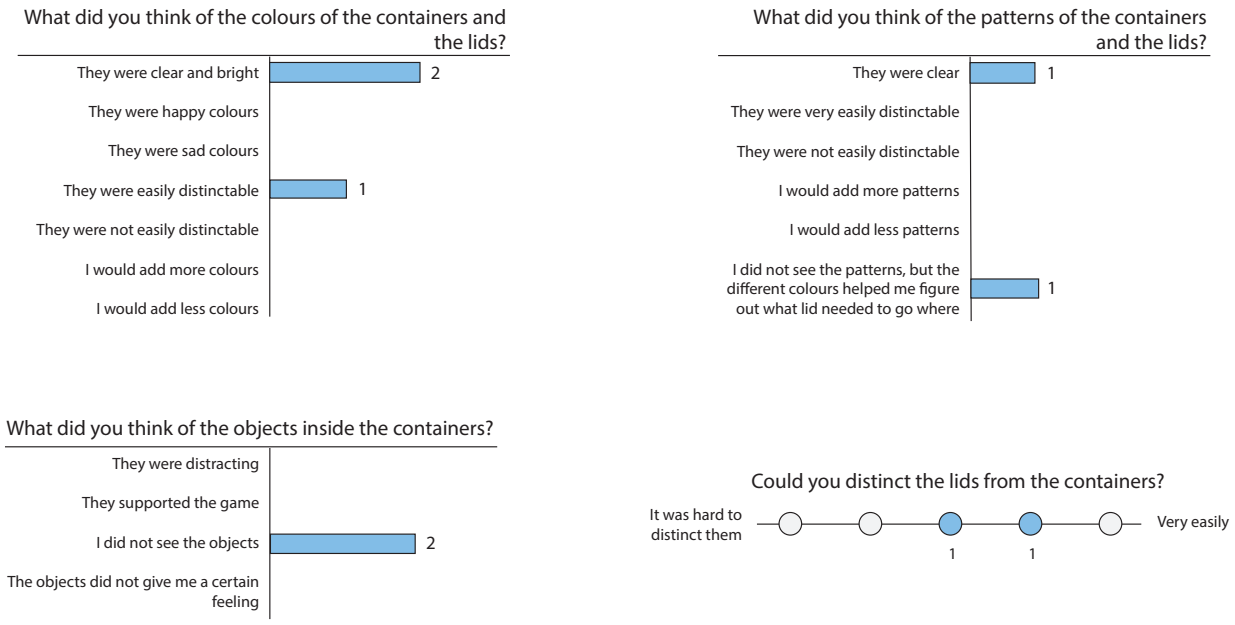


Figure 56: Answers of the third part of the survey

The colours were interpreted as clear and bright colours and they were easy to distinct according to the participants. Furthermore, one participant said that the patterns of the containers and lids were clear and the other participant stated that he did not really notice the patterns. However the colours of the containers and lids were very clear and helped him figure out which lid matched which container. Both participants did not notice what was inside the containers, but the reason for this was that the room was too bright and they had difficulties seeing the projection. See the results in figure 56.

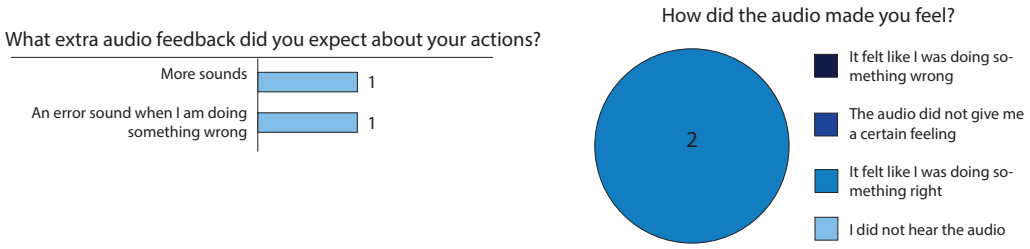


Figure 57: Answers of the fourth part of the survey

One participant did not expect more visual feedback while the other participants expected more arrows or colours. Both participants did expect more sounds about their actions, for example an error sound when doing something wrong. However the participants interpret the positive audio sound when the container is closed, as a sound informing about their right performed action. See figure 57.

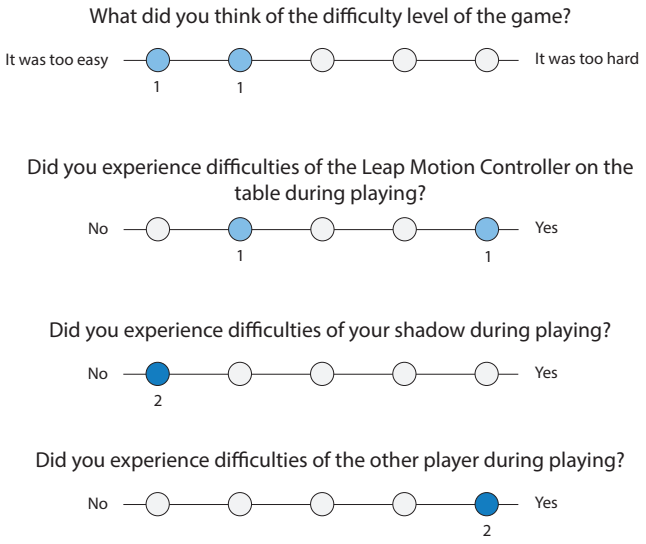


Figure 58: Answers of the last part of the survey

The participants indicated that the game was too easy for them. Besides, one participant experienced difficulties of the Leap Motion Controller on the table and neither of the participants experience difficulties of their own shadow while playing. Concluding, both participants experienced difficulties of each other since they could not play at the same time. See results in figure 58.

7.2.3 Conclusion

First, the game is not playable with two or more people. The reason for this is that the Leap Motion Controller does not measure two of the same hands, for example two right hands. This is programmed in the Unity Core Assets or the Interaction Engine and therefore it cannot be changed for this thesis. Therefore during the evaluation test one participant will play the game at a time. Accordingly the question: 'Did you experience difficulties of the other player?' (see figure 58) will be left out in the evaluation test.

The participants did not see the objects inside the containers. The main reason for this is that the room was very bright causing an underexposed projection. The Leap Motion Controller can still operate with a small amount of light, therefore the curtains of the room will be closed during the evaluation test.

Shadows formed a problem during the technology prototype testing (see section 5.5.3), however during this testing, none of the participants experience any problems of their shadow.

One player did experience difficulties of the Leap Motion Controller during playing the game. Therefore in the evaluation test, the Leap Motion Controller will be positioned in a

way that the cable can be out of sight.

The responses of the survey will be checked in the evaluation test to see whether more participants have the same experience after updating the procedure of the test. From the survey it could be concluded that the participants indicated that they expected more visual and audio feedback about their actions. Additionally, the participants stated that the transparent lids informed them well about what actions they needed to take. One participant experienced problems with closing the container with the zipper and has stated that the interactions with the system do not feel natural. Lastly, the game was too easy for the participants. However this test analyses the methods of the evaluation test and therefore no conclusions about the product will be drawn for this test.

7.3 Evaluation test

This section will focus on the evaluation test. Since there is only a small number of participants, the testing will be a qualitative test. The goal of the user test is to improve the quality of the interface by finding the major flaws, for example components of the interface that are missing or confusing. This will not include style or colour preferences, however the overall consistency of the game will be evaluated. The evaluation test will consist of an expert-base testing where a game developer will review the product to find interface flaws and an expert of the target group will review the suitability of the game for the target group. Additionally, a user-based testing will be performed, however the participants are not representative users of the product, but they will perform representative tasks. Since the effectiveness of specific design choices are analysed, the evaluation test falls into the category 'summative testing'. Besides, the end product is a hi-fi prototype.

7.3.1 Methods

Participants
There are two groups of participants in the evaluation test: face-to-face participants and online participants. Both groups will be explained below.

Face-to-face participants
There are three face-to-face participants in the evaluation test and they are all students of the University of Twente. One of the face-to-face participants is present during the testing with the online participants to show the online participants how novice users interact with the system. The other two face-to-face participants will test the product after that test session.

Online participants
During testing with one face-to-face participant, online participants will be available to give feedback as well. These are the expert of the target group and a game developer of the client.

Materials
The materials needed for the evaluation test are the projector, the Leap Motion Controller and a laptop on which the Unity game is running. Besides these materials, another laptop is used for online contact with the online participants and a camera with tripod is used to film the interactions between the face-to-face participants and the system. Lastly, the informed consents are showed to the face-to-face participants so that they could sign them. See Appendix C.2.1 for the informed consent for the face-to-face participants and Appendix C.2.4 for the informed consent for the online participants.

Procedures
The evaluation contains of two parts: first a test session will be held with one face-to-face participant and the online participants. After this test session, the other two face-to-face participants will test the end product.
The evaluation test will be held at the home of the researcher. The procedure will go as follows:

Before the test session takes places, all participants are informed about the test session. The informed consent form has been sent to them so that they could read it in advance. When the face-to-face participants arrive at the test-location they have to sign the form and they are asked questions regarding COVID-19. If one of the participant has COVID-19 symptoms, he or she cannot join the testing session anymore to prevent spreading.
The method 'thinking aloud' is added to the procedure to stimulate the user to say everything they think about the game while playing. This method allows the researcher to observe the stream of thoughts of the participants and makes it easier to identify flaws. For example if a user says: 'Oh I thought I had to rotate my hand to the right, but that does not work', the researcher would know that the rotation movement is not clear to the user and needs a better explanation.
Both parts of the evaluation test will be discussed separately below.

Procedure part one
After the face-to-face participant have signed the informed consent, an online connection is made with the online participants and an introduction is given to both participant groups. The introduction for the first part will be:

Welcome to the evaluation test of my bachelor thesis. I have created a game for people with a mild intellectual disability to practice their fine motor skills. On the table, there lies a Leap Motion Controller and this controller will measure hand movements. The game will be projected on the table and the user can interact with the game by moving his hands. The procedure of this test will go as follows: first I will ask my housemate to play the game once. During this play I will ask her to apply the method 'thinking aloud'. This means that you can say everything you think, for example: 'Now I am going to try this'. Thereafter I will ask her to play the game another time, but this time I will ask the online participants to fill in the observation sheet. After the housemate has played the game for the second time, I will ask all participant if they want to see or play the game again to see if things were missed. After the play-sessions, I will ask the online participants questions about their answers in the observation sheet and thereafter I will ask them some general questions. Then the testing for the online participants has ended. Lastly I will ask my housemate to fill in a survey. Before we start, I will record the audio of all participants, because I can listen to the test again to see if I missed something for my evaluation. The face-to-face participant will be filmed as well, because I can observe the test later again. However her face will not be present on the video. Lastly, I want to emphasize that you as participant can stop at any point with no consequences and on request all previous given answers can be deleted. I hope I have informed you right, are there any questions? I will now start the recording.

Thereafter the face-to-face participant is asked to play the game once. While playing the game, she is asked to apply the method: 'thinking aloud' meaning she has to say everything she thinks about the experience. After the face-to-face participant has played the game once, she is asked to play the game again. Now the online participants are asked to fill in the observation sheet. After this round of playing, all participants are asked whether things are unclear and whether they want to see the game again. If this is the case, the game is played

again until there are no questions anymore. After the play-sessions, the online participants and the researcher will analyse the observation sheet and the researcher will ask questions if things are unclear. Thereafter they are asked more interview questions about the game. Finally, the online session will be debriefed and the online participants are thanked for their contribution. Then the face-to-face participant is asked to fill in a survey. Thereafter, the face-to-face participant is thanked for their contribution and part one of the evaluation test has ended.

The whole test session will not take longer than one hour. The observation sheet can be found in Appendix C.2.5, the interview questions can be found in Appendix C.2.6 and the survey can be found in Appendix C.2.3.

Procedure part two
Since the game cannot be played together, the evaluation test is first tested with one face-to-face participant and then with the other two face-to-face participants.
After the face-to-face participants have signed the informed consent, an introduction is given. Since it is important to prevent bias, the same introduction is given to both participants. The introduction for the second part will be:

Welcome to the evaluation test of my bachelor thesis. I have created a game for people with a mild intellectual disability to practice their fine motor skills. On the table, there lies a Leap Motion Controller and this controller will measure hand movements. The game will be projected on the table and the user can interact with the game by moving his hands. The procedure of this test will go as follows: first I will ask you to play the game once. During this play I will ask you to apply the method 'thinking aloud'. This means that you can say everything you think, for example: 'Now I am going to try this'. After you have played the game, I will ask you if you want to play the game again to see if things were missed. Thereafter I will ask you to fill in a survey. Before we start, I will record audio and video, because I can listen and watch the test session again to see if I missed something for my evaluation. However faces will not be present on the video. Lastly, I want to emphasize that you as participant can stop at any point with no consequences and on request all previous given answers can be deleted. I hope I have informed you right, are there any questions? I will now start the recording.

Thereafter the face-to-face participants are asked to play the game while applying the method 'thinking aloud'. After this round of playing, the face-to-face participants are asked whether things are unclear and whether they want to see the game again. Lastly, they are asked to fill in a survey and then they are thanked for their contribution and part two of the evaluation test has ended.

Analysis
The face-to-face participants are being observed to see whether there are confusions about certain interactions or game elements. When they play the game the first time, they are asked to apply the method 'thinking aloud' in order to hear their stream of thoughts. If everything of the game is clear, they are asked to fill in a survey. Since there are only three face-to-face participants, every answer and comment will be taken into account.
A semi-structured focus group will be conducted with the online participants to stimulate a conversation between the experts. A focus group provides a wide range of viewpoints and discussions can show differences and similarities between opinions. A semi-structured focus group leaves space for asking improvised or follow-up questions.

7.3.2 Results

The result section will be split into two sections, one section in which the results of the face-to-face participants will be discussed. This includes the observations and a survey. The other section will contain the results of the online participants and includes the observation sheet and interview questions.

Results face-to-face participants
First, none of the face-to-face participants has ever used the Leap Motion Controller before, so the outcomes cannot be biased by that.
While observing the participants, it occurred that they had to get used to the interaction and therefore the interactions did not seem natural the first round. However they understood what they had to do immediately and knew which container matched which lid. They did not try to grab the containers with the food inside. One participant said while 'thinking aloud' that the lids are easily to grab, but a bit harder to place correctly on the container. Another participant noticed that the user should be able to see the round lid rotating while you rotate your hand to close the round container. This participant also stated that the user should not able to unzip the container with the zipper when the zipper has already been closed. In the last round, all users closed the square container first and the container with the zipper last.

The outcomes of the survey will be discussed below.

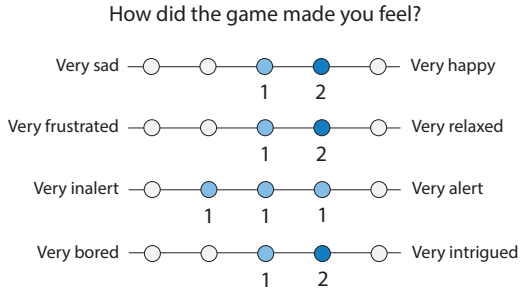


Figure 59: Answers of the first part of the survey

The game made the users feel slightly happy and relaxed. On average, the participants did not feel in-alert nor alert. The participants felt a bit intrigued by the game. See the results in figure 59.

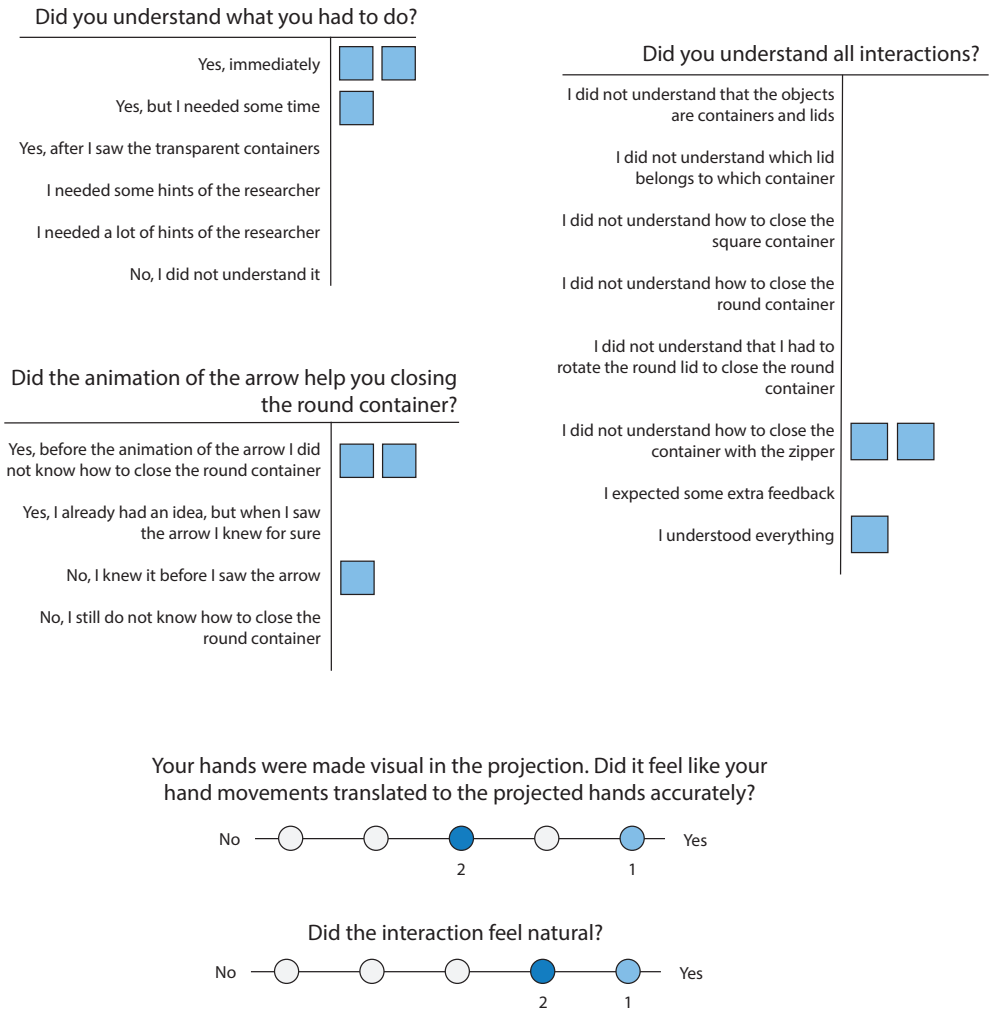


Figure 60: Answers of the second part of the survey

Two participants understood what they had to do immediately and one participant needed some time to understand the game. The positive sound of the container and the fact that the lids snapped into the right position gave the users the feeling that they were doing something right. Two participants needed the animation of the arrow in order to close the round container, however one participant knew already how to close the round container. Two participants also experienced difficulties with closing the container with the zipper. They often let the zipper go and needed multiple tries to zip the container. They tried to push the zipper to the top with their whole hand, but they could not move their hand in one straight line. When they tried to close the container using the tweezer grip, the movement was much smoother and they could close the container more easily. The interaction did feel natural to the user, however their visual hands did not really feel like their own hands. See the results in figure 60.

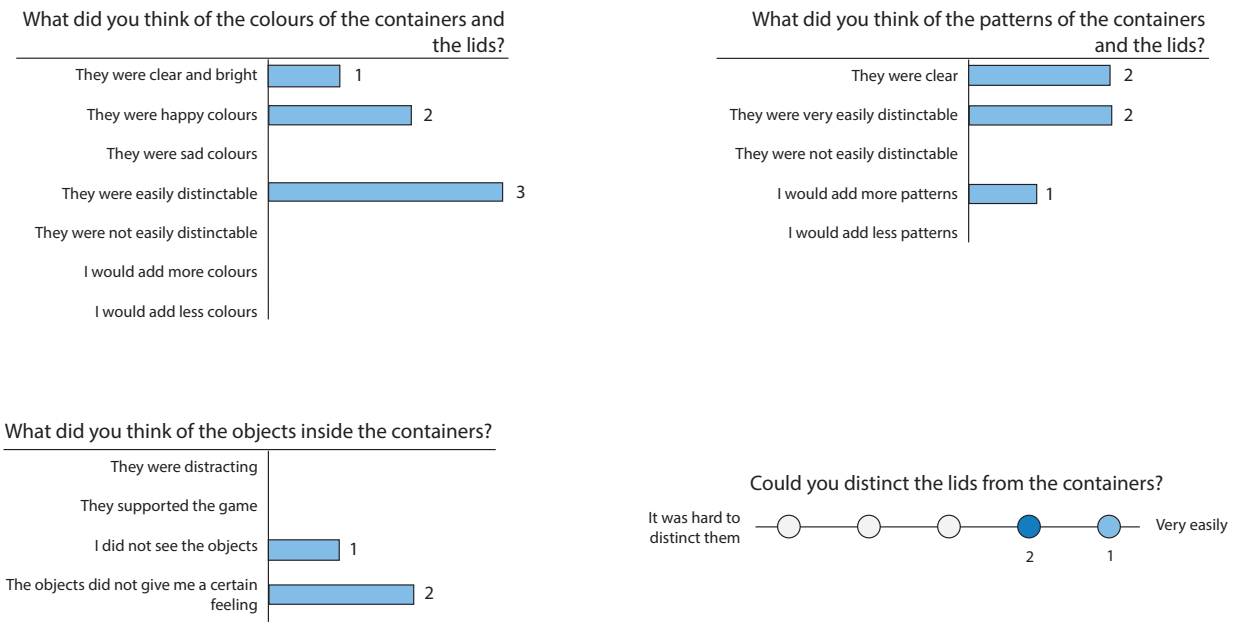


Figure 61: Answers of the third part of the survey

The participant thought that the colours of the containers were clear, bright and happy colours. All three participants said that the lids and containers were easy to distinct due to their colours. The patterns were clear and easy to distinct as well. One participant has suggested to add more patterns. The objects inside the containers did not provoke much emotions for two of the participant and one participant did not see the objects inside the containers. The other two participants thought the objects inside the containers were fruits and vegetables which means that they could see that the containers contained food. Lastly, the containers were easy to distinct according to all participants. See the results in figure 61.

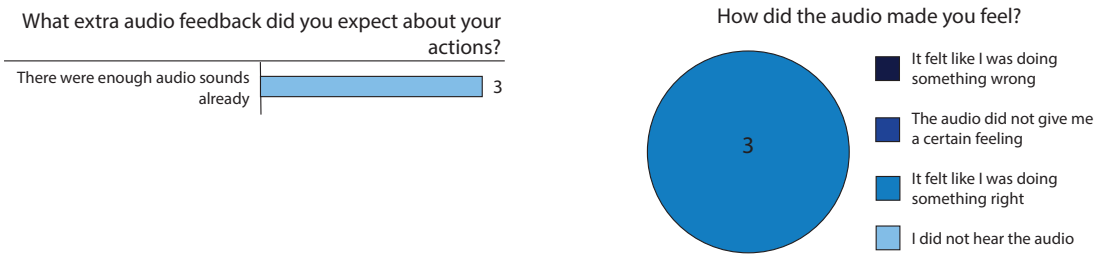


Figure 62: Answers of the fourth part of the survey

All participants said that there were enough audio sounds and that the audio indicated that they were doing something right. One participant stated that some sparks can be added as visual feedback. One other participant said that a check mark can be added as visual feedback and the third participant would have liked to see something green when he was performing a right action and something red when he was performing a wrong action. See

the results in figure 62.

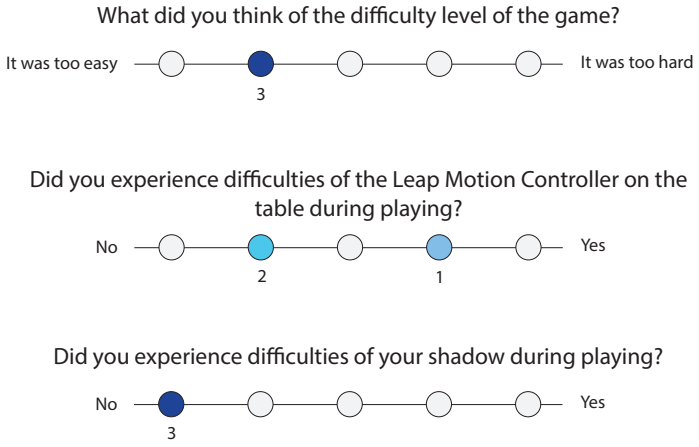


Figure 63: Answers of the last part of the survey

The participants thought that the game was too easy for them. Two participants did not experience difficulties of the Leap Motion Controller on the table during playing and one participant did slightly experience difficulties of the Leap Motion Controller during playing. Lastly, none of the participants experienced difficulties of their own shadow during playing. See the results in figure 63.

Results online participants

Firstly, both the client and the expert of the target group stated that the visual as well as the audio feedback could be increased, since the game does not contain enough stimuli right now. An example of the client was to add sparkles, particles or bubbles around the lid or zipper to stimulate people to touch it. Besides, the client stated that every time the users try to grab something, the game must show feedback. Moreover, when closing the containers, there should be more feedback, like confetti or stars.
When looking at audio feedback, the expert of the target group has stated that unnecessary audio feedback must be prevented. However, a short audio sound can be added when the user is doing something wrong, so that the user knows which actions are right and which actions are wrong.
Furthermore, the client stated that the target group will try to touch the containers on the table, because they might have difficulties in recognizing that the visual hand on the table can be controlled by their own hand. The expert of the target group said that this group does understand that the hand on the table is controllable by their own hand and therefore thinks that this will not form a problem.

When looking at the interactions of the system, the client thought all interactions were clear, but they might be difficult for the target group. The expert of the target group said that the game will never be played by the people alone and since there is always a supervisor or physiotherapist near, the game can be explained by them. Besides, she indicated that a cognitive challenge is also a positive side-effect, since the physique and mind will be trained at the same time.
Additionally, the client as well as the expert of the target group stated that the game would not be too childish for the target group, considering the game contains real objects with

bright colours and patterns. Additionally, since the game uses real objects, the people in the target group would be able to see the connection between the game and ADL according to the expert of the target group.
Lastly, the client as well as the expert of the target group has indicated that the game could be frustrating for the target group. However, on the contrary of daily life, in the game you can retry and therefore this does not cause a negative load on the user.

Both the client and the expert of the target group have indicated that the shadows did not form a problem for the participants during playing the game.

When looking at the amount of containers, the client has stated that there are too much containers at once on the table and this could be very frustrating for the users. A solution he proposed could be starting with one container at a time and if the interaction of this container is clear to the user, elaborate with more containers. On the other hand, the expert of the target group said that there are not too much containers on the table at a time. However, only practicing a certain movement once might be not enough and therefore she proposed to create two or three rounds containing the same containers and movements. Both agreed on keeping the most difficult interaction for last and this is the container with the zipper. It is best to start with the most easy interaction, the square container.
The containers itself should look like real containers or other objects that the target group knows. The expert of the target group stated that the food in the containers support the game, since the users can see which object is the container and which object is the lid. The foods inside the containers should therefore not be adjusted.
What is more, the client suggested that the containers should stay longer on the table after each round when implementing the game for the target group, since people with a mild intellectual disability have a slower understanding.
When looking at the colours of the containers, the client has stated that due to the patterns of the containers, people with a colour-blindness might distinguish the containers less easily. He suggested to use plain colours and less patterns for the containers and lids. However the expert of the target group stated that people with a mild intellectual disability have less problems with colour-blindness.
Lastly, the expert of the target group said that if the game trains fine motor skills, smaller objects can be added to train even smaller fine motor skills. Examples that she gave were bottles or puzzle pieces.

When using the game for physiotherapy sessions, the client has proposed to let the physiotherapist change the amount and type of containers manually. The expert of the target group agreed to this.

Since a stop or pause button was not built for this thesis, no feedback could be given on this. However the client and the expert of the target group were asked how to develop such a button for this game. The expert of the target group uses a remote control to control the Tovertafel, although this remote control is only used to turn on and off the Tovertafel and to change games. The client has stated to put this stop or pause button inside the game and when hovering with your index finger above a certain block for a X amount of seconds, a menu should pop up. The expert of the target group supported this idea. She added to put an option to change the amount of repetitions inside this menu as well, for example: put the square lid on the square container for a X amount of times.

When looking at the transparent containers, the client as well as the expert of the target group have stated that the they are very useful for the player. However they should appear

earlier, because otherwise the players are trying too long without any feedback. The expert of the target group added that the supervisor could also explain the exercise, but she thinks that the players might understand some interactions without the transparent containers already.

The expert of the target group noticed that the containers could be closed in multiple ways, for example the container with the zipper can be closed by pushing with a whole hand or it could be closed by using the tweezer grip. She stated that it is good that the containers can be closed in multiple ways, because this happens in real life as well. Sometimes people with a mild intellectual disability perform ADL in other ways than they are intended, for example holding a pen with a whole hand instead of three fingers. However if another solution works for the user as well, there is no need for practicing the user other movements. Finding solutions how to perform actions makes the user creative which they sometimes also need in daily life.

Lastly, the online participants had some overall comments on the game. Firstly, the client has indicated that the projection was too small and that it would be better if the interaction area and projection was increased in size. Secondly, the expert of the target group suggested that this game should be a game in a series of games. This game has a goal: closing all containers by performing different hand movements, and if this goal has been reached, another game could be played to train fine motor skills. Lastly, they both agreed that if the mouse is added to the game, the game should contain less containers at a time. Otherwise the user might be overstimulated. Besides, they did not think that the mouse would make the game too childish.

7.3.3 Conclusion

From observing the face-to-face participants, it can be stated that they really had to get used to the interaction, however from the survey, it can be concluded that the face-to-face participants understood what they had to do. The arrows and transparent lids helped in hinting what actions the users had to take. Most participants thought the interaction felt natural, however this might not be the case for the target group.

Furthermore, the face-to-face participants could distinguish the containers and lids better in the evaluation test than the participants in the pilot test. The reason for this might be that the food inside the containers could have been seen better in the evaluation test due to the closed curtains of the room.

According to the face-to-face participants, the game is intriguing and the containers are easy to distinguish. They noted that the game is too easy for them, however the client and the expert of the target group stated that when implementing this game for the target group, the level of difficulty is likely to be right.

The face-to-face participants stated that they expected more feedback. This was also a point of feedback of the client and the expert of the target group. The expert of the target group stated that there could be a small amount of negative feedback when the user does a wrong action. She has stated in an earlier interview in the ideation phase that negative feedback should not be added (see requirement 12 in table 13). However when thinking this statement over, it could be added in a small amount.

Concluding, the client and expert of the user group had some final points of feedback. A menu with a stop or pause button should be built into the game and in this menu there

should also be an option to choose the amount of repetitions. When having the option to choose the amount of repetitions, the game could be used during physiotherapy sessions. Moreover, the transparent containers must appear sooner, because otherwise the user is trying for too long without any feedback. Furthermore, the amount of containers should be diminished in the first rounds and should increase with the rounds and the projection should be bigger. Lastly, the experts sometimes contradicted each other, for example the client stated that the target group might experience problems with the interaction, while the expert of the target group stated that this might not be the case. However, how the target group perceives and interacts with the interactive tabletop should be tested with the target group, so no conclusion can be drawn from these statements.

7.4 Conclusion

The sub research questions of this phase are discussed below.

How do people experience the elements in interactive tabletops in terms of usability?
What is meant with usability is how well an user can perform a task effectively, efficiently and satisfactorily while enjoying the experience.
From observing as well as from the survey it can be concluded that the face-to-face participants did enjoy the experience. The participants could perform the interactions with satisfactory results and without problems. To increase the usability of the product, the face-to-face participants noticed that the round lid should rotate with your hand and the user should not be able to unzip the zipper, because this feels more natural to the user. Besides, they expected more visual or audio feedback. Nonetheless, the face-to-face participants understood what they had to do and could pass all rounds easily. Additionally, according to all users, the colours were easy to see and the containers, lids and the ground were easily distinguishable.
The online participants noticed that the face-to-face participant could easily perform all actions, however they were unsure whether this is also the case for the target group. Therefore no conclusions can be made about the suitability of the product for the target group, since the product should be tested with the target group itself. However both experts thought when having supervisors near, the target group is likely be able to perform all interactions.
When looking at the efficiency of the game, it can be stated that fine motor skills are trained without too much distraction of other actions. The game focuses on training fine motor skills and therefore the game could be seen as efficient.
Lastly, since the performed actions of the user directly translate to a result, the game can be seen as effective. The performed actions have a clear goal. Moreover, whether the game can reach the goal of stimulating people with a mild intellectual disability to train their fine motor skills, should be tested with the target group for a longer period of time.

What criteria should be contained in a game for people with a mild intellectual disability to stimulate the training of fine motor skills?
From observing the face-to-face participants, the survey, the observation sheet and the interview question of the online participants, there has been created a list of criteria containing the elements that the game should contain in order to be suitable for the target group and in order to stimulate people with a mild intellectual disability to train their fine motor skills. These criteria will be discussed below.

Providing audio and visual feedback
Enough audio and visual feedback is needed to inform the user about their actions and to keep the user motivated to play the game. Therefore the system should provide feedback before the user is interacting with the system, while the user is interacting with the system and after the user interacted with the system. An example of visual feedback that can be added before the user interacts with the system are vibrating lids or sparkles surround the lids to stimulate the users to interact with the lids. Feedback when the user is already interacting with the objects should be provided to inform the user about their actions. Lastly, when the user has finished performing an action, for example when closing a container, feedback should be provided about the status of that action. An example is, when the user puts the blue lid on the red container, the system makes a short negative sound. However when the user tries to put the blue lid on the blue container, the system makes a positive sound and confetti will pop surround the closed container.
Finally, unnecessary feedback or stimuli should not be provided, because the user should not be overstimulated.

Good variation
In order to keep the game interesting for the users, the game must provide a range of variations in hand movements, objects and visual aspects. For instance, in this game closing a normal size of containers is trained, but smaller containers could also be trained to increase the difficulty, like bottles. Besides, the game should offer the possibility to perform actions in different ways, because the creativity of thinking of multiple solutions is also useful in daily life. For example, the user closes the container with the zipper by pushing the zipper with his whole hand. However the zipper could also be closed by using the tweezer grip.

Increase in difficulty
The game should start with the most easy interaction and should keep the most difficult interaction for last. In this game, closing the square container is trained first and closing the container with the zipper is trained last. Besides the increasing difficulty of containers, also the colours could increase in complexity. The game could start with simple plain coloured containers and when the user has practiced with the containers for a while, different patterns can be added to the containers. Although, when changing the colours and patterns of the containers, it should be kept in mind that everyone should be able to play the game, also people with colour-blindness.

Flexibility of difficulty
As stated above, it is important that everyone can join playing. Therefore it should be possible to adjust the game to a users' degree of intellectual disability. Some users only have to perform an interaction once or twice before they remember the interaction and some users might have to practice the interaction seven or eight times. One option of adjusting the difficulty to someone's abilities is to have a menu as stated in the conclusion of the evaluation test (section 7.3.2) with a option to fill in the amount of repetitions.

Multiplayer
The experts stated that the game should be playable with multiple people. Playing together can cause a healthy competition wherein people are motivated to try their ultimate best. Moreover, playing serious games with multiple people can arise a discussion in which players can explain the game to each other or where players can solve the game together.
However this is not tested in this thesis and therefore it is unsure whether this specific game is suitable for multiplayer.

Lastly, all mouse elements were excluded in the realisation and evaluation phases. There-

fore the effect of the mouse could not be tested. However the mouse works the same as a timer, so this could be added in another way. It should be tested with the target group whether adding a timer to the game increases the stimulation of training fine motor skills.

To check whether all system requirements have been accomplished in the end product, the table below reviews whether these are fulfilled (table 17). Since the system did not contain a pause or stop button and multiplayer aspects, these system requirements could not have been tested in this thesis. Furthermore, the game does not consist out of multiple mini games, however this game could be in a series of other games.

Requirement ID	**Priority**	**Fulfilled**
#1 The system is able to track hand movements: horizontal and vertical	Must have	Yes
#2 The system works with a gaming engine	Must have	Yes
#3 The system is stable and measures what it should measure	Must have	Yes
#4 The system gives audio and visual feedback to the user	Must have	Yes
#5 The system contains a trigger to pause or stop the game	Must have	No
#6 The game can be played with multiple people	Should have	No
#7 The game consists out of multiple 'mini'-games that each practice other fine motor skills	Could have	No
#8 The game is easy to understand, but the content should not be too simple or childish	Must have	Yes
#9 The game provides sufficient time to react	Must have	Yes
#10 The game has a connection with activities of daily living (ADL)	Should have	Yes
#11 The game can be played without assistance of a supervisor	Could have	Yes
#12 The game does not give negative feedback (visual or audio)	Must not have	Yes

Table 17: Requirements created in the ideation phase (tables 2 till 13) with their prioritization and whether they have been fulfilled in the evaluation phase.

8 Discussion and Recommendations

This chapter will review the quality of the research. First, it will reflect on the sub-research questions and it will answer them from different sides. Thereafter, future recommendations will be given.

What fine motor skill difficulties do people with a mild intellectual disability encounter during activities of daily living (ADL)?
From the literature (chapter 2) it can be concluded that the fine motor skills that people with a mild intellectual disability experience difficulties with are:

- Hand-eye coordination
- Accuracy
- Using multiple fingers separately
- Using multiple fingers together (f.e. in the 'tweezer-grip')
- Rotating the hand

The final product created in this thesis practices hand-eye coordination, accuracy, using multiple fingers together and rotating the hand. The hand movement 'using multiple fingers separately' is not practiced in this final product, however this is an important hand movement when performing ADL. Chapter 4 states that this movement is used when pressing buttons, for example a button of a coffee maker or a stop button of a bus.

From the literature it appeared that Foletto et al. [43] has created a game in his study where the user has to practice moving all fingers separately. For a future game, this study could be used as inspiration to create a game that practices using multiple fingers separately.

How do people experience the elements in interactive tabletops in terms of usability?
From the evaluation phase it could be concluded that the face-to-face participants could perform all interactions with satisfactory results and without problems. They enjoyed the experience, however they expected more audio and visual feedback. The end product created in this thesis did contain audio and visual feedback when closing a container and visual feedback when the user tried to interact with the lid, however according to all participants more feedback could be added.

According to the studies of Lanyi and Brown [48] and Fernández-González et al. [42] it is important that enough audio and visual feedback is provided for the user to keep the user engaged (section 2.5). The game characteristics of Active Cues support this as well (figure 3) [11].

Therefore, a future system should contain more audio and visual feedback. How this extra feedback should look like, should be tested with the target group.

What criteria should be contained in a game for people with a mild intellectual disability to stimulate the training of fine motor skills?
From the evaluation test, a list of criteria has been established containing the following elements in order to be suitable for the target group and in order to stimulate the user to keep practicing fine motor skills:

- Audio and visual feedback to inform the user about the status of their actions
- A variation in hand movements and visual aspect to keep the user engaged

- An increasing difficulty with time. The most easy interaction should be trained first and the most difficult interaction should be trained last
- A flexible difficulty, since every user is different and has different needs and abilities
- The game should be playable with multiple people

As stated in the sub-research question above, the studies of Lanyi and Brown [48] and Fernández-González et al. [42] and the company Active Cues [11] support that enough visual and audio feedback should be provided for the users. Besides, Active Cues states that games should contain different layers so that people with different degrees of intellectual disability are able to join [19]. Moreover, the game should be playable with multiple people, because this can provoke a healthy competition in which people are motivated to try their ultimate best [11]. Lastly, from the conclusion of chapter 2 it can be stated that the game should contain some criteria, like providing enough reaction time, not adding too much or unnecessary stimuli, using bright colours, using different layers of difficulty and providing enough audio and visual feedback.

A future system should contain more audio and visual feedback. There should be feedback before, while and after the user interacts with objects. How much feedback is needed for the users, should be tested with the target group. Besides this, a future system should train even smaller fine motor skills, since the objects in the created system where quite large. Moreover, the difficulty level of the game should be flexible per user, therefore the game must contain an option where the amount of repetitions can be adjusted. Lastly, the system created for this thesis did not allow for the possibility to play it with multiple people. Therefore it is recommended to research and test multiplayer elements in the future.

8.1 Technology limits

The Leap Motion Controller involved some technology limitations, for example the interaction range was too small for an interactive tabletop game. Besides, the Leap Motion Controller could not track multiple users at the same time, for example two right hands. Therefore the game could not be tested with multiple people. Lastly, the controller is a tangible device that is placed on top of the table. Besides that in this area no objects can be spawned, the device could also accidentally be moved or touched out of curiosity. Therefore the controller might disturb the experience of the game. Whether the target group will experience difficulties with the device on the table should be tested in a user-test with the target group.
For a future product, it is recommended to place the Leap Motion Controller inside the table, so that the controller cannot be moved easily and no cables will lie on the table. From experience, the Leap Motion Controller can still measure hand movements when having walls the height of the controller on all sides.
Additionally, the end-product of this thesis required a laptop with the interactive tabletop game, although it would be preferred for the future if the game can be loaded on the projector and if no laptop is needed.

8.2 Recommendations for Future Work

Due to COVID-19, it was not possible to test the product with people with a mild intellectual disability and therefore the product is tested with the housemates of the researcher. Besides the fact that this could cause incorrect conclusions about the game experience, the participant pool was very small and no statistical conclusions could be drawn.
For the future, it is recommended to test the product with the a larger amount of people from the target group to see whether the criteria will fit their needs and abilities. When performing a user-test with the target group, it is also recommended to perform the Jebsen Test of Hand Function [35] (see section 2.4.2) to check whether fine motor skills have been improved after using the system.

During the evaluation test, the projector was placed diagonally on the ceiling, to prevent any difficulties with the shadow of the hands of the players while playing. Not all projectors can be hung diagonally from the ceiling and therefore a projector that lays on the table might be preferable. Projectors that are able to project on the table where the projector itself is positioned on are the Sony Xperia Touch [73] and the Sony Life Space UX Portable Ultra Short Throw Projector [74]. If the projector is positioned on the table, the shadow of the hands of the user is very small and this will improve the game experience (see figures 64 and 65)

Figure 64: Sony Life Space UX Portable Ultra Short Throw Projector projecting on the floor [75]

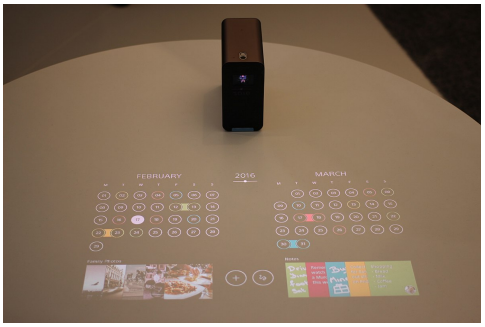


Figure 65: Sony Life Space UX Portable Ultra Short Throw Projector projecting on a table [76]

9 Conclusion

For this thesis a game is created to stimulate people with a mild intellectual disability to train fine motor skills. In the game, the user has to close containers in order to prevent the food inside them from being eaten by mice.

This chapter will reflect on the research aim and will review to what extent this aim had been reached. The research aim of this thesis was:

The aim of this thesis is to design a system to stimulate people with a mild intellectual disability to train fine motor skills by means of an interactive tabletop game.

From literature it can be stated that the game should contain some criteria, such as providing enough reaction time, not adding too much or unnecessary stimuli, using bright colours, using different layers of difficulty and providing enough audio and visual feedback.

Having these criteria in mind, the end product was created. After the evaluation test, the list of criteria has been adjusted. It can be concluded that a few criteria should be entailed in the product in order to make the game suitable for the target group. These criteria are: providing enough audio and visual feedback, good variation of hand movements and visual aspects, increasing the difficulty of the game with time, a flexible level of difficulty and multiplayer aspects.

However, the system should be tested with the target group for a longer period of time to see whether these criteria do stimulate people with a mild intellectual disability to train their fine motor skills.

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A Ideation

A.1 Sketched brainstorm

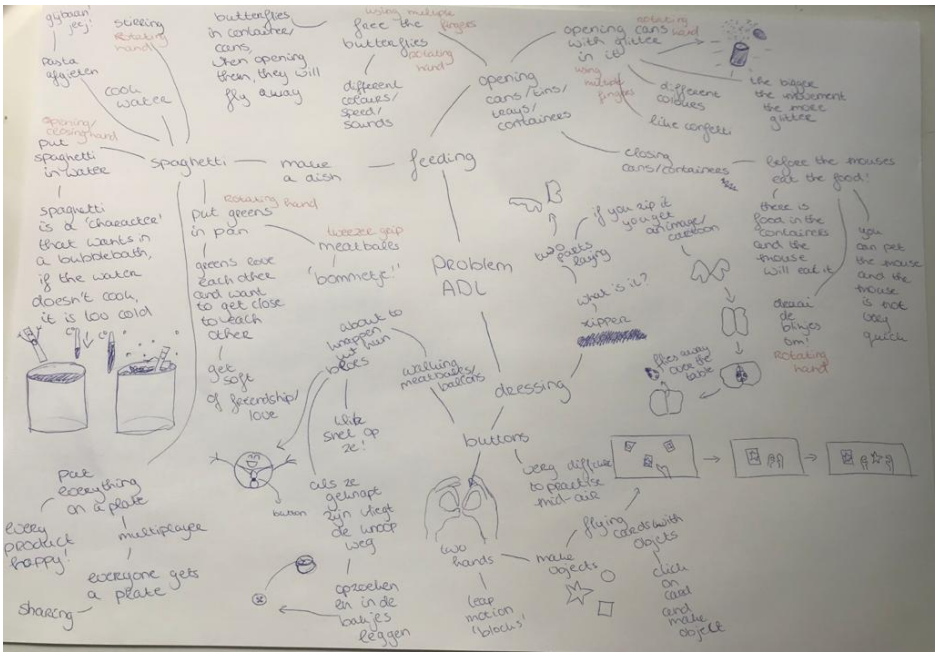


Figure 66: Brainstorm about game concepts

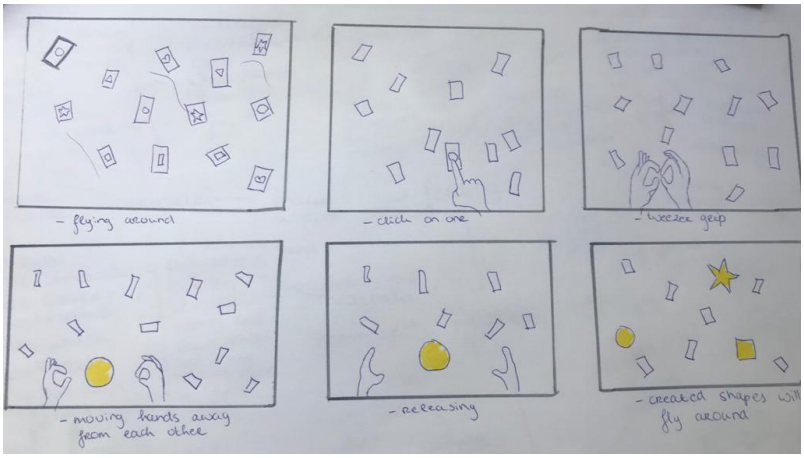


Figure 67: Brainstorm about game concepts

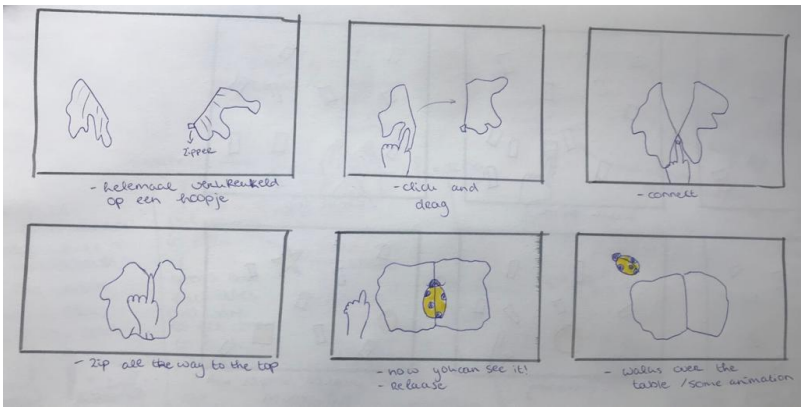


Figure 68: Brainstorm about game concepts

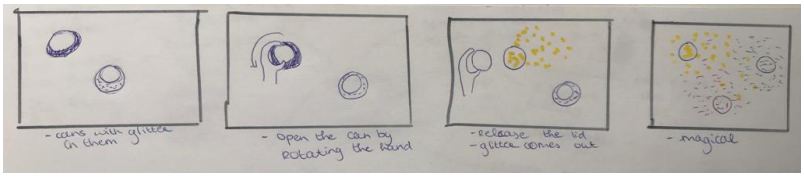


Figure 69: Brainstorm about game concepts

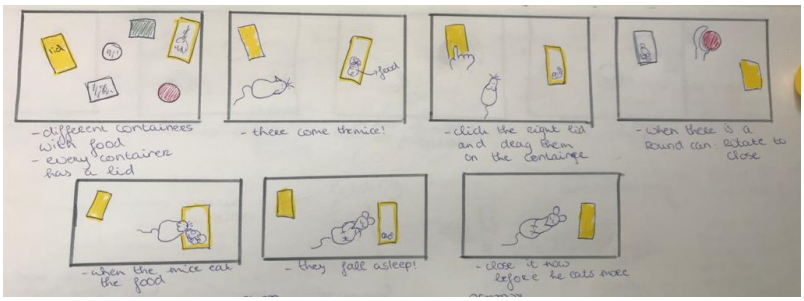


Figure 70: Brainstorm about game concepts

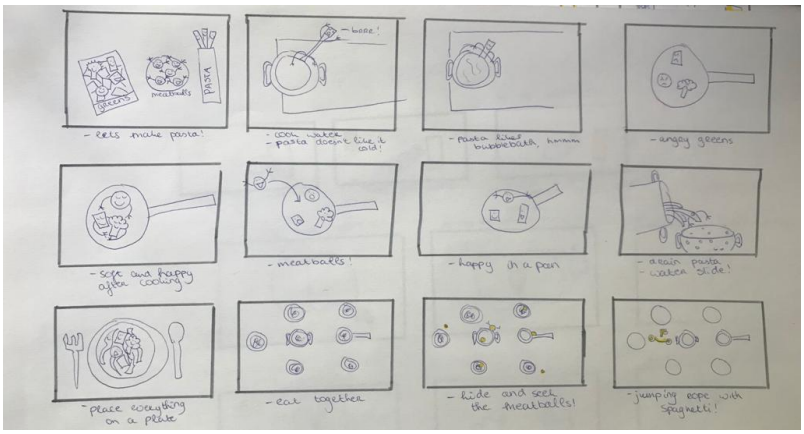


Figure 71: Brainstorm about game concepts

A.2 Written brainstorm

This is the same brainstorm as in Appendix A.1, but than written out.

Feeding

- Opening cans / trays / containers / caps / tins
  - Butterflies: Cans with butterflies in it. When opening the cans, the butterflies fly away. They will fly over the table and have different colours.
  - Glitter: Cans have glitter in it. When opening one, the glitter pours out like confetti in all different colours. Should be very magical. The bigger the can/movement, the more glitter/the more magical it looks.
  - Mice: Closing cans/containers before all mice eat the food! These mice are very slow and not very alert, but they can eat your food inside the cans. Find the right lid and close the can to prevent them from eating the food.
- Make a dish!
  - Spaghetti: In this game, we are making spaghetti. All foods are 'characters/persons', express emotions. First you need to cook the water. When it is cooking, put the spaghetti in the pan. The spaghetti does not like the water when it is not cooking, brrr! When the water is cooking, the pan is like a hot tub for spaghetti (chilling spaghetti in the pan). Then you are going to make the sauce: put all angry greens in the pan with the sauce. When they get softer, they will be less angry and they will crawl towards each other/hugging each other. Then the meatballs, throw them in the pan by rotating your hand. Give it a good stir and then it is done! Drain the pasta in a strainer. This is like a slide for them! Put the spaghetti on a plate. Multiplayer idea: everyone at the table gets a plate, because sharing food is fun! End with a happy cartoon: every pasta/green/meatball is happy. Extra idea on this: play games with spaghetti! Meatballs are jumping rope with spaghetti (opening, closing hand or tweezer grip and releasing when jumping, should be funny if the meatballs trip over the spaghetti) or hide and seek (click on the meatballs that are hidden).
  - Pancakes: First you need to choose the ingredients. All kinds of foods are floating over the table: eggs, tomatoes, flour, hamburgers, pasta, etc. You need

to click on the ingredients that you need for pancakes: eggs, flour and milk. Thereafter you need to mix all ingredients by rotating your hand clockwise. Put a pan on the stove and put one scoop of pancake mix inside the pan. When the pancake turns brown, you can flip it. When the other side is brown as well, you can shove the pancake on your plate. Bon appetit! Extra idea: you can play with the pancakes. When you shove your pancake from your plate, you can throw the pancake over with multiple people. The pancake bounces against the walls. Another idea is that you can make a pancake pie: first a layer of pancake on your plate, then a layer of jam, then a layer of pancake again, then a layer of cheese, etc.

Dressing

- Buttons: very hard to practice this in mid-air
- Meatballs: Walking meatballs/balloons with blouses. They are very fat and the buttons are about to snap. Quickly release the buttons by using the tweezer grip (two/three fingers moving away from each other). If they explode the button will fall somewhere in the playfield (exploding blouses should be funny and not seen as negative). You can collect them by clicking on them and dragging them to a can.
- Zip it up: Create images by zipping. Two pieces of clothing are laying on the table, you cannot really see what is on these pieces. Connect the ends/zippers by dragging one piece to the other. With one finger connect the bottom/top of the pieces. Then with the tweezer grip, zip the pieces together. You can now see what it is! It can be a ladybug for example! For a few moments the piece of clothing is visible and you can see what it is. Then an animation happens: the ladybug starts flying away around the screen.

Other ideas

- Create shapes!: There are cards flying over the table with shapes on them: blocks, triangles, stars, hearths. When clicking on one, it moves to you. You can now create the shape that is on the card by using the tweezer grip with both hands: you start with tweezer grip with both hands very close to each other and then move the hands away from each other. Release the shape bij opening your fingers. Thereafter shapes will fly over the table. Just like the cards. This game has no end. Can also be with more difficult shapes: like cats/dogs. When creating them they are trying to catch the other cards. Or butterflies/bugs: smash the bugs!
- Beach: A beach will be displayed on the table. You will see a map that points out where the keys and the chest are. When you know where the keys and the chest are, you need to dig them up by making a bowl with your hand and then rotate the hand to release the sand elsewhere. Grab the key and put it in the lock. Rotate your hand to unlock the chest. Inside the chest is gold (or something else).
- Soccer: Play soccer by using the tweezer grip in order to push away the soccer ball. This game is a multiplayer game.
- Pool: You can play pool on a pool table by rotating your hand in order to point at the direction your ball is going. When opening your hand, the ball is shooting away.
- Virtual dog or cat: You live in a house and you have a dog or cat. You can give the dog or cat food, you can pet them, play with them and take them for a walk. If you pet your dog or cat, you will learn how to use multiple fingers together and seperate

(tickle with your fingers underneath their chin). If you give your dog or cat food, you will grab the can with food and rotate your hand to put it in their food bowl. Before you will take your dog or cat for a walk, you need to collect some items: a collar, a poo bag and keys. If you have collected these items, you can go! Before walking with your dog or cat, you can outline the route you want to walk (hand-eye coordination). While walking you need to pay attention, because maybe you will find some surprises, like toys for your dog or cat! When you come back home, you need to unlock the door with your key. At home, you can play with your dog or cat by throwing a toy: close your hand to pick up a toy, open your hand to throw the toy. The dog or cat will catch it for you!

- Money: Teaching how to handle money and at the same time training fine motor skills. The money-element can be added to all games, like f.e. baking pancakes: for every pancake you bake, you will receive 5 euros. You can shop for new pancake mixes, toppings, kitchen tools, etc.

B Prototypes

B.1 Unity scripts

B.1.1 Script: ContainerRotation

```
/* This script is written by Frederique Voskeuil for her bachelor thesis
    for Creative Technology */

using System.Collections;
using System.Collections.Generic;
using UnityEngine;


public class ContainerRotation : MonoBehaviour
{
    //initializing components and getting components of script
        ContainerRound
    [SerializeField] private ContainerRound containerround;
    private Animator anim;
    private MeshRenderer arrowmesh;

    // Start is called before the first frame update
    void Start()
    {
        //get animator and mesh renderer of two objects
        anim = GetComponent<Animator>();
        arrowmesh = GetComponent<MeshRenderer>();
    }

    // Update is called once per frame
    void Update()
    {
        //call function CheckRotation
        CheckRotation();
    }

    void CheckRotation()
    {
        //set mesh renderer to false
        arrowmesh.enabled = false;

        //if closed and rotated are true in ContainerRound script
        if (containerround.closed == true && containerround.rotated ==
            false)
        {
            //enable mesh renderer and play animation
            arrowmesh.enabled = true;
            anim.Play("ArrowAnim");
        }
    }
}
```

B.1.2 Script: ContainerRound

```
/* This script is written by Frederique Voskeuil for her bachelor thesis for Creative Technology */

using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class ContainerRound : MonoBehaviour
{
    //initializing components and getting components of script RotationManager and SceneHandler
    private GameObject target;
    [SerializeField] private float offsety;
    [SerializeField] private RotationManager rotationmanager;
    private Vector3 offset = new Vector3(0, 0, 0);
    private BoxCollider box;
    public bool closed = false;
    public bool rotated = false;
    private float range = 0.1f;
    private float rangex1;
    private float rangex2;
    private float rangez1;
    private float rangez2;

    [SerializeField] private string tag;
    [SerializeField] private SceneHandler scenehandler;
    public bool closedround1;
    public bool closedround2;

    private AudioSource positiveAudio;
    private bool played1;
    private bool played2;

    private Vector3 spawnposition;
    private Rigidbody rb;

    private float TimeNothing = 20.0f;
    public bool NothingHappenedRound = false;

    // Start is called before the first frame update
    void Start()
    {
        //get box collider, audio source and rigid body from three objects
        offset.y = offsety;
        box = GetComponent<BoxCollider>();
        positiveAudio = GetComponent<AudioSource>();

        spawnposition = transform.position;
        rb = GetComponent<Rigidbody>();
    }

    // Update is called once per frame
    private void Update()
    {
        //
        if (target != null)
        {
            //if the lid is in certain range of the container, snap to position above container
            transform.position = target.transform.position + offset;
            transform.rotation = target.transform.rotation;
            box.enabled = false;
            closed = true;
```

```
61
62              Vector3 temppos = transform.position;
63              rangex1 = temppos.x - range;
64              rangex2 = temppos.x + range;
65
66              rangez1 = temppos.z - range;
67              rangez2 = temppos.z + range;
68
69              //if the hand is rotated and the hand is above the container,
                    set booleans true and play audio
70              if (rotationmanager.rightpalmrotationy > 0.15f &&
                    rotationmanager.rightpalmpositionx > rangex1 &&
                    rotationmanager.rightpalmpositionx < rangex2 &&
                    rotationmanager.rightpalmpositionz > rangez1 &&
                    rotationmanager.rightpalmpositionz < rangez2)
71              {
72                  rotated = true;
73                  if (played1 == false)
74                  {
75                      positiveAudio.Play();
76                      played1 = true;
77                  }
78              }
79
80              if (rotationmanager.leftpalmrotationy < -0.7f &&
                    rotationmanager.leftpalmpositionx > rangex1 &&
                    rotationmanager.leftpalmpositionx < rangex2 &&
                    rotationmanager.leftpalmpositionz > rangez1 &&
                    rotationmanager.leftpalmpositionz < rangez2)
81              {
82                  rotated = true;
83                  if (played1 == false)
84                  {
85                      positiveAudio.Play();
86                      played1 = true;
87                  }
88              }
89
90              if (played1)
91              {
92                  //check which round container has been closed
93
94                  if (target.tag == "Round1")
95                  {
96                      scenehandler.closedround1 = true;
97                  }
98
99                  if (target.tag == "Round2")
100                 {
101                     scenehandler.closedround2 = true;
102                 }
103                 if (target.tag == "Round3")
104                 {
105                     scenehandler.closedround3 = true;
106                 }
107             }
108         }
109
110         //check if the user has already closed the containers
111         TimeNothing -= Time.deltaTime;
112         if (TimeNothing < 0.0f)
113         {
114             if (rotated)
115             {
116                 NothingHappenedRound = false;
```

```
            }
            else
            {
                NothingHappenedRound = true;
            }
        }
        else
        {
            NothingHappenedRound = false;
        }

        //if the lid is out of range of the user, snap to start position
        if (Vector3.Distance(transform.position, spawnposition) > 0.35f)
        {
            transform.position = spawnposition;
            rb.velocity = Vector3.zero;
        }
    }

    void OnTriggerEnter(Collider other)
    {
        //check if the lid has entered the collider of the container
        if (other.tag == tag)
        {
            target = other.gameObject;
        }
    }
}
```

B.1.3 Script: ContainerSquare

```
/* This script is written by Frederique Voskeuil for her bachelor thesis
    for Creative Technology */

using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class ContainerSquare : MonoBehaviour
{
    //initializing components and getting components of script
        SceneHandler
    private GameObject target;
    [SerializeField]private float offsety;
    private Vector3 offset = new Vector3(0,0,0);
    private BoxCollider box;

    [SerializeField] private SceneHandler scenehandler;
    [SerializeField] private string tag;

    private AudioSource positiveAudio;
    private bool played1;
    private bool played2;
    private bool played3;

    float TimeNothing = 30.0f;
    public bool NothingHappened = false;

    private Vector3 spawnposition;
    private Rigidbody rb;

    // Start is called before the first frame update
    void Start()
    {
```

```
32          //get box collider, audio source and rigid body, set spawnposition
33          offset.y = offsety;
34          box = GetComponent<BoxCollider>();
35          positiveAudio = GetComponent<AudioSource>();
36          spawnposition = transform.position;
37          rb = GetComponent<Rigidbody>();
38      }
39
40      // Update is called once per frame
41      void Update()
42      {
43          if(target != null)
44          {
45              //if the lid is in certain range of the container, snap to
                    position above container
46              transform.position = target.transform.position + offset;
47              transform.rotation = target.transform.rotation;
48              box.enabled = false;
49              NothingHappened = false;
50
51              //check which round container has been closed
52
53              if (target.tag == "Square1")
54              {
55                  scenehandler.closed1 = true;
56                  if (played1 == false)
57                  {
58                      positiveAudio.Play();
59                      played1 = true;
60                  }
61              }
62
63              if (target.tag == "Square2")
64              {
65                  scenehandler.closed2 = true;
66                  if (played2 == false)
67                  {
68                      positiveAudio.Play();
69                      played2 = true;
70                  }
71              }
72              if (target.tag == "Square3")
73              {
74                  scenehandler.closed3 = true;
75                  if (played3 == false)
76                  {
77                      positiveAudio.Play();
78                      played3 = true;
79                  }
80              }
81          }
82          else
83          {
84              //check if the user has already closed the containers
85              TimeNothing -= Time.deltaTime;
86              if (TimeNothing < 0.0f)
87              {
88                  NothingHappened = true;
89              }
90              else
91              {
92                  NothingHappened = false;
93              }
94          }
95
```

```
96          //if the lid is out of range of the user, snap to start position
97          if (Vector3.Distance(transform.position, spawnposition) > 0.3f)
98          {
99              transform.position = spawnposition;
100             rb.velocity = Vector3.zero;
101         }
102     }
103
104     void OnTriggerEnter(Collider other)
105     {
106         //check if the lid has entered the collider of the container
107         if(other.tag == tag){
108             target = other.gameObject;
109         }
110     }
111 }
```

B.1.4 Script: ExampleLid

```
1  /* This script is written by Frederique Voskeuil for her bachelor thesis
       for Creative Technology */
2
3  using System.Collections;
4  using System.Collections.Generic;
5  using UnityEngine;
6
7  public class ExampleLid : MonoBehaviour
8  {
9      //initializing components and getting components of script
           ContainerSquare, ContainerRound and Toggle
10     [SerializeField] private ContainerSquare containersquare;
11     [SerializeField] private ContainerRound containerround;
12     [SerializeField] private Toggle toggle;
13     [SerializeField] private Animator examplelid;
14     [SerializeField] private Animator examplelid2;
15     [SerializeField] private Animator exampletoggle;
16
17     private bool playOnce;
18     private bool playOnceRound;
19     private bool playOnceToggle;
20
21     // Update is called once per frame
22     void Update()
23     {
24         //check if the user has already closed the squared containers,
               otherwise play animation with example lid
25         if(containersquare.NothingHappened)
26         {
27             transform.GetChild(0).gameObject.SetActive(true);
28
29             if (playOnce == false)
30             {
31                 examplelid.Play("ExampleLid");
32                 playOnce = true;
33             }
34         }
35         else
36         {
37             transform.GetChild(0).gameObject.SetActive(false);
38         }
39
40         //check if the user has already closed the round containers,
               otherwise play animation with example lid
41         if(containerround.NothingHappenedRound)
```

```
42          {
43              transform.GetChild(1).gameObject.SetActive(true);
44
45              if (playOnceRound == false)
46              {
47                  examplelid2.Play("ExampleLidRound");
48                  playOnceRound = true;
49              }
50          }
51          else
52          {
53              transform.GetChild(1).gameObject.SetActive(false);
54          }
55
56          //check if the user has already closed the container with the
                zipper, otherwise play animation with example lid
57          if(toggle.NothingHappenedToggle)
58          {
59              transform.GetChild(2).gameObject.SetActive(true);
60
61              if (playOnceToggle == false)
62              {
63                  examplelid2.Play("ExampleToggle");
64                  playOnceToggle = true;
65              }
66          }
67          else
68          {
69              transform.GetChild(2).gameObject.SetActive(false);
70          }
71      }
72  }
```

B.1.5 Script: RotationManager

```
1  /* This script is written by Frederique Voskeuil for her bachelor thesis
       for Creative Technology */
2
3  using System.Collections;
4  using System.Collections.Generic;
5  using UnityEngine;
6
7  public class RotationManager : MonoBehaviour
8  {
9      //initializing components and getting components of Leap Motion
           packages
10     [SerializeField] private GameObject rightpalm;
11     [SerializeField] private GameObject leftpalm;
12     [HideInInspector] public float rightpalmrotationy = 0f;
13     [HideInInspector] public float leftpalmrotationy = 0f;
14     [HideInInspector] public float rightpalmrotationx = 0f;
15     [HideInInspector] public float leftpalmrotationx = 0f;
16     [HideInInspector] public float rightpalmpositionx = 0f;
17     [HideInInspector] public float rightpalmpositionz = 0f;
18     [HideInInspector] public float leftpalmpositionx = 0f;
19     [HideInInspector] public float leftpalmpositionz = 0f;
20     [HideInInspector] public Vector3 rightpalmposition;
21     [HideInInspector] public Vector3 leftpalmposition;
22
23     // Update is called once per frame
24     private void Update()
25     {
26         //set palm positions
27         rightpalmposition = rightpalm.transform.position;
```

```
        leftpalmposition = leftpalm.transform.position;

        rightpalmrotationy = rightpalm.transform.rotation.y;
        leftpalmrotationy = leftpalm.transform.rotation.y;

        rightpalmrotationx = rightpalm.transform.rotation.x;
        leftpalmrotationx = leftpalm.transform.rotation.x;

        rightpalmpositionx = rightpalmposition.x;
        rightpalmpositionz = rightpalmposition.z;

        leftpalmpositionx = leftpalmposition.x;
        leftpalmpositionz = leftpalmposition.z;
    }
}
```

B.1.6 Script: SceneHandler

```
/* This script is written by Frederique Voskeuil for her bachelor thesis
    for Creative Technology */

using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class SceneHandler : MonoBehaviour
{
    //initializing components
    public bool closed1;
    public bool closed2;
    public bool closed3;

    public bool closedround1;
    public bool closedround2;
    public bool closedround3;

    public bool closedrect1;
    public bool closedrect2;
    public bool closedrect3;

    private bool round1;
    private bool round2;
    private bool round3;

    float timeLeft = 2.0f;
    float timeOver = 2.0f;
    float timer = 2.0f;

    [SerializeField] private GameObject vink;

    // Update is called once per frame
    void Update()
    {
        //check if containers are closed
        if (closed1 && closed2)
        {
            vink.SetActive(true);

            //start timer and if no time left, set game objects on false
                and reset time
            timeLeft -= Time.deltaTime;
            if(timeLeft < 0)
            {
                transform.GetChild(0).gameObject.SetActive(false);
```

```
45                  transform.GetChild(1).gameObject.SetActive(false);
46                  closed1 = false;
47                  closed2 = false;
48                  timeLeft = 3.0f;
49                  round1 = true;
50              }
51          }
52          else
53          {
54              //enable check mark
55              vink.SetActive(false);
56          }
57
58          if (round1)
59          {
60              //disable check mark
61              vink.SetActive(false);
62
63              //start timer and check if no time left
64              timeLeft -= Time.deltaTime;
65              if (timeLeft < 0)
66              {
67                  //check whether containers are closed in the first and
                        second round
68                  if (closedround1 && closedround2)
69                  {
70                      //enable check mark
71                      vink.SetActive(true);
72
73                      //start timer and if no time left, set game objects to
                            false and reset timer
74                      timeOver -= Time.deltaTime;
75                      if (timeOver < 0)
76                      {
77                          transform.GetChild(2).gameObject.SetActive(false);
78                          transform.GetChild(3).gameObject.SetActive(false);
79                          timeLeft = 3.0f;
80                          round1 = false;
81                          round2 = true;
82                      }
83                  }
84                  else
85                  {
86                      //set game objects true
87                       transform.GetChild(2).gameObject.SetActive(true);
88                       transform.GetChild(3).gameObject.SetActive(true);
89                  }
90              }
91          }
92          else
93          {
94              //set game objects false
95              transform.GetChild(2).gameObject.SetActive(false);
96              transform.GetChild(3).gameObject.SetActive(false);
97          }
98
99          if (round2)
100         {
101             //set check mark false
102             vink.SetActive(false);
103
104             //start timer and check if no time left
105             timeLeft -= Time.deltaTime;
106             if (timeLeft < 0)
107             {
```

```
108                 //if containers are closed in first and second round, set
                        check mark true, start timer and check if no time left
109                 if (closedrect1 && closedrect2)
110                 {
111                     vink.SetActive(true);
112 
113                     timer -= Time.deltaTime;
114                     if (timer < 0)
115                     {
116                         //set objects false of one toggle
117                         transform.GetChild(4).gameObject.SetActive(false);
118                         transform.GetChild(5).gameObject.SetActive(false);
119 
120                         //set objects false of two toggles
121                         transform.GetChild(6).gameObject.SetActive(false);
122                         transform.GetChild(7).gameObject.SetActive(false);
123                         timeLeft = 3.0f;
124                         timer = 3.0f;
125                         round2 = false;
126                         round3 = true;
127                     }
128                 }
129                 else
130                 {
131                     //set objects true of one toggle
132                     transform.GetChild(4).gameObject.SetActive(true);
133                     transform.GetChild(5).gameObject.SetActive(true);
134 
135                     //set objects true of two toggle
136                     transform.GetChild(6).gameObject.SetActive(true);
137                     transform.GetChild(7).gameObject.SetActive(true);
138                 }
139             }
140         }
141         else
142         {
143             //set objects false of two toggle
144             transform.GetChild(4).gameObject.SetActive(false);
145             transform.GetChild(5).gameObject.SetActive(false);
146 
147             //set objects false of two toggle
148             transform.GetChild(6).gameObject.SetActive(false);
149             transform.GetChild(7).gameObject.SetActive(false);
150         }
151 
152         //check if round 3 has started
153         if (round3)
154         {
155             //set check mark false
156             vink.SetActive(false);
157 
158             //start timer and check if no time left
159             timeLeft -= Time.deltaTime;
160             if (timeLeft < 0)
161             {
162                 //set round and square containers true
163                 transform.GetChild(8).gameObject.SetActive(true);
164                 transform.GetChild(9).gameObject.SetActive(true);
165 
166                 //set container with zipper true
167                 transform.GetChild(10).gameObject.SetActive(true);
168                 transform.GetChild(11).gameObject.SetActive(true);
169 
170                 if (closedround3 && closed3 && closedrect3)
171                 {
```

```
                    vink.SetActive(true);
                }
            }
        }
        else
        {
            //set round and square containers false
            transform.GetChild(8).gameObject.SetActive(false);
            transform.GetChild(9).gameObject.SetActive(false);

            //set container with zipper false
            transform.GetChild(10).gameObject.SetActive(false);
            transform.GetChild(11).gameObject.SetActive(false);
        }
    }
}
```

B.1.7 Script: Toggle

```
/* This script is written by Frederique Voskeuil for her bachelor thesis
    for Creative Technology */

using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class Toggle : MonoBehaviour
{
    //initializing components and getting components of script
        SceneHandler
    public float togglepositionz;
    [SerializeField] private Animator zipper1;
    [SerializeField] private string label;
    [SerializeField] private SceneHandler scenehandler;

    private AudioSource positiveAudio;
    private bool played1;
    private bool played2;

    float TimeNothing = 20.0f;
    public bool NothingHappenedToggle = false;

    // Start is called before the first frame update
    void Start()
    {
        //get audio source
        positiveAudio = GetComponent<AudioSource>();
    }

    // Update is called once per frame
    void Update()
    {
        if (tag == label)
        {
            togglepositionz = transform.position.z;

            //create temporary positions for every position in which the
                toggle could be, this is used for the animation of the
                zipper
            float tempprog = (togglepositionz - 0.653f) * 6.188f;
            zipper1.SetFloat("Progress", tempprog);

            //check if zipper is above a certain position
            if (togglepositionz > 0.80f)
```

```
42              {
43                  //check which round container
44
45                  if (tag == "Toggle1")
46                  {
47                      scenehandler.closedrect1 = true;
48                      //check if closed and if closed, play audio sound
49                      if (played1 == false)
50                      {
51                          positiveAudio.Play();
52                          played1 = true;
53                      }
54                  }
55
56                  if (tag == "Toggle2")
57                  {
58                      scenehandler.closedrect2 = true;
59                      //check if closed and if closed, play audio sound
60                      if (played1 == false)
61                      {
62                          positiveAudio.Play();
63                          played1 = true;
64                      }
65                  }
66
67                  if (tag == "Toggle3")
68                  {
69                      scenehandler.closedrect3 = true;
70                      //check if closed and if closed, play audio sound
71                      if (played1 == false)
72                      {
73                          positiveAudio.Play();
74                          played1 = true;
75                      }
76                  }
77              }
78          }
79
80          //check if the user has already closed the containers
81          TimeNothing -= Time.deltaTime;
82          if (TimeNothing < 0.0f)
83          {
84              if (togglepositionz < 0.73f)
85              {
86                  NothingHappenedToggle = true;
87              }
88              else
89              {
90                  NothingHappenedToggle = false;
91              }
92          }
93          else
94          {
95              NothingHappenedToggle = false;
96          }
97      }
98  }
```

C User tests

C.1 Interview expert of target group

This interview is performed in the ideation phase (chapter 4).

C.1.1 Informed consent

Informed consent form

Dit onderzoek wordt gedaan door Frederique Voskeuil, een derdejaars Creative Technology student van de University of Twente. Dit onderzoek wordt gedaan voor haar bachelor thesis: 'Everyone has the right to play.'

Doel bachelor thesis
De bacheloropdracht focust zich op de problemen die optreden tijdens de algemene dagelijkse levensverrichtingen (ADL) van verstandelijk beperkten. De insteek hierbij is dat games kunnen bijdragen aan de bewegingsontwikkeling van verstandelijk beperkten. Voor de thesis zal een speeltafel ontworpen worden waar games op geprojecteerd worden. De gebruikers kunnen deze games spelen door middel van het bewegen van hun armen en handen. De combinatie van spelen en het oefenen van bewegingen is erg sterk. Het doel is om door middel van de speeltafel bewegingen te oefenen die in het dagelijks leven terug komen.

Procedure interview en COVID-19
Om een beter beeld te vormen over de problemen die verstandelijke beperkten ondervinden tijdens de algemene dagelijkse levensverrichtingen, vindt er een onderzoek plaats waarin een expert wordt geïnterviewd. Tijdens dit onderzoek met de deelnemende expert, zal aan de deelnemer interviewvragen worden gesteld over de problemen tijdens de algemene dagelijks levensverichtingen van verstandelijk beperkten. Vanwege COVID-19 zal het onderzoek online plaatsvinden via Skype of Google Hangout. Hierdoor zal er geen extra besmettingskans ontstaan. Het interview zal ongeveer 30 minuten duren. Deze sessie is eenmalig.

Risico's
Audio en video-beelden zullen niet worden opgenomen tijdens het onderzoek. Mocht de deelnemer zich oncomfortabel voelen bij de vragen of de procedure, mag de deelnemer op elk moment stoppen met het interview. Op aanvraag van de deelnemer kunnen de al reeds gegeven antwoorden verwijderd worden uit het onderzoek.

Vertrouwelijkheid
De deelnemers privacy zal gerespecteerd worden en de uitkomsten zullen alleen voor de bachelor thesis gebruikt worden. De uitkomsten van het interview zullen niet gebruikt worden zolang hier geen toestemming voor gegeven is.

Rechten
Deelname is vrijwillig. De deelnemer mag elk moment stoppen met deelnemen aan het onderzoek. Op aanvraag van de deelnemer kunnen de al reeds gegeven antwoorden verwijderd worden uit het onderzoek. Mocht er nieuwe informatie beschikbaar komen die de deelnemers' deelname zal beïnvloeden, zal die gedeeld worden met de deelnemer.

Contact informatie
Mochten er vragen of opmerkingen over het onderzoek zijn, kunt u onderstaand nummer bellen of mailen naar het email-adres.
Frederique Voskeuil
+ 06 13723998
a.f.voskeuil@student.utwente.nl

Het toestemmingsformulier bevat: (kruis in de vakjes aan waar van toepassing is)

	Ik geef toestemming om mijn antwoorden te gebruiken voor het onderzoek
X	Ik geef toestemming voor de bovenstaande onderdelen. Hiermee geef ik aan dat ik juist geïnformeerd ben over het onderzoek en de procedures. Ik weet dat ik vragen mag stellen en mag stoppen op elk moment. Ik geef toestemming voor mijn deelname aan het onderzoek.

Naam _____

Datum _____

Handtekening _____

Figure 72: Informed consent forms of the interview with the expert of the target group in the ideation phase

C.1.2 Questions

Interview questions

Tovertafel
Why are you using the Tovertafel?
Waarom gebruiken jullie de Tovertafel?

When are you already using Tovertafel?
Wanneer gebruiken jullie nu de Tovertafel?

How long are the sessions in which you use the Tovertafel?
Hoe lang gebruiken jullie de Tovertafel per keer?

With how many people are you using the Tovertafel?
Met hoeveel mensen gebruiken jullie de Tovertafel?

Who are you using the Tovertafel for?
Bij welke verstandelijk beperkten groepen gebruiken jullie de Tovertafel?

Why don't you use the Tovertafel with some groups?
Waarom bij sommige groepen niet?

How would Tovertafel be applicable in physio/ergotherapy?
Hoe denken jullie dat Tovertafel gebruikt kan worden tijdens fysio-/ergotherapie?
Bv bij strek oefeningen? En waarom wel/niet?

Are there things that you would like to add to the Tovertafel?
Zijn er dingen die jullie zelf graag willen toevoegen of veranderen aan de Tovertafel? Waarom wel niet?

Intellectual disability
What does the day of a life of a person with an intellectual disability look like?
Hoe ziet de dag van verstandelijke beperkten eruit?

What difficulties do intellectual disabled people encounter in their day to day life?
Tegen welke dagelijkse problemen lopen verstandelijk beperkten aan?

Do you see a difference in when the patient arrives and when he leaves?
Zien jullie verschil bij de patiënt als hij bij jullie 'praktijk' aankomt met als hij weg gaat?

Do you have different groups of intellectual disabled people?
Welke verschillende groepen verstandelijke beperkten hanteren jullie?

Physio-/ergotherapy
What types of physio/ergotherapie are intellectual disabled persons already encountered with?
Wat voor soorten fysio-/ergotherapie gebruiken jullie?

What methods are used in these therapies?
Wat voor methodes gebruiken jullie tijdens deze therapieën?

Why are you using fysio/ergotherapie with intellectual disabled persons?
Waarom gebruiken jullie fysio/ergotherapie bij verstandelijke beperkten?

What are the goals with these types of therapy?
Wat zijn de doelen van deze therapie?

What are the short-term goals (goals within one session) of physio/ergotherapie?
Wat zijn de doelen van de therapie die jullie tijdens één sessie willen bereiken?

What are the long-term goals (goals over multiple sessions) of physio/ergotherapie?
Wat zijn de doelen van de therapie die jullie over een langer termijn willen bereiken?

Are there other goals you are trying to achieve different from better movement?
Zijn er naast … (beter bewegen) nog andere doelen die jullie willen bereiken met fysio-/ergotherapie?

How long does a session of physio/ergotherapy last?
Hoe lang duurt een fysio/ergotherapie sessie?

Games
Are you already using games during physio/ergotherapie?
Gebruiken jullie al spellen/games tijdens fysio/-ergotherapie?

Are intellectual disabled people already playing games?
Spelen verstandelijke beperkten buiten de fysio/ergotherapie al spellen?

Why are they (not) playing games?
Waarom spelen ze wel of niet spellen?

How often are they playing games?
Hoe vaak spelen zij al spellen?

What kind of games are they playing? Could you give an example?
Wat voor soort spellen spelen zij? Kunt u een voorbeeld geven?

What difficulties do they encounter when playing games?
Tegen wat voor problemen lopen zij aan tijdens het spelen van spellen?

Figure 73: Interview questions asked to the expert of the target group in the ideation phase

C.2 User tests

C.2.1 Informed consent face-to-face participants

Informed consent form for face-to-face participants that participated in the technology prototype test, pilot test and evaluation test.

Informed consent form

Dit onderzoek wordt gedaan door Frederique Voskeuil, derdejaars Creative Technology student van de University of Twente. Dit onderzoek wordt gedaan voor haar bachelor thesis: 'Everyone has the right to play.'

Doel bachelor thesis
De bacheloropdracht focust zich op de problemen die optreden tijdens de algemene dagelijkse levensverrichtingen (ADL) van verstandelijk beperkten. De insteek hierbij is dat games kunnen bijdragen aan de bewegingsontwikkeling van verstandelijk beperkten. Voor de thesis is een speeltafel ontworpen waar games op geprojecteerd worden. De gebruikers kunnen deze games spelen door middel van het bewegen van hun armen en handen. De combinatie van spelen en het oefenen van bewegingen is erg sterk. Het doel is om door middel van de speeltafel bewegingen te oefenen die in het dagelijks leven terug komen.

Risico's en COVID-19
Vanwege COVID-19 is iedereen genoodzaakt om thuis te blijven. Daarom zal de test in het huis gehouden worden waar de onderzoeker woont, samen met de huisgenoten van de onderzoeker. Tijdens de test kan de 1.5 meter afstand van elkaar niet gewaarborgd worden, omdat de deelnemer op minder dan 1.5 meter afstand zit van zijn andere huisgenoten. Daarnaast kan het voorkomen dat de de deelnemers elkaars handen aanraken. Daarom zijn de volgende maatregelen getroffen:

- Mocht de onderzoeker ziek zijn, gaat de testsessie niet door.
- Mocht een van de huisgenoten ziek zijn, dan mag deze niet mee doen met het onderzoek.
- Onder 'ziek' wordt verstaan: verkoudheid, griep verschijnselen (koorts, keelpijn, koude rillingen, etc.) of een besmetting met COVID-19.
- Na de test wordt aangeraden om de handen te wassen.

Daarnaast zullen audio en video beelden worden opgenomen. Hierover meer in het kopje 'Vertrouwelijkheid'. Mocht de deelnemer zich oncomfortabel voelen bij de vragen of de procedure, mag de deelnemer op elk moment stoppen met de test. Op aanvraag van de deelnemer kunnen de al reeds gegeven antwoorden verwijderd worden uit het onderzoek.

Test procedure
Tijdens de testsessie zullen de deelnemers gevraagd worden aan een tafel plaats te nemen. Op deze tafel worden games geprojecteerd en door middel van het bewegen van armen en handen kunnen de deelnemers interactie hebben met de tafel. Na deze test-sessie zullen de deelnemers een korte vragenlijst over de testsessie moeten invullen. De totale duur van de testsessie zal ongeveer 30 minuten zijn.

Vertrouwelijkheid
De deelnemers' privacy zal gerespecteerd worden en de uitkomsten zullen alleen voor de bachelor thesis gebruikt worden. De uitkomsten van de vragenlijst zullen niet gebruikt worden zolang hier geen toestemming voor gegeven is. De uitkomsten zullen geen persoonlijke informatie bevatten, dus anonimiteit zal gewaarborgd worden.

Daarnaast zullen audio en video beelden worden opgenomen van de deelnemers (u). De reden voor het opnemen van de audio en video is dat de onderzoeker achteraf deze fragmenten kan terugluisteren om de testsessie om te analyseren en te gebruiken voor het onderzoek. De audiofragmenten zullen 1 maand worden opgeslagen (vanaf de datum van het onderzoek) en zullen niet gedeeld worden met anderen. Alleen de onderzoeker zelf zal naar de audiofragmenten luisteren. De antwoorden en opmerkingen die door u genoemd zijn tijdens het onderzoek zullen anoniem verwerkt worden in het verslag. Na het afsluiten van het afstudeerproject of na de afgesproken datum (1 maand na het onderzoek) zullen de audiofragmenten verwijderd worden. Daarnaast zullen uit de videobeelden fragmenten worden genomen voor in het verslag en de presentatie, maar enkel de handen en de tafel zullen worden opgenomen en uw gezicht zal niet op deze beelden staan.

Rechten
Deelname is vrijwillig. De deelnemer mag op elk moment stoppen met deelnemen aan het onderzoek. Op aanvraag van de deelnemer kunnen de al reeds gegeven antwoorden verwijderd worden uit het onderzoek. Mocht er nieuwe informatie beschikbaar komen die de deelnemers' deelname zal beïnvloeden, zal die gedeeld worden met de deelnemer.

Contact informatie
Mochten er vragen of opmerkingen over het onderzoek zijn, kunt u onderstaand nummer bellen of mailen naar het email-adres.
Frederique Voskeuil
+ 06 13723998
a.f.voskeuil@student.utwente.nl

Het toestemmingsformulier bevat: (kruis in de vakjes aan waar van toepassing is)

	Ik heb geen ziekteverschijnselen zoals die in het kopje 'Risico's en COVID-19' genoemd worden
	Ik geef toestemming om mijn antwoorden te gebruiken voor het onderzoek
	Ik geef toestemming om mij te filmen en de beelden op te slaan voor het onderzoek
	Ik geef toestemming om mijn stem en antwoorden op te nemen voor het onderzoek
X	Ik geef toestemming voor de bovenstaande onderdelen. Hiermee geef ik aan dat ik juist geïnformeerd ben over het onderzoek en de procedures. Ik weet dat ik vragen mag stellen en mag stoppen op elk moment. Ik geef toestemming voor mijn deelname aan het onderzoek.

Naam _____

Datum _____

Handtekening _____

Figure 74: Informed consent form for the face-to-face participants

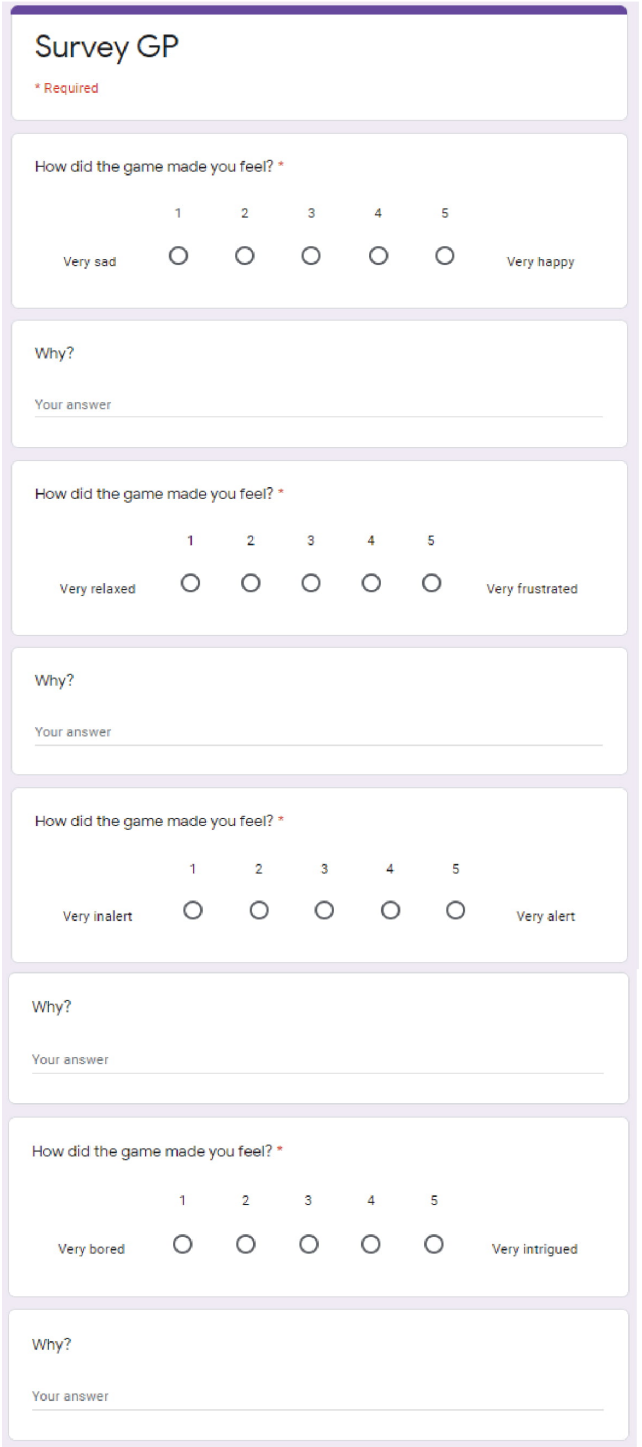
C.2.2 Questions prototype test face-to-face participants

Questions asked about the prototype in the specification phase (chapter 5).

Figure 75: Questions for participants prototype test.

C.2.3 Survey face-to-face participants

Survey for face-to-face participants, filled in after evaluation test (chapter 7).



Interactions

Questions about the interactions

Did you understand what you had to do? *

- ○ Yes, immediately
- ○ Yes, but I needed some time
- ○ Yes, after I saw the transparent containers
- ○ I needed some hints of the researcher
- ○ I needed a lot of hints of the researcher
- ○ No, I did not understand it

Did you understand all interactions? *

- ☐ I did not understand that the objects are containers with lids
- ☐ I did not understand which lid belongs to which container
- ☐ I did not understand how to close the square containers
- ☐ I did not understand how to close the round containers
- ☐ I did not understand that I had to rotate the round lid to close the round container
- ☐ I did not understand how to close the container with the zipper
- ☐ I expected some extra feedback
- ☐ I understood everything
- ☐ Other: _____

Did the animation of the arrow help you closing the round container? *

- ○ Yes, before the animation of the arrow I did not know how to close the round container
- ○ Yes, I already had an idea, but when I saw the arrow I knew for sure
- ○ No, I knew it before I say the arrow
- ○ No, I still did not know how to close the round container

Your hands were made visual in the projection. Did it feel like your hand movements translated to the projected hands accurately? *

	1	2	3	4	5	
No	○	○	○	○	○	Yes

Did the interaction feel natural? *

	1	2	3	4	5	
Not natural at all	○	○	○	○	○	Very natural

How did you know you were doing the right thing? *

Your answer

Containers

Questions about the elements of the containers.

What did you think the objects inside the containers were? *

Your answer

What did you think of the objects inside the containers? *

- [ ] They were distracting
- [ ] They supported the game
- [ ] I did not see the objects
- [ ] The objects did not give me a certain feeling

What did you think of the patterns of the containers and the lids? *

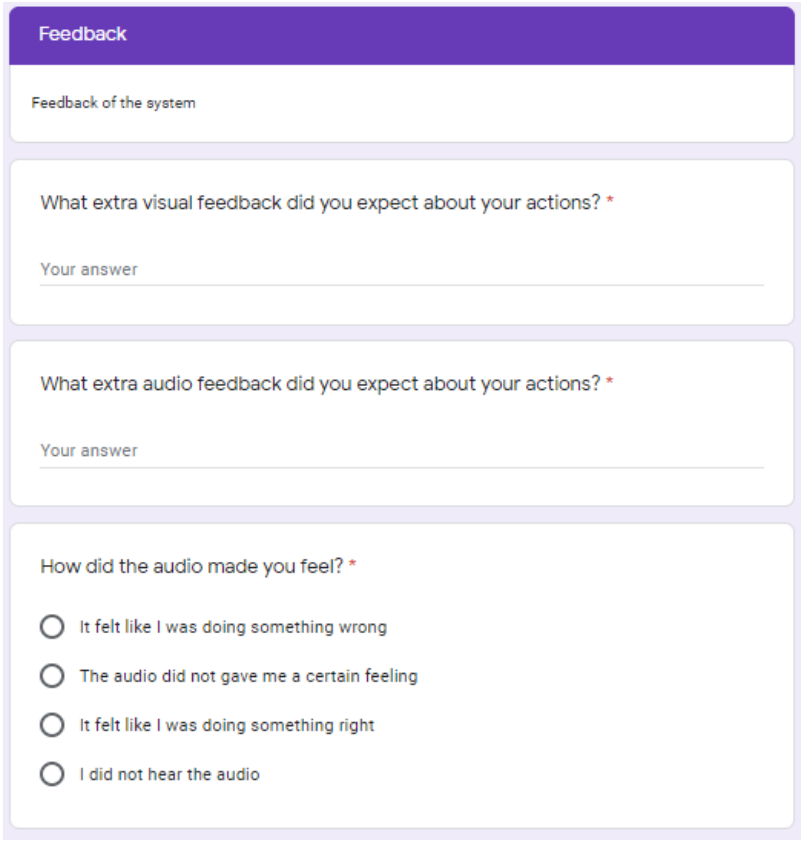
- [ ] They were clear
- [ ] They were easily distinctable
- [ ] They were not easily distinctable
- [ ] I would add more patterns
- [ ] I would add less patterns
- [ ] Other:

What did you think of the colours of the containers and the lids? *

- [ ] They were clear and bright
- [ ] They were happy colours
- [ ] They were sad colours
- [ ] They were easily distinctable
- [ ] They were not easily distinctable
- [ ] I would add more colours
- [ ] I would add less colours
- [ ] Other:

Could you distinct the lids from the containers? *

	1	2	3	4	5	
Very easily	○	○	○	○	○	It was hard to distinct them


Feedback
Feedback of the system
What extra visual feedback did you expect about your actions? *
Your answer
What extra audio feedback did you expect about your actions? *
Your answer
How did the audio made you feel? *
It felt like I was doing something wrong
The audio did not gave me a certain feeling
It felt like I was doing something right
I did not hear the audio

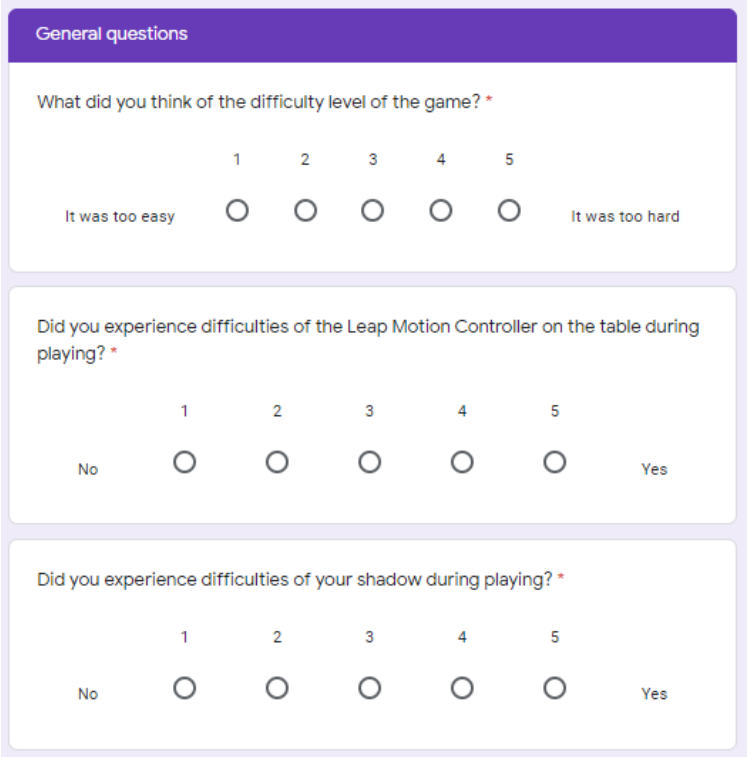


Figure 76: The survey questions asked to the face-to-face participants in the evaluation test

C.2.4 Informed consent online participants

Informed consent for the online participants in the evaluation test (chapter 7).

Informed consent form

Dit onderzoek wordt gedaan door Frederique Voskeuil, een derdejaars Creative Technology student van de University of Twente. Dit onderzoek wordt gedaan voor haar bachelor thesis: 'Everyone has the right to play.'

Doel bachelor thesis
De bacheloropdracht focust zich op de problemen die optreden tijdens de algemene dagelijkse levensverrichtingen (ADL) van verstandelijk beperkten. De insteek hierbij is dat games kunnen bijdragen aan de bewegingsontwikkeling van verstandelijk beperkten. Voor de thesis is een speeltafel ontworpen waar games op geprojecteerd worden. De gebruikers kunnen deze games spelen door middel van het bewegen van hun armen en handen. De combinatie van spelen en het oefenen van bewegingen is erg sterk. Het doel is om door middel van de speeltafel bewegingen te oefenen die in het dagelijks leven terug komen.

Test procedure
De testsessie bevat twee groepen deelnemers: de fysieke deelnemers en de online deelnemers. De fysieke deelnemers zijn de huisgenoten van de onderzoeker. Deze deelnemers zullen de test fysiek uitvoeren. De online deelnemers (u) bestaan uit twee deelnemers: een expert van verstandelijke beperking en een expert van interactieve tafel toepassingen.

Tijdens de testsessie zullen de fysieke deelnemers gevraagd worden aan een tafel plaats te nemen. Op deze tafel worden games geprojecteerd en door middel van het bewegen van armen en handen kunnen de deelnemers interactie hebben met de tafel. De online deelnemers wordt gevraagd om feedback te geven tijdens de testsessie. Deze feedback zou bijvoorbeeld kunnen gaan over spelelementen, maar kan ook gaan over de aansluiting van het spel bij de doelgroep. Alle feedback is welkom. De totale duur van de testsessie zal ongeveer 30 minuten zijn.

Risico's en COVID-19
Vanwege COVID-19 is iedereen genoodzaakt om thuis te blijven. Daarom zal de fysieke test in het huis gehouden worden waar de onderzoeker woont, samen met de huisgenoten van de onderzoeker. Daarnaast is er voor gekozen om te videobellen met de online deelnemers (u). Hierdoor loopt u geen extra kans op besmetting met het COVID-19 virus.

Daarnaast zullen audio en video beelden worden opgenomen van de huisgenoten en de audio beelden van de online deelnemers (u). Van u wordt dus geen video opgenomen. De reden voor het opnemen van de audio is dat de onderzoeker achteraf de audiofragmenten kan terugluisteren om de testsessie om te analyseren en te gebruiken voor het onderzoek. De audiofragmenten zullen 1 maand worden opgeslagen (vanaf de datum van het onderzoek) en zullen niet gedeeld worden met anderen. Alleen de onderzoeker

zelf zal naar de audiofragmenten luisteren. De antwoorden en opmerkingen die door u genoemd zijn tijdens het onderzoek zullen anoniem verwerkt worden in het verslag. Na het afsluiten van het afstudeerproject of na de afgesproken datum (1 maand na het onderzoek) zullen de audiofragmenten verwijderd worden. Mocht de deelnemer zich oncomfortabel voelen bij de vragen of de procedure, mag de deelnemer op elk moment stoppen met de test. Op aanvraag van de deelnemer kunnen de al reeds gegeven antwoorden verwijderd worden uit het onderzoek.

Vertrouwelijkheid
De deelnemers' privacy zal gerespecteerd worden en de uitkomsten zullen alleen voor de bachelor thesis gebruikt worden. De uitkomsten zullen geen persoonlijke informatie bevatten, dus anonimiteit zal gewaarborgd worden.

Rechten
Deelname is vrijwillig. De deelnemer mag op elk moment stoppen met deelnemen aan het onderzoek. Op aanvraag van de deelnemer kunnen de al reeds gegeven antwoorden verwijderd worden uit het onderzoek. Mocht er nieuwe informatie beschikbaar komen die de deelnemers' deelname zal beïnvloeden, zal die gedeeld worden met de deelnemer.

Contact informatie
Mochten er vragen of opmerkingen over het onderzoek zijn, kunt u onderstaand nummer bellen of mailen naar het email-adres.
Frederique Voskeuil
+ 06 13723998
a.f.voskeuil@student.utwente.nl

Het toestemmingsformulier bevat: (kruis in de vakjes aan waar van toepassing is)

	Ik geef toestemming om mijn antwoorden te gebruiken voor het onderzoek
	Ik geef toestemming om mijn stem en antwoorden op te nemen voor het onderzoek
	Ik geef toestemming om de audiofragmenten van mijn stem te bewaren voor 30 dagen vanaf de datum van het onderzoek.
X	Ik geef toestemming voor de bovenstaande onderdelen. Hiermee geef ik aan dat ik juist geïnformeerd ben over het onderzoek en de procedures. Ik weet dat ik vragen mag stellen en mag stoppen op elk moment. Ik geef toestemming voor mijn deelname aan het onderzoek.

Naam _____

Datum _____

Handtekening _____

Figure 77: Informed consent forms of the evaluation test of the online participants

C.2.5 Observation sheet online participants

Observation sheet filled in by the online participants during the evaluation test (chapter 7).

Vragen voor Rombout

Interacties

Vormen de schaduwen een probleem voor de speler en het spel?

Nee	Een beetje	Ja

Welke interactie is **niet** duidelijk voor de speler?

X	**Interactie**	**Waarom**
	Alles is duidelijk	
	Het juiste dekseltje bij het juiste bakje zoeken	
	De vierkante dekseltjes op de vierkante bakjes doen	
	De ronde dekseltjes op de ronde bakjes doen	
	De ronde dekseltjes ronddraaien om het bakje dicht te doen	
	De 'rits' naar boven schuiven	
	Als alle soorten bakjes op tafel staan, de juiste deksel bij het juiste bakje zoeken	
	Iets anders	

Audio

Er is een geluid wanneer er een bakje dichtgaat. Wat voor gevoel geeft dit geluid?

	Positief gevoel
	Negatief gevoel

Heeft het geluid een goed volume?

Te zacht	Iets te zacht	Precies goed	Iets te hard	Te hard

Visuele effecten

Zouden de bakjes korter/langer moeten blijven staan nadat de speler een 'ronde' heeft afgerond?

Veel korter	Iets korter	Het is al precies goed	Iets langer	Veel langer

Zou er meer of minder tijd moeten zijn waarin er niks gebeurd tussen de ‘rondes’ door?

Minder tijd	Iets minder tijd	Het is al precies goed	Iets meer tijd	Veel meer tijd

Zijn er genoeg bakjes op tafel?

Te weinig	Precies goed	Te veel	Soms..

Is het duidelijk wat de speler moet doen (de dekseltjes bij de bakjes zoeken)?

Te onduidelijk	Een beetje onduidelijk	Duidelijk

Bevat het spel te weinig of te veel prikkels voor de doelgroep?

Te weinig	Precies goed	Te veel

Is het spel geschikt voor de doelgroep?

Te makkelijk	Een beetje te makkelijk	Precies goed	Een beetje te moeilijk	Te moeilijk

Is het spel te kinderachtig voor de doelgroep?

Nee	Een beetje	Ja

Is er genoeg reactietijd tijdens het spel?

Veel te weinig	Iets te weinig	Genoeg	Iets te veel	Veel te veel

Zou het spel **te** frustrerend kunnen zijn voor de spelers?

Nee	Een beetje	Ja

Vragen voor Esther

Is het duidelijk wat de speler moet doen (de dekseltjes bij de bakjes zoeken)?

Te onduidelijk	Een beetje onduidelijk	Duidelijk

Bevat het spel te weinig of te veel prikkels voor de doelgroep?

Te weinig	Precies goed	Te veel

Is het spel geschikt voor de doelgroep?

Te makkelijk	Een beetje te makkelijk	Precies goed	Een beetje te moeilijk	Te moeilijk

Is het spel te kinderachtig voor de doelgroep?

Nee	Een beetje	Ja

Is er genoeg reactietijd tijdens het spel?

Veel te weinig	Iets te weinig	Genoeg	Iets te veel	Veel te veel

Zou het spel te frustrerend kunnen zijn voor de spelers?

Nee	Een beetje	Ja

Figure 78: Observation sheet used for the evaluation test and filled in by the online participants

C.2.6 Questions online participants

Questions asked to the online participants after the evaluation test (chapter 7).

Interview questions

Algemeen
Waren er onduidelijkheden op sommige momenten in het spel?
- Op welk moment?

Muisjes
De muisjes zijn geen onderdeel meer, wat voor effect heeft dit op het spel denken jullie?

Interacties
Zijn alle interacties duidelijk voor de speler?

Schaduw
Ik heb er niet voor gekozen om de Leap Motion Controller op te hangen, omdat de LMC maar 60 cm omhoog kan meten en dan in de weg zit. Daarnaast zou iets voor je handen kunnen zitten (je hoofd). Is de schaduw nog een probleem?

Containers
Was het duidelijk welk dekseltje bij welk bakje hoorde?

Wat zitten er in de bakjes?
- Zou dit duidelijker zichtbaar moeten zijn?
- Leidt dit juist af?

Leidt het voedsel in de bakjes af van het spel?

Wat zouden jullie veranderen aan de volgorde van de bakjes?

Hoe veel bakjes op tafel zouden goed zijn?
- Maakt de vorm hierbij nog uit?

Is het nodig om de bakjes meer op 'normale' bakjes te laten lijken?
- Bv. doorzichtig/grijs/blauw.

Vervagen de bakjes op de juiste manier aan het eind van een ronde?

Staan ze nadat de deksels dicht zitten te lang of te kort op tafel?

Zou het helpen voor de spelers dat elk dekseltje op elk potje past?

Visuele effecten

Zijn de kleuren van de bakjes goed zichtbaar en duidelijk?

Zijn de verschillende patronen te verwarrend of te onrustig?

Is er genoeg visuele feedback aanwezig die de speler vertellen over zijn acties?

- Wat voor extra visuele effecten zouden de spelers kunnen informeren over hun acties?

Audio

Wat voor extra audiofragmenten zouden er nog meer kunnen zijn, die de speler informeren over zijn acties?

Rondes

Is het duidelijk voor de speler dat er een ronde is afgelopen en dat er meer komt?

- Zo nee, waarom is dit onduidelijk?
- Hoe zou dit duidelijker gemaakt kunnen worden?

Wat zou het duidelijker maken voor de speler dat er een ronde is afgelopen en dat er meer komt?

- Is het nuttig om 'levels' toe te voegen?

Is er genoeg visuele feedback wanneer een 'ronde' is afgelopen?

Doorzichtige deksel en arrow

Zou de doorzichtige deksel op deze manier de speler kunnen helpen om te hinten wat de speler moet doen?

- Wat is er onduidelijk aan de doorzichtige deksel?
- Zou de doorzichtige deksel eerder moeten verdwijnen?
- Zou de doorzichtige deksel eerder moeten verschijnen?

Is meer introductie in de game nodig? Meer speluitleg?

Wat zijn andere (misschien betere) ideeën om de speler te kunnen helpen met de interacties?

Helpen de pijlen de speler om te laten zien wat de speler moet doen?

- Waarom zouden de pijlen wel/niet kunnen helpen?
- Hoe zouden de pijlen wel kunnen helpen?

Wat zijn andere ideeën om de speler te kunnen helpen?

Stop knop
Waarom hebben jullie gekozen voor een afstandsbediening?

Wordt de knop vaak gebruikt?

Door wie wordt de knop gebruikt?

Wat zou de beste optie zijn voor een stopknop?

Tot slot
Wat zou er aan het product veranderd moeten worden zodat het bij het bedrijf past?

Target group
Bevat het spel genoeg prikkels voor de doelgroep?
- Als te weinig: hoe zouden er meer prikkels kunnen zijn?
- Als te veel: hoe zouden er minder prikkels kunnen zijn?

Hoe zou het spel frustrerend kunnen zijn voor de spelers?
- Waarom?
- Wat zou dat kunnen veranderen?

Is het spel begrijpbaar voor de spelers?
- Waarom?
- Wat zou dat kunnen veranderen?

Is het spel te kinderachtig?
- Waarom?

Geven de spellen genoeg reactietijd?

Algemeen
In welke mate denken jullie dat de spelers de connectie kunnen leggen met ADL?
- Waarom wel/niet?
- Denken jullie dat het helpt om de connectie te zien, zodat ze zien waarvoor ze oefenen?
- Wat zou er kunnen veranderen voor wel?

Denken jullie dat het spel gespeeld kan worden zonder begeleiding?
- Is het nodig dat het spel zonder begeleiding gespeeld kan worden?

In welke mate zou het spel nuttig kunnen zijn tijdens fysiotherapie sessies?
- Waarom wel/niet?

Als jullie 1 ding moeten veranderen aan dit product, wat zou het zijn?

Figure 79: Questions asked to the online participants during the evaluation test