ASYMDROIDS

Controllers for asymmetric VR gaming

M2.1 + FMP Proposal Report

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M2.1 Project - AsymDroid

1. Introduction

Virtual Reality (VR) is becoming increasingly widespread as developers discover new use cases for the technology, such as for social, design, and educational purposes, among others. However, many people will associate VR with video gaming, as this is one of the most common applications of the medium. VR gaming can be an incredibly fun and interactive experience during which the player can get highly immersed in the virtual world [37]. While the prices of industry-leading VR head-mounted displays (HMDs), such as the Meta Quest 2 [21], are coming down, getting into VR gaming can still be expensive. The stereoscopic vision that these HMDs create requires gaming scenes to be rendered for two separate displays. Therefore, more powerful computing hardware is needed to run such games. Limitations like these are holding VR back from being experienced by a wider audience.

Companies offering VR experiences make it possible for people to give VR a try without them needing to invest in the technology themselves. 'Enversed' [1] is one of these companies, and they are the client of the project described in this report. They offer VR games and other experiences for occasions such as company outings, birthday parties, or private events. Furthermore, they have a VR development team at their disposal in the form of 'Enversed Studios' [9], which gives them the ability to create custom VR games.

Most of the games that can be played at their Virtual Reality Center can only be played by two people simultaneously. However, most groups that visit them consist out of more than that. Therefore, Enversed desired a solution to keep these people engaged and involve them in the VR experience. The development of the AsymDroid gaming controllers described in this report are an answer to this desire.

These controllers were specifically designed for asymmetric VR (AVR) gaming at the Enversed VR Center. This game style can help make VR a less isolating and more social experience, by letting players connect with the people physically around them [26]. The AsymDroid controllers are to be used by non-VR players to help create an intuitive and engaging AVR experience located in a shared magic circle together with every player around them.

2. Theoretical Background

2.1 Asymmetric games

Asymmetric games can be described as “a genre of games where there are two or more groups of players with different objectives and gameplay mechanics” [4]. Harris et al. [12] list mechanical manipulations that designers can employ to add asymmetry to a game: asymmetry of Ability, Challenge, Interface, Information, Investment, Goal/Responsibility, and Dependence. Asymmetry can make less skilled players feel useful by making more skilled players having to rely on them [46], or by letting the choose the abilities that suit them best [11]. Furthermore, asymmetry in information can force people to communicate, enhancing social interaction [12, 38, 46]. Additionally, if players choose to switch roles, their experience of the game can be vastly different, leading to an increase in replayability [12]. Stepping into unique game roles can also aid in increasing immersion [38].

Asymmetry can also be applied to VR games. In asymmetric VR (AVR) games one or more VR players play together with one or more non-VR players using a different interface type to interact with the game world [8]. Therefore, an asymmetry of interface exists. The distinct interfaces offer players different affordances to interact with and perceive the game world, which can easily open up opportunities for the implementation of asymmetry of information or ability. Motion sickness is a symptom often induced by VR [15, 32]. Therefore, the switching of roles can also offer players that are prone to get sick a moment to recover, without the need for them to stop play completely. Shorter sessions with the HMD on can make it more appealing for such players to give VR a try, making it more inclusive.

2.2 Controller design

Controllers are a physical part of the interface with which people can interact with and experience games. Not only do they let players provide inputs, they can also respond by giving feedback. Feedback in games can come in several different forms and has been shown to increase immersion levels [35], while also providing information to players about what is happening in the game world. Haptics are one form of feedback that can often be found in controllers and refers to “sensing and manipulation through touch” [39]. Vibration motors produce haptic feedback in most popular controllers. Audio is also an extremely frequently used form of feedback that emotionally engages and immerses players [3].

A good player experience is highly dependent on the quality of the video game control scheme [23]. Natural mappings using body movements such as embodied interactions have been proven to have a positive impact on engagement, social interaction, spatial presence, and game enjoyment [18, 36]. Some of the most common controllers such as those of the Playstation,& Xbox offer their users a wide range of inputs. For example, Sony’s DualSense has 17 buttons for digital inputs, 2 analog triggers, 2 analog joysticks, and a capacitive touchpad [28]. This wide arrangement of possible inputs can be ideal for complex games that offer the player the ability to perform a lot of actions. However, the complexity of control of a controller is a function of the type and number of available inputs [23]. For people with less experience with such controllers, who have not developed a mental model for interacting with such devices, learning how to master the use of these buttons can take many hours [19]. Furthermore, research suggests that the use of less advanced controllers can actually increase enjoyment [17, 23]. Therefore, it would be advisable to use as few controls as possible, especially for core gameplay.

The gaming company Activision has developed Control Dimensionality (CD) to measure the degree of complexity inherent in a control mechanism [5]. While controllers do not have an inherent CD, they do have a maximum potential CD [7]. The CD is determined in two steps [7, 23]:

Determine the primary movement scheme:

- One dimension of movement (left-right) CD = 1
- Two dimensions of movement (left-right, up-down) CD = 2
- Three dimensions of movement (left-right, up-down, in-out) CD = 3

Add additional CDs for secondary dimensions of control:

- For each additional movement dimension: strafe back-forth, accelerate-brake, rewind or fast-forward time, etc. (typically use two buttons) CD +1
- For each embedded action: jump, attack, rotate, etc (typically use one button) CD +0.5

Using this method, the maximum CD of a controller such as Sony's DualShock 4 can be determined to be 12.5. A high CD produces extended affordance, but also increased complexity of use.

2.3 Pervasive games

Pervasive games "extend the gaming experience out into the real world" [6]. Games where digital elements are projected onto the physical world, like with AR, are an example of this. However, in other instances, such as with augmented tabletop games, players interact with physical objects, making the digital world react to these actions [6, 20]. This genre helps to extend the magic circle of a game into the real world, by not just limiting play to the digital space [22]. The magic circle is "where the game takes place. To play a game means entering into a magic circle, or perhaps creating one as a game begins." [40]. When people play VR games, their magic circle is often confined to the digital space they experience through their HMD. While this confinement can be extremely immersive, it is also isolating. AVR can help bridge the gap to the physical realm by including elements from the real world in the form of other players. Taking inspiration from pervasive games can then also help take elements from the digital space, through which the VR player traverses, and present them to non-VR players in the form of physical artifacts. Combining both these approaches can aid in including all local players into a shared magic circle, promoting social interaction [20].

Taking physical and digital elements and translating them to each other's world can also be an approach to telling a story around a game. Storytelling is one of the oldest tools to amuse and engage an audience [25]. AVR as a genre lends itself especially well to transmedia storytelling, a process in which "integral elements of a fiction get dispersed systematically across multiple delivery channels for the purpose of creating a unified and coordinated entertainment experience. Ideally, each medium makes its own unique contribution to the unfolding of the story." [13]. Asymmetry lets players experience a game and its story from various perspectives and in different ways. As the non-VR player, seeing the VR player get excited might make you curious about what it is like to step into their shoes. Aside from being an input tool, a gaming controller can also be used to tell the story. The device can become a reflection of the in-game events, perhaps providing additional information. Its aesthetics can already aid in sparking curiosity, before players have even seen the game. The use of a "special" controller across a series of games can also help to tie their stories together to some degree. If people enjoyed one game, they might be additionally motivated to try the others.

3. Design Process

3.1 Discover

Meeting the client

Before the start of this project, I was already in contact with the company Enversed. I reached out to them, since they find themselves in quite a unique situation. Not only can you visit them directly to explore mixed reality experiences, they also have their own development team, giving them the ability to create these experiences themselves. During my first meeting with their CCO, Tim van der Grinten, who would be my contact person for the rest of the project, some possible design cases were proposed. One of them immediately stood out to me. They were faced with the problem that for most of their VR games, only two people can play together simultaneously. However, groups of visitors are often substantially larger than that. Therefore, they were interested in finding a solution to engage more people in one experience. We discussed this topic and we quite quickly came to the conclusion that AVR could be an interesting direction to go into. Furthermore, we both thought it would be interesting to see if a controller could be developed for this specific type of experience. A custom controller for non-VR players opens up an opportunity to create one larger enhanced and shared experience, that can be immersive, inclusive and foremost fun for all players involved. I would meet biweekly with Tim, to give progress updated and receive feedback from him as a client, but also as an expert.

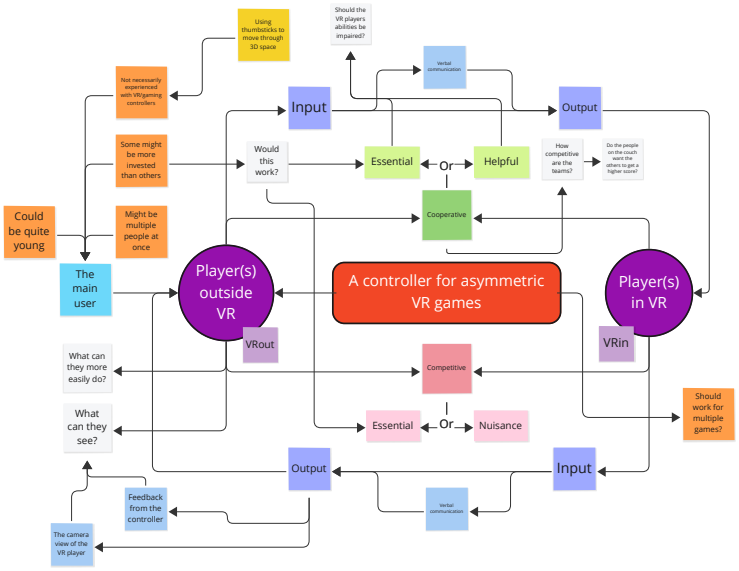

Figure 1 *Initial context map*

Understanding the context

First, I mapped out my thoughts about and understanding of the context (Figure 1). I wanted to know more about the context and the different stakeholders and potential users. Therefore, I met with Tim again to discuss the topic in more detail. Additionally, I met with Kaz Voeten, one of the external coaches of the Games & Play squad. At the time, he was also still employed as a VR developer at Enversed, so he also had a good understanding of the use context and possible opportunities. He could provide information from a slightly different perspective than Tim. After these meetings I also visited the Enversed VR center, so I not only heard about the context, but also experienced it.

These conversations and this visit gave me a greater understanding of the environment in which my design would be used. Preferably the controllers could be applied to a variety of games. However, part of the interface could definitely be designed with quite specific game interactions in mind, since this could also make the interaction with the controller feel unique and more engaging. Furthermore, to make the gaming experience unique for each individual player, it was also an option to design a set of controllers or to make some components modular. The intuitiveness and relative simplicity of the interface was very important. The visi-

tors of the VR Center, which is the main user group, do not necessarily have much gaming experience. Their ages could range from 6 to 65 years old and all could have different levels of skill and controller experience. Therefore, I wanted my design to be usable and enjoyable, and thus inclusive to as many people as possible. The exact location of the VR experiences are in 7 “VR-rooms” (Figure 2). These rooms include an open space through which the VR players can walk freely and a couch for the non-VR players to sit on. Additionally, there are two TVs which are normally used as a spectator screen. These can be part of the interface of a non-VR player in an AVR game. Enversed discouraged letting non-VR enter the open space, since it would be difficult to accurately track them, which could lead to players running into each other. Furthermore, the controllers had to be so called “jerk-proof”. Some customers, especially younger ones, could be quite reckless with Enversed’s hardware, leading to damage and wear & tear. Therefore, my design should not be too fragile or at least be easily repairable by their staff. Enversed’s personnel is also a user group. I took them into account too when designing the controller. For them it would be valuable if they can intuitively connect the controller to the PCs, receive feedback about things such as the battery level, and also easily recharge them.

Figure 2 *The VR-Rooms in which visitors play games in the Enversed VR Experience center*

Literature research

My coach advised me to also look into Pervasive Games and Transmedia Storytelling. These approaches could help me increase the immersion, engagement and social interaction levels of the experience I was creating [20, 25], assisting in the creation of one large shared magic circle [22]. Additionally, I analyzed asymmetric video games (Appendix A) and theory around them to better understand player dynamics. Lastly, I investigated literature about controller design. Some of the key findings of this literature research can be found in the section “Theoretical Background”.

3.2 Define

Establishing requirements

Based on the established design context I now defined the requirements for my design:

- The controller has to be a tool to engage the non-VR players and bring them into the same magic circle as the VR players, encouraging social interaction. Taking inspiration from pervasive games and transmedia storytelling can aid in reaching this goal. Playing around with the design aesthetics can make the controller feel part of the story of the game, as if it stepped out of and is a link to the digital world.
- The interface has to be intuitive and simple, so it is accessible to users with different gaming experience levels. It also has to be somewhat compact, so people with different hand sizes can hold and interact with it.
- The Enversed staff should have a pleasant experience interacting with the design. The controllers need to work wirelessly, since the non-VR players are sitting far away from the computer. Therefore, staff should be informed about when to charge the devices. Additionally, repairability needs to be considered, since customers can break parts.

As a next step, the desired affordances of the controller had to be established, so components can be selected based on this. I created three affordance categories: Selection (& Locomotion), Action (& Confirmation), and Feedback (& Feedforward). These categories are not static and some components can serve purposes within multiple categories.

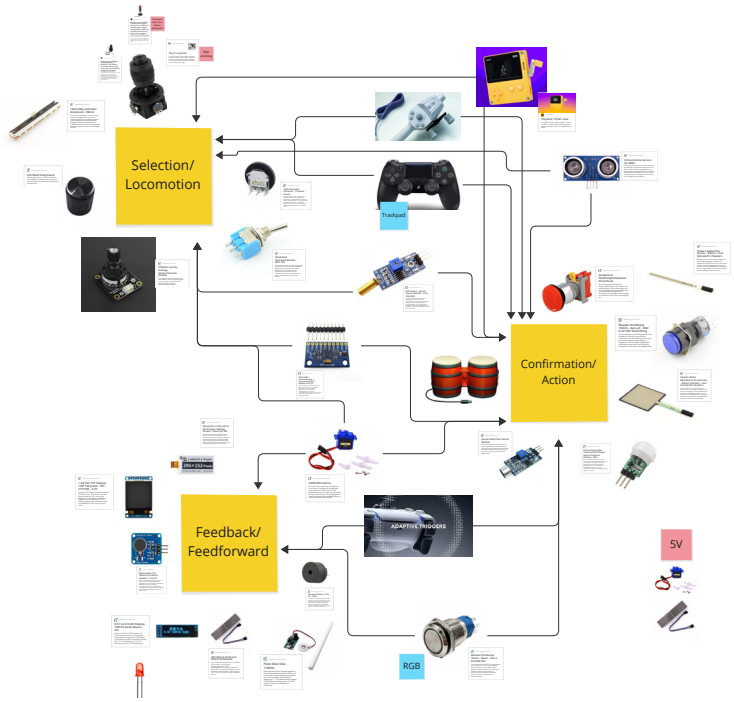

Figure 3 *Overview of possible controller components categorized by affordance type*

Technological exploration

An overview of some of the technologies I considered adding to the controller can be seen in Figure 3 (& Appendix D). I considered a wide variety of technological parts, taking inspiration from both existing controllers and separate input and output components. Consequently, an ideation session was done highlighting possible applications of such parts when integrated in a possible controller for AVR gaming (Figure 4).

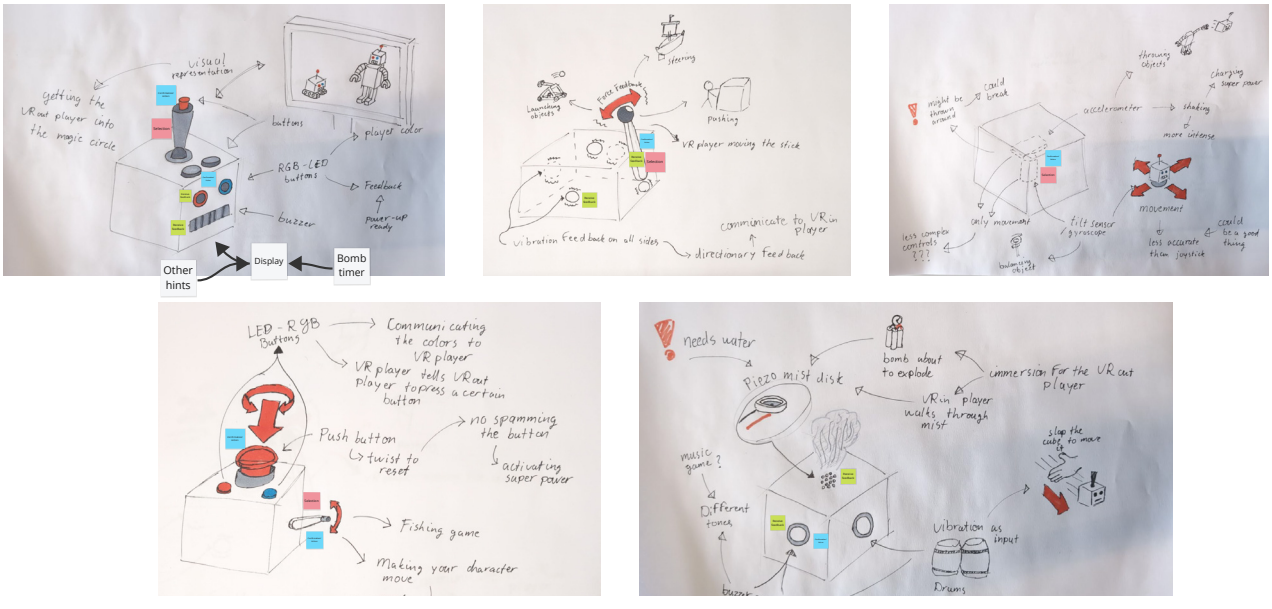

Figure 4 *First ideas for integration components in controller*

One idea was to aesthetically make the controller represent a robot. The reasoning behind this decision was that this way the controller could be a representation of the character it controls. A robot was specifically chosen due to the neutral alliance of such a character type. Robots can be friendly, like “Clank” from the “Ratchet & Clank” game series [31]. However, they can also be hostile, such as the many robot enemies from the “Sonic the Hedgehog” franchise [48]. Therefore, robot characters can be implemented in games where the relation between VR and non-VR players is competitive, but also when it is cooperative.

Adding cranks or force feedback levers was considered. A crank could be interesting for selection or action affordances. The value of the input, and therefore the speed at which something can be selected, moved, or performed is dependent on how fast the user turns the crank. Therefore, the use of such a component asks players to put in physical effort to achieve a better results, requiring them to be engaged. Furthermore, the turning of the crank can also be used as an embodied interaction and natural mapping. Adding components such as a big red emergency button could perhaps be used to give players a sense of power, importance, or urgency. Letting smoke come out of the controller using Piezo mist disks could excite, engage, and immerse people. Providing different players with different feedback through small displays, LEDs, and speakers could encourage or even require social interaction through communication. Figure 5 shows sketches illustrating how such components could be applied to expand one of Enversed’s games, where VR players have to run a restaurant kitchen by cooking burgers.

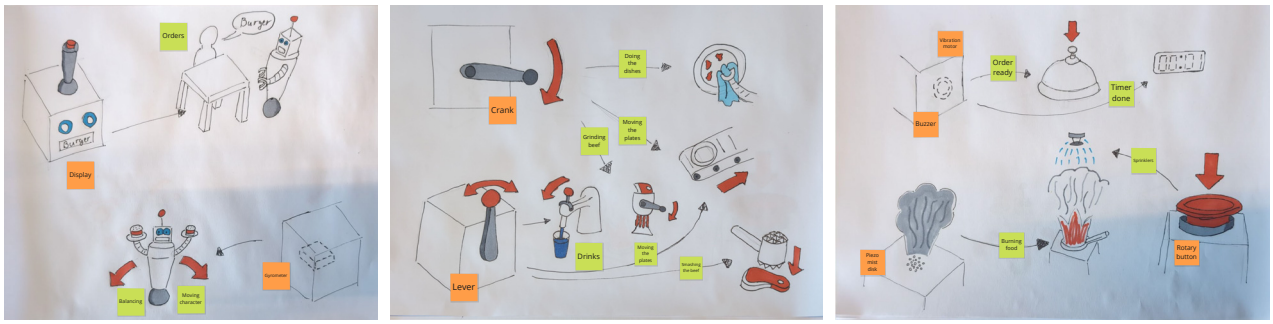

Figure 5 *Ideas for how controller components can be used in cooking game*

3.3 Develop

The controller

In this phase of the project, the AsymDroid controller began to take shape. Like already suggested, the aesthetics of the controller were going to mimic a robot, to open up an opportunity to create a connection to the digital world. The device would also take inspiration from retro arcade controllers, for their simplicity in interface. Furthermore, this layout might also more easily fit into the gaming controller mental models of older users, making interaction easier for them [43]. Repairability was taken into account when choosing all of the components. Every part should either be easy to order, or be produceable by Enversed themselves using their 3D printers or laser cutters. Furthermore, the controller had to be able to be used wirelessly. After investigating and testing several solutions to achieve this goal, I settled on using an ESP32-Wrover-B microcontroller as the core of the controller [16]. This specific model has a large amount of GPIO pins to handle enough inputs and outputs. Furthermore, it has built-in Bluetooth 4.2. This version of Bluetooth can use the Bluetooth Classic protocol and is therefore able to easily connect to a PC and communicate with the gaming engine “Unreal Engine”. Furthermore, the board possesses over a charging chip and Li-ion battery holder, making it easy for Enversed staff to charge the controller using a USB cable. I designed a 3D printed battery casing (Figure 6) to mount on the board for extra protection in case of damage. The maximum control dimensionality of the base AsymDroid controller is 3.5, compared to the 12.5 of a DualShock 4. This rating is significantly lower, making the interface less complicated.

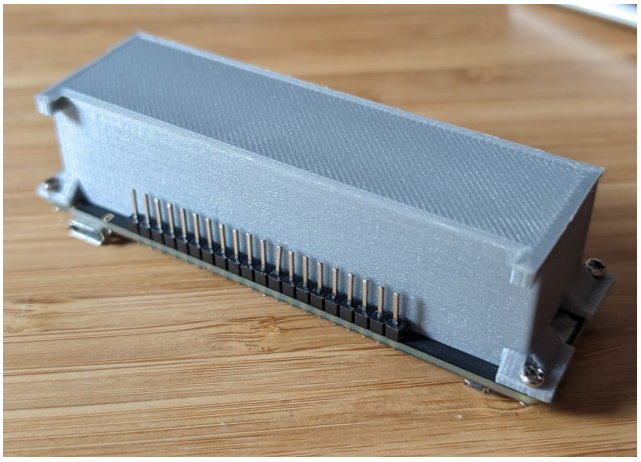

Figure 6 *The ESP32 microcontroller with the battery casing mounted on*

Joystick

At first, the use of several “complete” joysticks were considered. However, non were found that had small enough dimensions, were easily deliverable, provided analog inputs, and had a button mounted on it. The requirement for the button was set, since I did not want the user to have to ever move their hand away from the joystick, to make interaction easier. Not having any buttons available for one hand would limit the action/confirmation affordances perhaps too much. Analog inputs were also desired over digital, since they offer more affordance, while not increasing control dimensionality. Finally, the decision was made to go for an analog joystick module on which a custom 3D printed joystick body could be mounted to fulfill all requirements. After testing a first version of this body, I realized that the print was too heavy for the spring that makes the joystick return to its central position. After considerable effort trying out solutions such as the use of rubber bands, a new smaller joystick body, and looking at different modules, the decision was made to partly desolder the module and insert a stronger spring. This option is not ideal from a repairability perspective, but it was sufficient for making the controller user testable.

Figure 7 *First iteration of the prototype (left) together with the second version (right)*

Feedback

The custom joystick also made it possible to incorporate haptics in it. This location is ideal, since the user is intended to always hold it. Therefore, a vibration motor was inserted. Additionally, the joystick button has a built-in RGB LED. Its location on top of the joystick makes it possible for this LED to replicate a light on top of an antenna on the head of the digital version of the robot. It can also provide feedforward to the player about when to press the button. The use of an active buzzer in the controller offers the possibility to provide players with individual audio feedback. Furthermore, it can help make the robot controller feel more alive, by replicating sounds that its digital counterpart would make based on in-game events. Lastly, an RGB LED protrudes from the back of the device, displaying different colors based on the battery level, providing feedback to employees about when it needs to be charged.

Buttons

Two buttons are mounted on the front of the controller representing the eyes of the robot. Several different ones were tested, but these were selected for their dimensions and satisfactory haptic feedback when clicked. These had to be somewhat larger than the joystick button, since the user does need to move their thumb from one button to the other, without having to look. Furthermore, these buttons came in different colors, so they can indicate the players color.

Accelerometer & gyroscope

An accelerometer & gyroscope module was included internally in the controller, since it opens up opportunities for embodied and naturally mapped interactions. Furthermore, it is a hidden affordance, not visible to the player, so it does not make the interface more complicated when not being used.

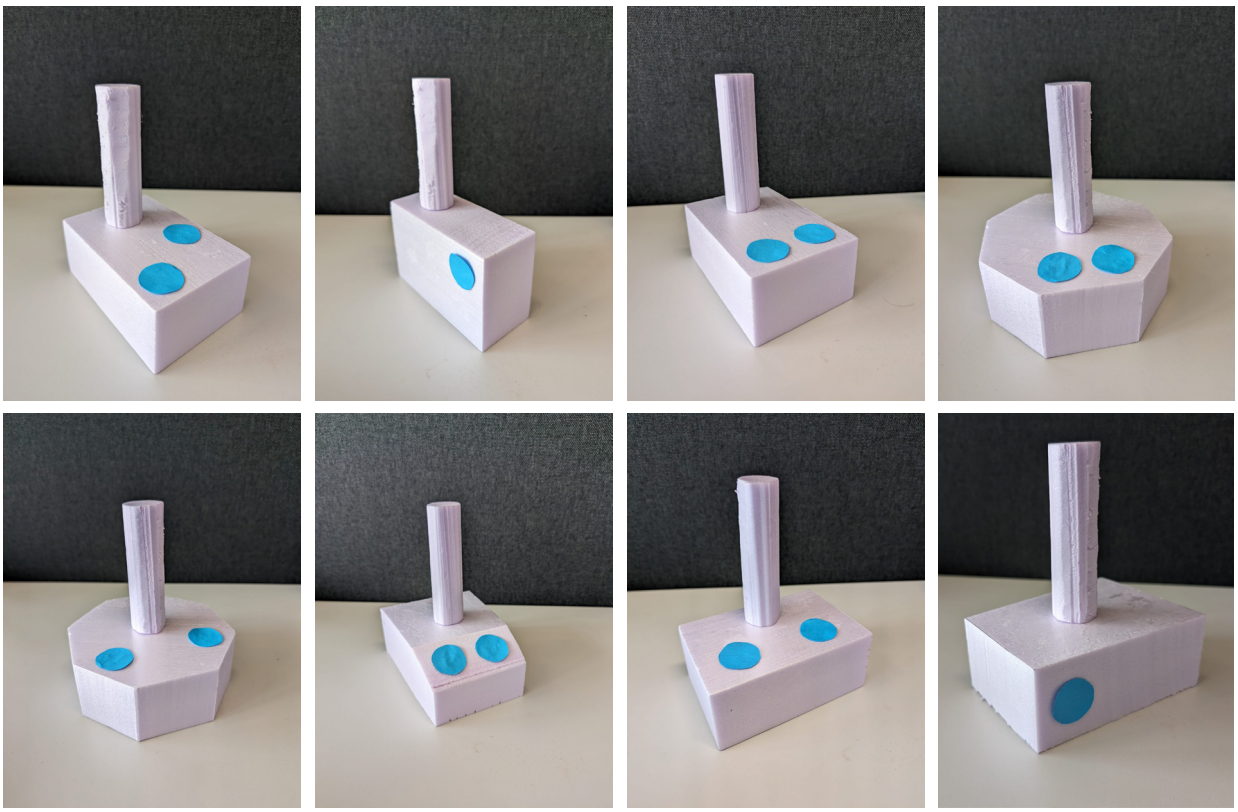

Figure 8 *Foam exploration for ergonomics controller*

Ergonomics

Styrodur foam was used to make several models for determining the shape of the controller based on ergonomic qualities (Figure 8). The minimal required dimensions were determined based on the size of all the components. Several locations for the buttons and joystick were tested by sticking a foam cylinder (joystick) and paper cutouts (buttons) on the models with needles. Several people held these models, which led to the evolution of the final shape. As little travel of the hands and fingers as possible was highly valued and the small hands of younger potential users were also taken into consideration.

The game

The AVR game would take inspiration from the old arcade game “Pac-Man”. One VR player will have to find their way through a maze in an attempt to collect 7 purple stars. Two non-VR players will play as robots and have to work together to protect these stars by hunting down the VR player. Catching the VR player gives the robots a star back. The robots start off with all the stars on their team and the team with the majority of the stars 3 minutes after the collection of the first one wins. Asymmetry of ability, challenge, interface, information and goal/responsibility makes this game a true AVR game [12, 33]. This game was developed as a showcase for the abilities AysmDroid controller and as a tool to test it. I produced it in Unreal Engine over at the office of Enversed Studios, which gave me the opportunity to ask some questions to VR developers and have them assist in playtesting.

VR player

The main ability of the VR player was that they could quite quickly locomote through the maze using teleportation. They pick up stars and invisibility power-ups by touching them. Furthermore, embodied interactions were applied, such as letting them try to peek over the walls to spot the top of antennas on the robots head, by standing on their toes. The wall height can be adjusted based on the VR player’s height, to make it more balanced. Additionally, a gun is hidden somewhere in the maze which gives the VR player the ability to become the hunter for a limited time (Figure 9). It was a conscious decision to let them pick it up from the ground, since this makes them vulnerable while doing so. However, it is worth the effort, since it also gives them shields for some time, making them invincible.

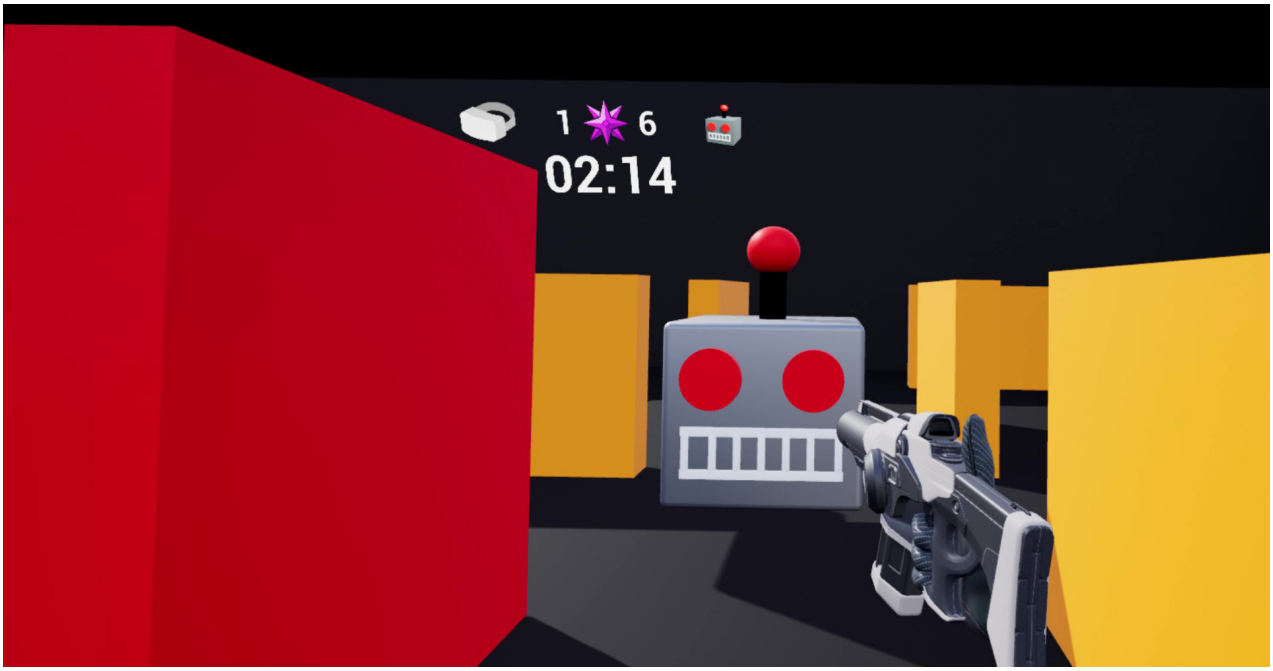

Figure 9 *The game from the perspective of the VR player, who is aiming the the gun power-up at one of the robot characters (non-VR player)*

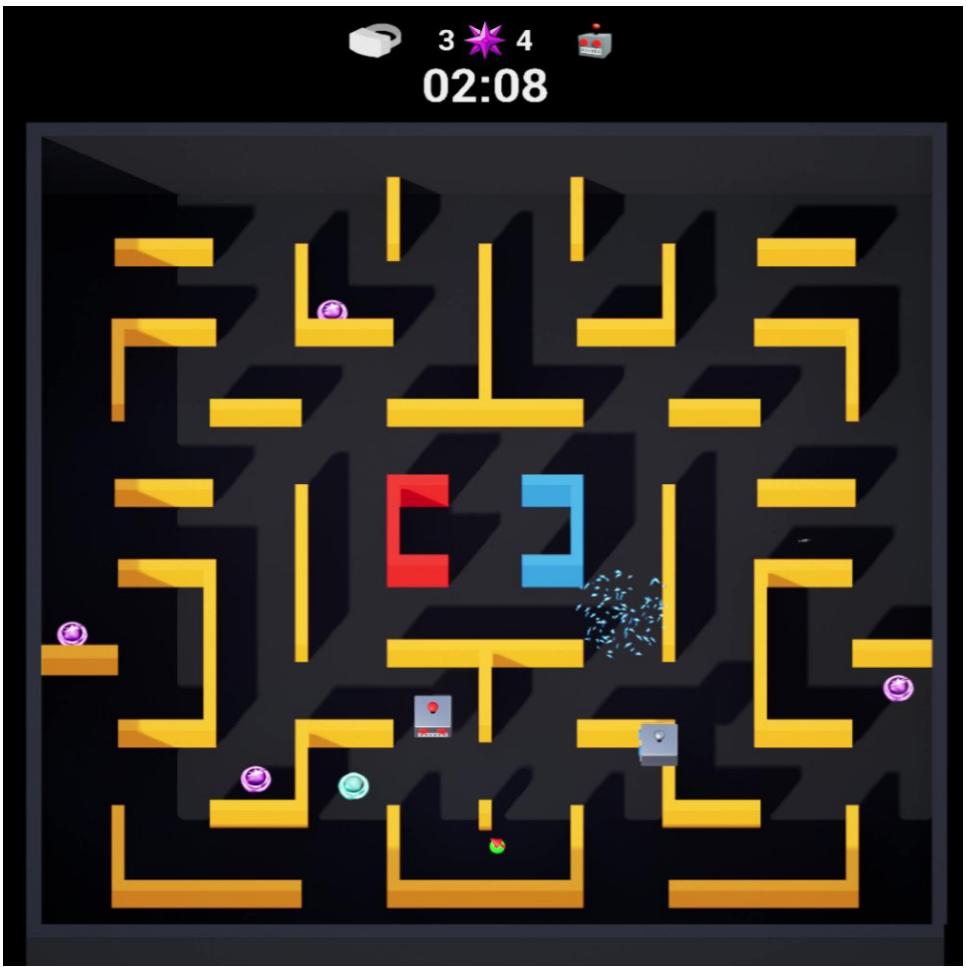

Figure 10 *The top-down isometric perspective of the non-VR players showing several game elements: Stars (purple circles), Invisibility power-up (blue circle), Lighting power-up trap placed down by the blue non-VR player (blue spots), Playable robot characters (grey cubes), VR player (small green circle with red arrow on head), and Scoreboard & Timer (top of image)*

Non-VR player

These players use a monitor and the AsymDroid controllers to interface with the game. They have a mirrored dependence on each other [12], making them have to cooperate and communicate to win. The robots move slower than the VR player, but they do have a top-down isometric view of the entire maze (Figure 10). The accelerometer was utilized for natural mapping through embodied interactions by letting the players shake the controller up to make the robots jump over walls. Haptic feedback was provided on landing, simulating impact. The buzzer informs them when the jump is available again by making a linear upward tone. The buzzer also makes the robots produce a happy sound when catching the player, and a sad one when being shot. In both these cases haptic feedback is provided to replicate explosions. The LED of the joystick button lights up in the players color, together with its digital counterpart in the form of the antenna, to indicate that the button can be pressed to activate a power-up. Using it will provide haptic feedback and makes the robots drop lightning bolts. These can block the path of the VR player. Lastly, one of the front facing buttons can be pressed to make the robot crouch down to hide the antenna, halving their speed. However, it also makes the robots completely silent, while normally they produce spatial audio, indicating their location to the VR player.

3.4 Deliver

Adjusting the controller

A second controller prototype was produced for the other robot player. During my experience assembling the different parts from the first iteration, I noticed that it could be somewhat difficult to assemble. The fact that some components like the buzzer and the microcontroller were mounted to the top 3D printed cover, while others like the joystick and the accelerometer to the base plate, made it so that wires were unnecessarily long. These wires got damaged more easily during assembly and by the joystick pushing against during use. Therefore, the microcontroller and buzzer were also mounted on the base plate in this improved version, making the assembly and repair process exponentially easier. I do want to comment that I should have also mounted the front facing buttons to this base, since this would make the cover just a cover. This adjustment would have opened up the possibility for easily swapping out these covers for different games, enabling different designs to be used for various games.

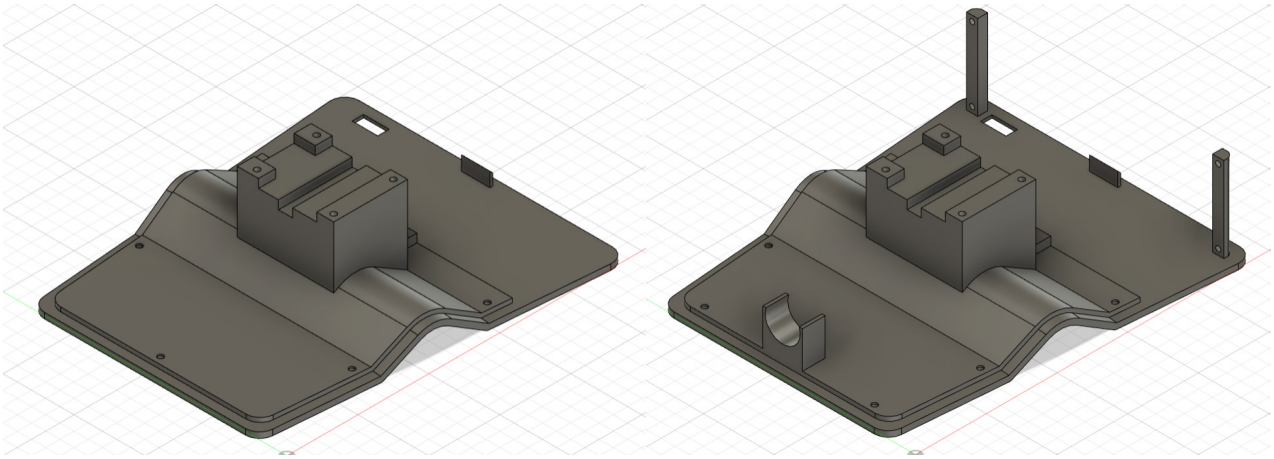

Figure 11 *Old (left) & new (right) models used to 3D print the two versions of the base plate*

User test

The main goal of this user test was to evaluate the AsymDroid controller and its usability. Furthermore, it was investigated if the functionalities of the controller together with its custom-made game could lead to a satisfactory player experience.

Method

In total, 6 people participated in two sessions of 3. After signing the consent form, participants were introduced to the controller and game. During the session, 3 rounds of the AsymDroid game were played so each participant got to play as the VR player once. After having played the game using the Meta Quest 3 HMD, the player experience was measured using the Player Experience Inventory (PXI) [30]. Participants also had to fill in the PXI once more after having played the game using the controller. After all 3 rounds were finished, participants had to fill in a form containing the ISO 9241-9 Device Assessment Questionnaire as used in other research evaluating gaming controllers [24, 45]. Additionally, they had to fill in the System Usability Scale (SUS). Lastly, the sketches from Figure 5 were presented to gain feedback on the idea of asymmetric controllers, and a semi-structured group interview (Appendix B) was done. The interview data was recorded and transcribed, and a thematic analysis was performed (Appendix C). The PXI was analyzed by performing one tailed one sample t-tests comparing the results with the means of benchmark data [29] in the category “Party games”. To see if the results were significantly lower of higher compared to benchmark data, the test were either left tailed for a negative t-value, or right tailed for a positive. The SUS gives out a score that was compared to other SUS scores.

	μ	M	SD	df	t	p
Meaning	-0.34	1.22	1.33	5	2.87	0.0174
Mastery	1.33	0.61	2.23	5	-0.79	0.2315
Immersion	0.58	2.39	0.53	5	8.29	0.0002
Autonomy	0.75	1.22	1.33	5	0.87	0.2118
Curiosity	-0.67	1.5	1.09	5	4.86	0.0023
Ease of Control	2.67	1.22	1.83	5	-1.93	0.0560
Challenge	0.33	1.17	1.49	5	1.37	0.1139
Progress Feedback	2.17	0.94	1.53	5	-1.96	0.0537
Audiovisual Appeal	0.83	1.94	0.44	5	6.15	0.0008
Goals & Rules	2.42	2.11	0.93	5	-0.80	0.2293

Table 1 *One sample t-test results PXI for VR players*

	μ	M	SD	df	t	p
Meaning	-0.34	0.72	1.61	5	1.61	0.0845
Mastery	1.33	0.5	1.83	5	-1.11	0.1585
Immersion	0.58	0.94	1.29	5	0.69	0.2612
Autonomy	0.75	1.06	1.27	5	0.59	0.2909
Curiosity	-0.67	1.39	1.65	5	3.05	0.0143
Ease of Control	2.67	2.17	0.75	5	-1.62	0.0829
Challenge	0.33	1.11	1.71	5	1.12	0.1575
Progress Feedback	2.17	1.89	0.75	5	-0.90	0.2043
Audiovisual Appeal	0.83	2.22	0.50	5	6.78	0.0005
Goals & Rules	2.42	2.5	0.59	5	0.34	0.3723

Table 2 *One sample t-test results PXI for non-VR players*

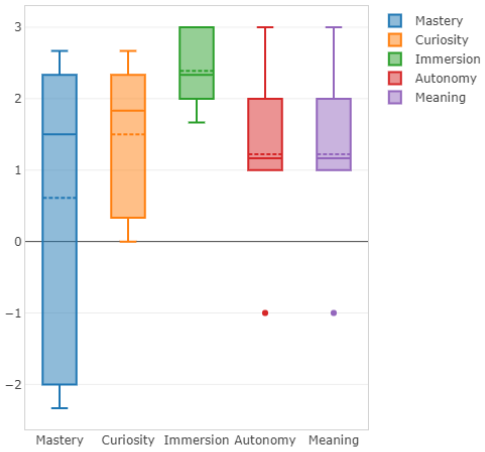

Figure 12.1 *Psychosocial consequences PXI VR player*

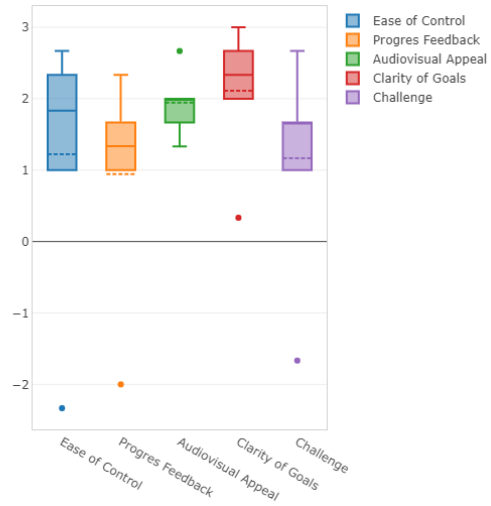

Figure 12.2 *Functional consequences PXI VR player*

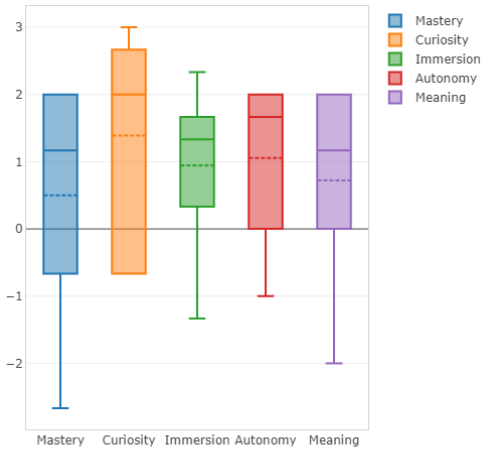

Figure 12.3 *Psychosocial consequences PXI non-VR player*

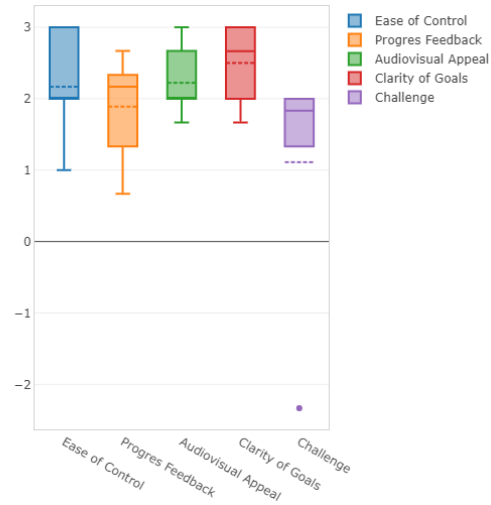

Figure 12.4 *Functional consequences PXI non-VR player*

Results

For the PXI, no test results were significantly lower than the benchmark data. For the VR player experience, the levels of meaning ($M = 1.22$, $SD = 1.33$) are significantly higher, $t(5) = 2.87$, $p < 0.05$, along with immersion ($M = 2.39$, $SD = 0.59$), $t(5) = 8.29$, $p < 0.05$, curiosity ($M = 1.5$, $SD = 1.09$), $t(5) = 4.86$, $p < 0.05$, and audiovisual appeal ($M = 1.94$, $SD = 0.44$), $t(5) = 6.15$, $p < 0.05$. For the non-VR player experience, curiosity ($M = 1.39$, $SD = 1.65$) was significantly higher, $t(5) = 3.05$, $p < 0.05$, and audiovisual appeal ($M = 2.22$, $SD = 0.50$), $t(5) = 6.78$, $p < 0.05$. It does need to be noted that the size of the benchmark data is limited. No benchmark data exists for enjoyability, but both for VR ($M = 2.56$, $SD = 0.40$) and non-VR ($M = 2.17$, $SD = 1.13$), scores were high. $M = 82.08$ & $SD = 8.13$ for the SUS score. This rating makes it into the top 10% compared to other benchmark scores, and could be rated as excellent [34]. The results of the ISO 9241-9 questionnaire can be seen in Figure 13 and the main takeaways from the thematic analysis can be found in Table 3. Both these images show that improvements can be made to the actuation force of the joystick.

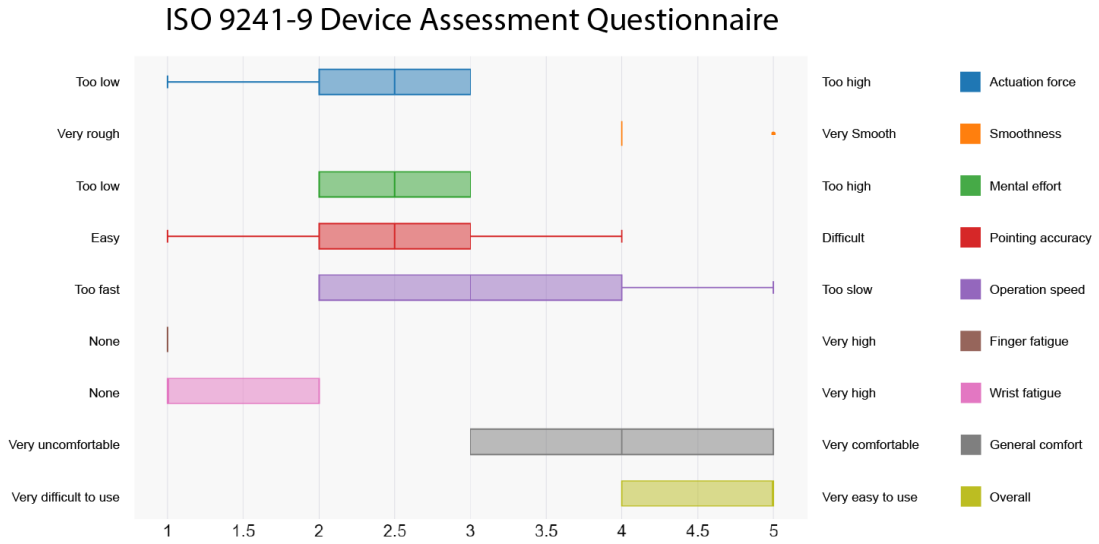

Figure 13 *Boxplot showing the result from the ISO 9241-9 questionnaire*

VR experience		**Non-VR experience**		**General experience**	
Positive	*Negative*	*Positive*	*Negative*	*Positive*	*Negative*
- Interacting with the gun - Exciting - Enjoyable & fun	- Locomotion difficulty - Feedback amount of coins	- Trapping VR player - Commun-ication - Skill required for jumping	- Friction against wall - Game balance	- Switching roles - Intuitive - Enjoyment	- Perhaps not playable for hours
Input controller		**Output controller**		**Aesthetic controller**	
Positive	*Negative*	*Positive*	*Negative*	*Positive*	*Negative*
- Very intuitive - Liking simple layout - Moving controller to jump	- Desire for jump button	- Enjoyed haptic feedback - Liked sounds	- Need more feedback for starting jump	- Fun - Liked old school vibe - Enjoyed robot look - Well made	
Ergonomics		**Asymmetry controller**			
Positive	*Negative*	*Suggestions*			
- The bump on the bottom - Joystick easy to grab	- Cable on the bottom - Actuation force joystick higher	- Scroll wheel - Crank - Voice control - Putting controller on wheels - Force feedback lever			

Table 3 *Overview of the results from the thematic analysis*

4. Discussion & Conclusion

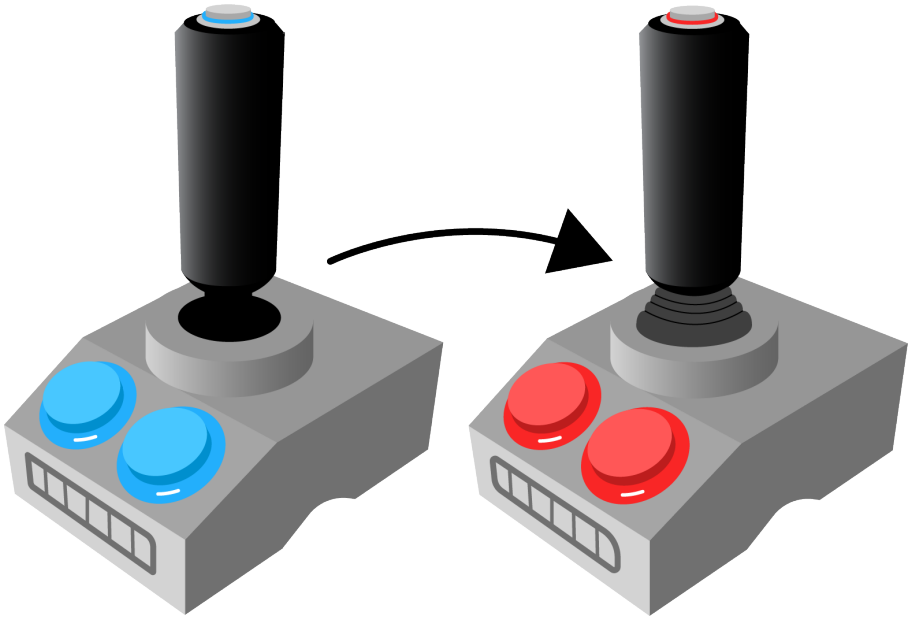

Figure 14 *Adding a flexible dust cover to solve the problem of the low actuation force of the joystick*

4.1 Discussion

It is important to reflect on the earlier set requirements for the controller, taking the results from the user test into account. The AsymDroid controllers together with the game seem to be very good at engaging players. All players enjoyed playing the game and most were also immersed in at least the VR part of the game. My design sparked curiosity and players seemed to be sucked into a shared magic circle. However, it was not clear if this magic circle was always shared between both the VR and non-VR players. The player groups did interact with each other in-game, but there was not as much verbal and actual social interaction between them as I would have hoped. Therefore, I think it would be extremely interesting to also produce a cooperative or collaborative [46] AVR game for a new version of the AsymDroid controller. This way, asymmetry can be utilized to manipulate team dynamics to bring people together through games. The aesthetics of the controller were appreciated by users, since some expressed they thought it added something to the experience. Moreover, people stated that interaction with AsymDroid was intuitive. Nonetheless, changes to the design should still be made to enhance the interaction, such as increasing the actuation force of the joystick by implementing a dust cover or rubber ring (Figure 14). Repairability of the controller is already quite good, but it can still be improved by removing all components from the top cover. This change gives staff members the ability to easily swap these covers for different designs that not just replicate the aesthetics of a robot. Using the accelerometer to jump was seen as somewhat gimmicky by some, while greatly enjoyed by others. It would be very interesting to explore embodied interactions further in new iterations, to see if they can aid in engaging and connecting players to create one shared magic circle.

4.2 Conclusion

Enversed was very satisfied with the work I delivered and are interested in discovering together how the AsymDroid controller can be developed further. During the summer, they will make some improvements to my game to make it run more smoothly and perhaps change some of the aesthetics. The game together with the controllers will then be made available for play at their VR center so customers can give it a try. Based on the response from the client and the feedback from the user tests, it can be concluded that AsymDroid is going into the right direction to bring people together through AVR. However, improvements can still be made and explored in an attempt to generate more joy and create shared magic circles.

5. Reflection M2.1 Project

Last semester, I failed my M2.1 Project. One of the reasons for this was that I did not properly frame the actual problem my design was solving. Therefore, I wanted to collaborate with a company for my new project, in an attempt to avoid this happening again. Having a client could help me identify a clear problem statement relevant to the market. I really noticed that this helped me progress my project quicker. I feel like I tend to get stuck when I am not too sure what my next step is. Having someone as a client and meeting with them gave me a lot of opportunities to reflect on my choices specify next steps. Additionally, I met significantly more often with my coach. These meetings did not always have to be long, but they did made me reflect on my activities more often, helping to improve my work flow and planning. I also made a more specific and extensive planning for the whole semester before I started the project. While this planning ended up changing significantly (which is not necessarily a bad thing), it also gave me a clearer indication of where I wanted to be at certain moments throughout my process. This experience learned me how valuable reflection can be throughout processes, not just mainly at the end. During my FMP I will try to better focus on writing my report throughout my process, instead of doing most of it at the end. Putting my thoughts down on paper more often and earlier can also help me to reflect more on my choices. It will really make me think about my actions, so I can assess sooner whether or not they are validated.

My interest in play is a big part of my Professional Identity & Vision (see Appendix). Therefore, one of my goals for this project was to actually develop a game. For my previous M2.1 attempt I did make something in Unity, but that could barely be called an actual game. It perhaps was more like a showcase. I did end up making a game where one of the main goals was just to make it as enjoyable as possible, which I really enjoyed. I found it really fun to see people get excited just because they were testing my controller and game. Furthermore, I found it incredible to see how my game could bring people together as a group, just to enjoy themselves. To me, this project only confirmed what I try to express in my PI&V.

Furthermore, I learned a lot from my experience working with Enversed. It gave me insights into how companies like them function. I never did an internship, so I think it was essential for me to have this experience. I developed the game for my project over at their office, where I shared a room together with their entire VR development team. It was interesting to see how the dynamics in such a group are, and to some degree be part of it. I had never worked in Unreal Engine before, so it was also very helpful to be surrounded by people with a lot of experience with it. While I managed to figure out most things myself, it was still nice to have the ability to ask questions. Furthermore, it was also interesting to hear tips about what are good practices while working in such software. Advice like this gives you a deeper understanding of the program you are working in, and it will also make it more pleasant for other to continue working in the files you have created. This latter part can be extremely valuable when working in teams during my professional life.

FMP Proposal

1. Topic FMP

I plan for my FMP to be a clear continuation upon my M2.1 Project. During my M2.1, I worked together with the client 'Enversed'. I developed a fully functioning controller for them, that is to be used specifically in the context of Asymmetrical Virtual Reality games (AVR). One of the main advantages of this controller compared to standard gaming controllers is its interface simplicity. This was a requirement for the controller, since interaction with it needed to be intuitive for all the customers of Enversed. They are not necessarily all gamers, and therefore have not developed a correct mental model for how to interact with gaming controllers. Furthermore, by taking inspiration from pervasive games and transmedia storytelling, this device attempts to become part of the game by utilizing its aesthetics.

Enversed will set up a booth at their VR Center during the summer holiday, so visitors will be able to experience my device together with an AVR game I have developed for it. People visiting this booth can provide me with a lot of feedback on how my design can be improved. However, during my FMP, I do not simply just want to improve my design. My M2.1 project showed me how enjoyable and versatile asymmetry in gaming can be. Therefore, I want to further discover the power of asymmetry.

I will continue the collaboration with my client Enversed. I propose that I will develop a set of controllers, taking AsymDroid as a base. My previous project only tried to create an enjoyable and shared gaming experience through the use of AVR. However, I think that the asymmetry of interface that makes AVR so special can be taken a step further, in an attempt to create a totally unique experience. The interfaces of the controllers within this set will all be different from each other, through the use of a wide variety of technical components, selected to create all kinds of unique affordances. Another option for these devices is that they will be made modular, so the interfaces can be changed depending on factors such as what game is being played, or the skill level of the player.

My experience from my previous project also showed me that this asymmetry of Interface can easily be combined together with different forms of asymmetry. Examples include asymmetry of Ability, Challenge, Information, Investment, Goal/Responsibility, and Dependence [12]. I do think that such unique controllers also require a unique game. Otherwise, not all asymmetries and functionalities can be fully utilized for the creation of good gameplay and social dynamics. Therefore, I will build upon the work I have done creating the AsymDroid game, and create a new AVR gaming experience. In the previous game the relationship and dynamics between the VR player and non-VR players were competitive in nature. However, for this game I want VR and non-VR players to either cooperate, or at the very least collaborate. The reasoning behind this choice is that I want all players to join in one large shared magic circle. In my previous game, VR players and non-VR players did definitely interact with each other in the digital world, but not necessarily as much as I would have hoped through the physical world. I did observe some social interaction and communication, but I hope this can be stimulated by forcing players to cooperate or collaborate with the help of all the different interfaces. However, I do need to be careful, since one of the pitfalls of collaborative games is that strong personalities or more highly skilled players can degenerate the game into only one player making the decisions for the entire team [46]. Therefore, a clear rationale for collaboration needs to exist.

In asymmetric games, designers can create specific mechanics to set the directions of interdependence between players [12, 33]. The three directional dependence types are Mirrored Dependence, Unidirectional Dependence, and Bidirectional Dependence. Which of these dependencies will be used, will be determined during the FMP, and can differ from player to player. Moreover, I think it will be interesting to make this new game playable for two local VR players, to explore what kind of effects on dynamics this can have. Perhaps it would still be interesting to make the relationship between these players competitive. The non-VR players could then either be divided up into teams together with one of these VR players, or perhaps they can choose who they want to support and switch allegiance mid-game. Other options for enhancing the gameplay experience can be found in the fact players can be co-located in their own open VR-Room over at the Enversed VR Center. Co-located VR games can utilize the physical space around them in an interesting manner. Namely, they can leverage the fact that different players can experience the space uniquely due to

their distinctive UIs [33]. It does need to be noted that designers need to be careful that players do not run into each other during play, due to a lack of spatial awareness. An example of an AVR game that heavily utilizes the space around it to encourage social interaction can be found in the paper “Astaire: A Collaborative Mixed Reality Dance Game for Collocated Players” [47]. Like the title suggests, a VR player needs to dance hand in hand together with a non-VR player. Through the use of the space around them and the difference in interfaces, both players take a leading role in the dancing at certain moments.

There is a reason why I explain all these different factors that can be played around with by designers during the creation of an asymmetric VR game. I want to highlight the versatility of asymmetry in games. I feel like that there is plenty of room within the subject of this FMP proposal to experiment and find creative solutions to enhance the gameplay experience. The creation of a set of controllers with asymmetrical interfaces seems to me like a very strong tool to engage players together into one large shared magic circle.

1.1 Why is the topic relevant?

At the end of the last paragraph I was trying to hint at the fact that the results of work like this might even be interesting for people outside of the field of games. I think that playing around with asymmetry can overall be a good tool for gathering information about group dynamics, not just for in games. People encounter situations where not everyone is treated equally on a daily basis. Some people in society just have more power, status or wealth. A metaphor could be someone with a physical injury having asymmetry of ability compared to a healthy person. In some contexts, for example, someone less wealthy could also be seen as having an asymmetry of challenge, compared to someone born rich. Perhaps games with a lot of asymmetry incorporated in them can learns us more about more general social dynamics.

Furthermore, research into making VR in general more accessible and inclusive can also be very useful. VR is used for more than just gaming. It is commonly used as a very powerful tool in contexts such as training scenarios. Custom interfaces are also definitely worth looking into for such instances. These controllers can make the interaction with VR more natural and life-like. Virtual interactions that more closely resemble their real-life counterparts can be especially useful for VR training. In these experiences, certain scenarios are often simulated. Custom controllers can more closely replicate the tools a person might need during the actual activity they are being trained for. Therefore, research like this can help people better prepare for their jobs, therefore reducing accidents.

Lastly, I would like to note that just simply making playful experiences more enjoyable can already be a worthwhile reason to work on this topic. Aside from making people happy, play has been proven to have countless other benefits. Engaging in it not only assists in the development of cognitive and social skills, but is also a natural stress reliever [41, 42, 44]. Furthermore, it can bring people together.

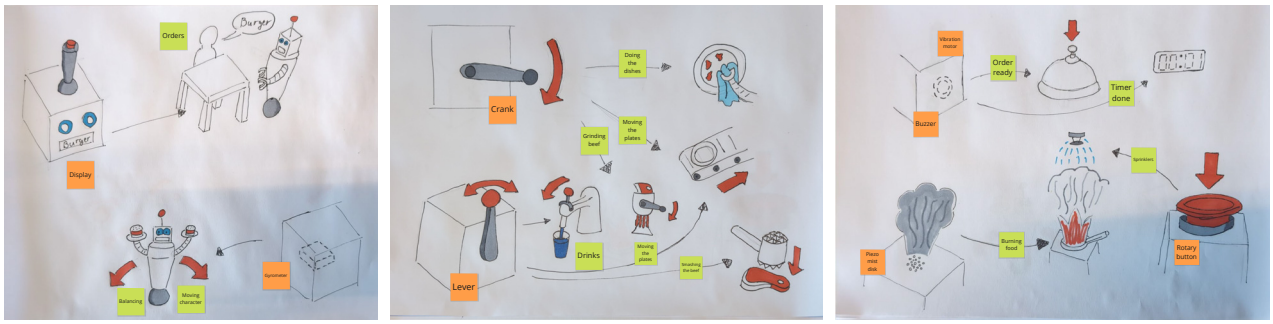

Figure 15 *(same as Figure 5) Ideas from M2.1 project that could perhaps be used in FMP concept*

2 Why me?

Taking into account the work I have delivered during my M2.1 project, I think I am capable of undertaking a project like this. One of my main points of interest when looking at my professional identity and vision (see Appendix) is games & play. The context of this proposal is very playful one and therefore, it intrigues me incredibly. Furthermore, I am extremely interested in exploring how the digital world of games can be bridged to the physical realm, with the goal of creating one large enhanced experience. In the context of video games, the interface is the portal between these worlds. For this reason, I would love to discover what happens when I manipulate this link. Moreover, this project offers me an opportunity to increase gaming inclusivity. I value it very much that my work is inclusive, since I feel like play should be for everyone, no matter your age, gender, background, etc. . My M2.1 project made play specifically more inclusive for people with less gaming experience, thanks to the intuitive design of my controller interface. However, this simplicity might be less attractive to a more experienced gamer, who already has a well-developed mental model for interacting with controllers. By creating several different controllers, people are given the option to pick the controller that fits them best. This choice can be made based on their skill level, but also just out of personal preference.

2.1 Can I achieve this?

I believe that I should be able to develop a series of controllers within the given timeframe of this project. First of all, I already underwent a large part of the learning process that goes into finding out how to build such prototypes during my M2.1. Furthermore, possible expansion of the platform I built for the AsymDroid controller was already taken into account when I developed it. Since the core of the device is an ESP32 microcontroller with more than enough GPIO pins, more inputs and outputs can easily be added and controlled. The prototyping process will progress a lot faster due to all the knowledge and experience I have already gained, even if my new ideas stray further away from the AsymDroid design.

At the end of last project I also developed a game from scratch in Unreal Engine in about three weeks. I had no prior experience with this software, but still managed to create a fully working AVR game. Furthermore, I got two way communication between my custom controller and the gaming engine working. During my FMP I also want to make a game that accompanies the set of controllers. However, I believe that this should be no problem at all thanks to the experience I now have. Additionally, I do not have to create entirely new code for the microcontroller to communicate with Unreal Engine, which also took me quite some time.

Lastly, I would like to mention that I will still be able to count on the support of my client, since I will still be collaborating with Enversed. Therefore, I can get input from actual VR and game developers. I will definitely try to take more advantage of this opportunity during my FMP, by also involving them in co-creation sessions.

3. Planned activities

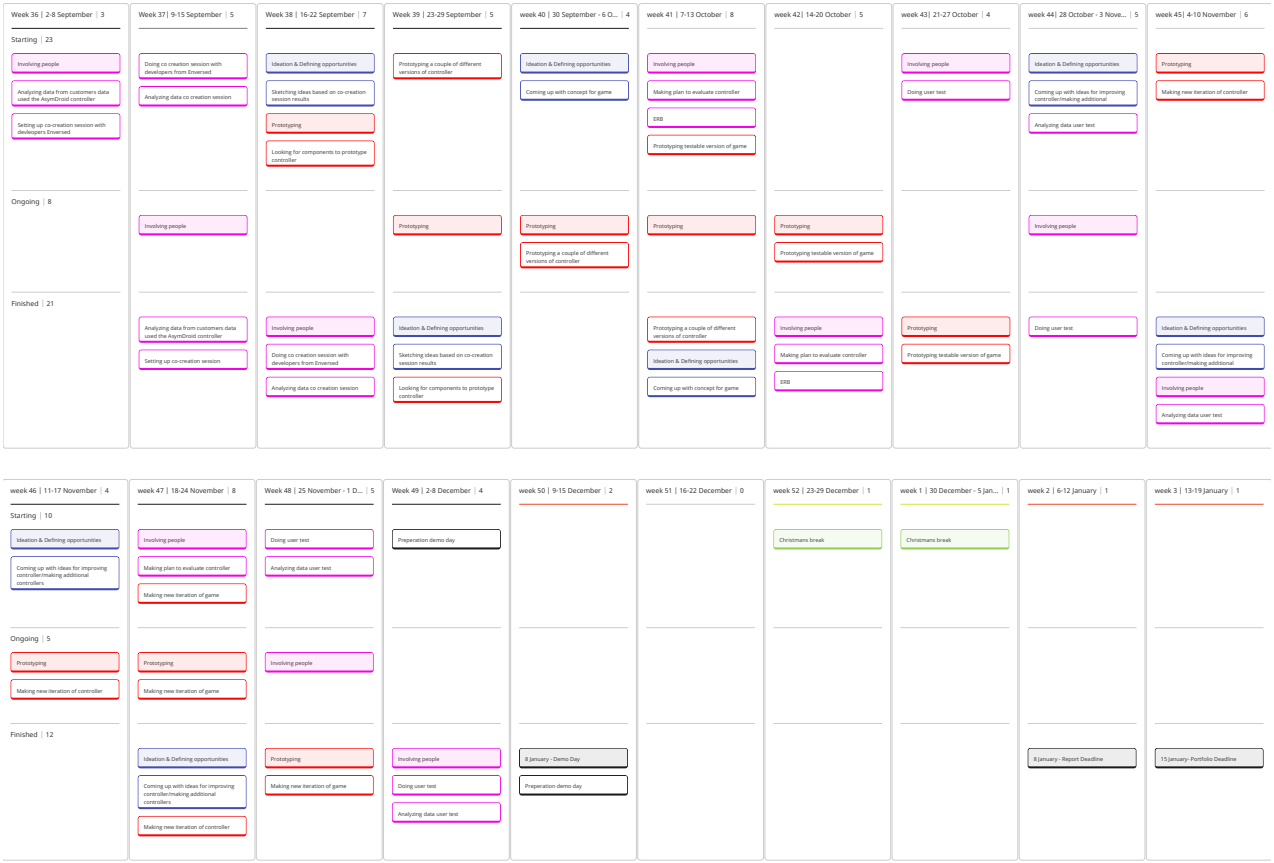

Figure 15 *Planning FMP*

An overview of my plan for next semester can be found in Figure 15.

Customer feedback

As I mentioned earlier, Enversed was quite satisfied with the development of the AsymDroid controller and its accompanying game. Therefore, they want to showcase it to customers at their VR Center during the summer break. I will support them in doing this by helping them get the controllers set up. Furthermore, Enversed is going to let some of their developers make some improvements to the AsymDroid maze game. The focus will mainly be on bug fixes and making the game run more efficiently. Perhaps this is also an opportunity for me to learn about how I can make my games more efficiently by discussing this with the developers. By the time that I will officially start my FMP, I will have additional information from actual customers about what they enjoyed about my work. Perhaps I can also figure out a way for people to leave feedback on what they would like to see added to an asymmetric controller for AVR gaming.

Co-Creation

Last semester, I worked on the development of the AsymDroid game over at the office of Enversed Studios. Doing so gave me the chance to ask some questions to the developers in case I got stuck. However, what is more important is that they could playtest my game and the controller. They have a good understanding of the mechanics, dynamics and aesthetics of games, and how people interact with and experience them. Therefore, they could give me clear and constructive feedback on how to improve my game and controller. For this reason, I want to involve them more directly from the start of my FMP. My plan was to immediately start with the planning of a co-creation session that is to be done together with the developers. By doing so, I can gather valuable insights and ideas that assist me in coming up with new ideas for my both my set of controllers, but also a new accompanying game.

Prototyping

I want to start prototyping early in the project, especially since I figure that it can take quite a lot of time and effort to create prototypes of several different controllers. Luckily, I do already have the infrastructure set up by the development of the AsymDroid controller. Additionally, I am faced with the problem that I will likely need another game, if I want to properly assess my design. Perhaps I can build upon the maze game I already developed to make this process go faster. However, I am exponentially more skilled in using Unreal Engine than before, and I have already the code set up to make Unreal communicate to the controller over Bluetooth or by wired connection.

User testing

My desire is to have the prototypes done as fast as possible, so people can interact with them. I think that it is essential to get your prototypes quickly in the hands of people who can give you feedback on their experience with them, especially now that I have planned to make the controllers work for a cooperative or collaborative game. I feel like it is really difficult to predict how the social interactions between players are going to work out, so playtesting is crucial.

I will immediately incorporate the results from the test into a new iteration of the set of controllers. I will then try to also evaluate this iteration with another round of testing with users.

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Appendix

PI&V + PDP

Vision

Life can be very demanding. The world is struggling with economic, geopolitical, and environmental instability [2], while an ever-increasing amount of people are dealing with mental health issues [3]. The transition to the age of information and the dawn of social media has exacerbated political and societal polarization [1] and has assured that most people face these harsh realities daily.

Therefore, I believe that as a designer, it is not so bad to occasionally take things a little less seriously. I see design as a powerful tool to create meaningful and joyful experiences. A designer enables the interaction between technology and human by transforming technological innovations into intuitive affordances that make products accessible and usable to larger audiences. The work and insights of a designer are crucial to not only unlocking the full potential a technology, but also for countering immoral implementations that try to exploit users for economic or other gains.

Good design is not only key to bringing user and technology closer together; it can also bring people closer together. I strive to harness the power of playful design to accomplish this goal. Play is not just fun, it is essential to a person's development. Engaging in it fosters creativity and helps develop cognitive and social skills [4–6]. Furthermore, play is a natural stress reliever [4, 6], helping people deal with the seriousness of life. I strive for my designs to be inclusive, since play can and should be for everyone, no matter your age, gender or background.

Technology in combination with play can be transformed into meaningful and joyful experiences through embodied interactions in both the digital and physical space. When experienced with others, good playful design can build lasting relationships that help people go through and get the most out of life.

Identity

Both as a designer and person, I am just trying to have some fun. Games & play have always been integral to me, helping me take the edge off of life. Consequently, one of my main goals is to share the joy I experience from play by incorporating it into and facilitating it through my designs.

The development of my technical skills is essential, enabling me to not only come up with innovative ideas, but also put them to the test utilizing highly interactive prototypes. My proficiency with industry-standard gaming engines such as Unreal Engine & Unity enable me to create immersive and enjoyable virtual experiences. However, I am particularly interested in exploring the bridge between the physical and virtual world. I enjoy experimenting with various technologies to uniquely integrate them into physical gaming interfaces. Through this approach, I aim to stimulate people's senses in unexpected ways, creating novel, memorable, immersive, joyful, and inclusive experiences. My expertise in working with electronics, microcontrollers and 3D modelling gives me the confidence to produce tangible physical prototypes that are ready for rigorous testing.

Getting my ideas in the hands of potential users is essential to my design process. An academic analysis of user feedback forms the backbone of the validation of my concepts. Furthermore, this testing data assists me in the creation of design iterations that fit people's needs and desires. I understand that users are not a homogeneous group. Different individuals will interact with my products in different ways and at different moments. It is of utter importance to me that the abilities and interests of all these various users and stakeholders are considered, ensuring that my designs are inclusive and bring people together through play.

Goals

While I have mainly developed my technical game development skills, I still feel like I have a lot more to learn about the theory behind games. More theoretical knowledge can help me implement certain methods into my designs to perhaps make them more motivating or persuasive, but certainly more enjoyable.

Goal 1
Read the book 'Rules of Play: Game Design Fundamentals'. Read at least half of the book before the end of Q1 and the other half before the end of Q2.

I do have experience with assessing my game designs by doing user test. However, I think it can be very beneficial to also be able to generate new ideas for my work together with potential users aside from just letting them validate them.

Goal 2
Get the book 'Games User Research' and pick a co-design method from it. This method should then be applied during Q1 for my FMP project to generate new ideas for game mechanics. This co-design session can be performed with the VR developers of Enversed Studios.

Up until this point I have never put a lot of effort into adding sounds to my games. Even when I did, I downloaded free sounds from the internet. However, I think that sounds can add a lot to my work and make them feel more 'juicy'.

Goal 3
Make at least 5 sounds myself and edit them so they can be added to the game I will make for my FMP.

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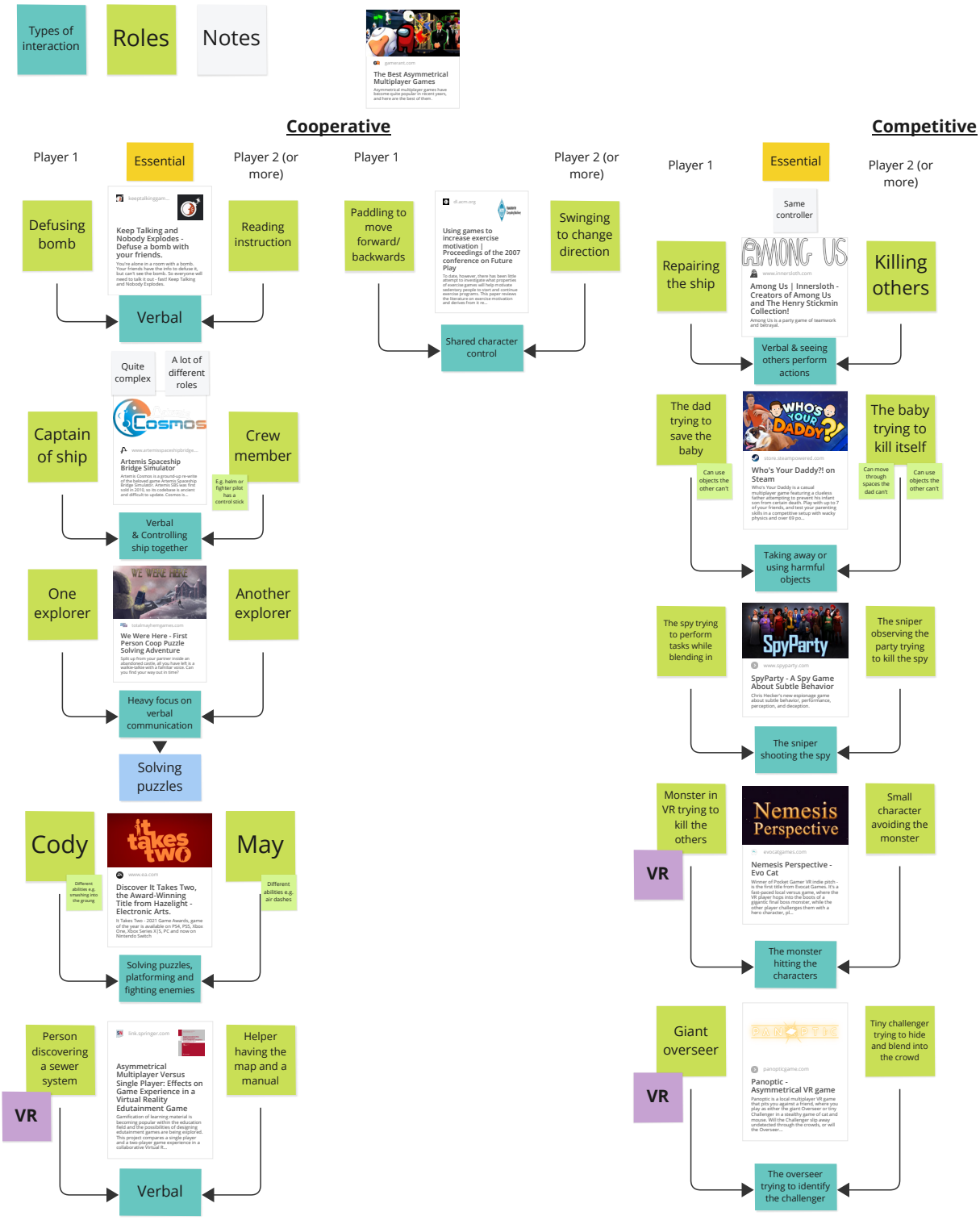
Appendix A – Analysis asymmetric games

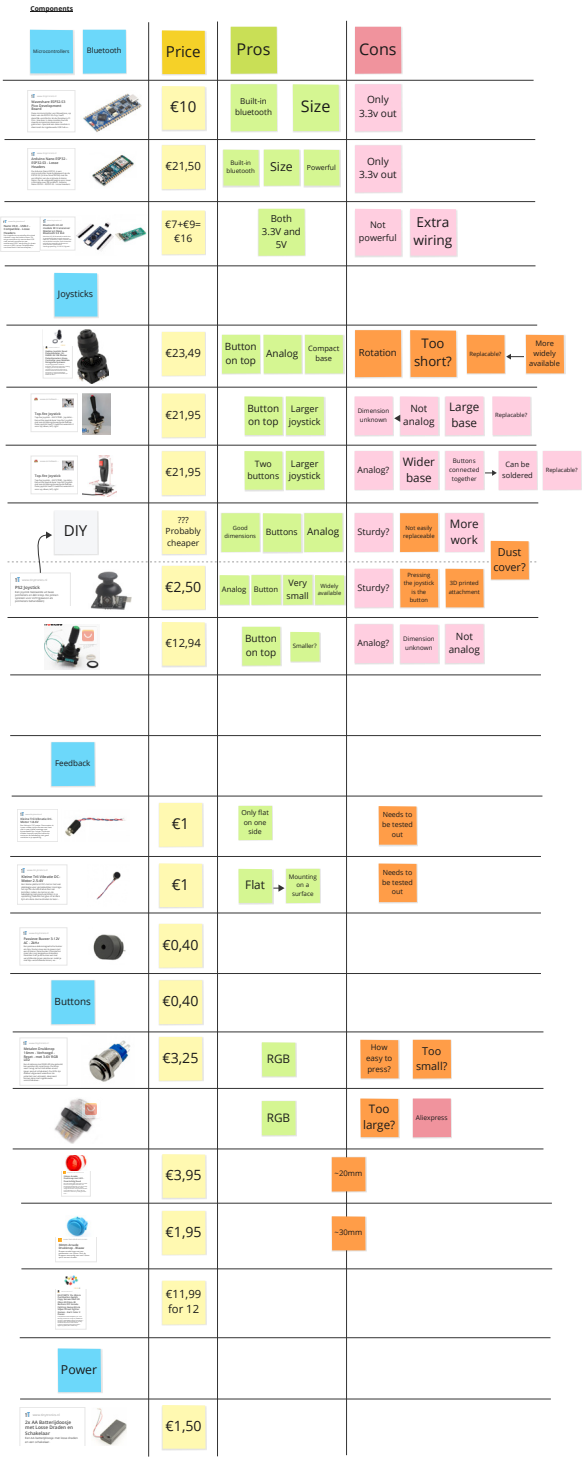


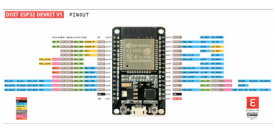
Appendix B – Questions semi-structured interview

How would you describe your experience playing the game with the controller?
How would you describe your experience playing the game as the VR player?
How would you describe your experience with the controller itself?
What did you think of the visuals of the controller?
What did you think of the feedback provided by the controller?
Let them look at the possible options for the controller
What would you like to see added to the controller?

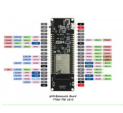
Appendix C – Results thematic analysis

Appendix D – Overview possible components for base controller



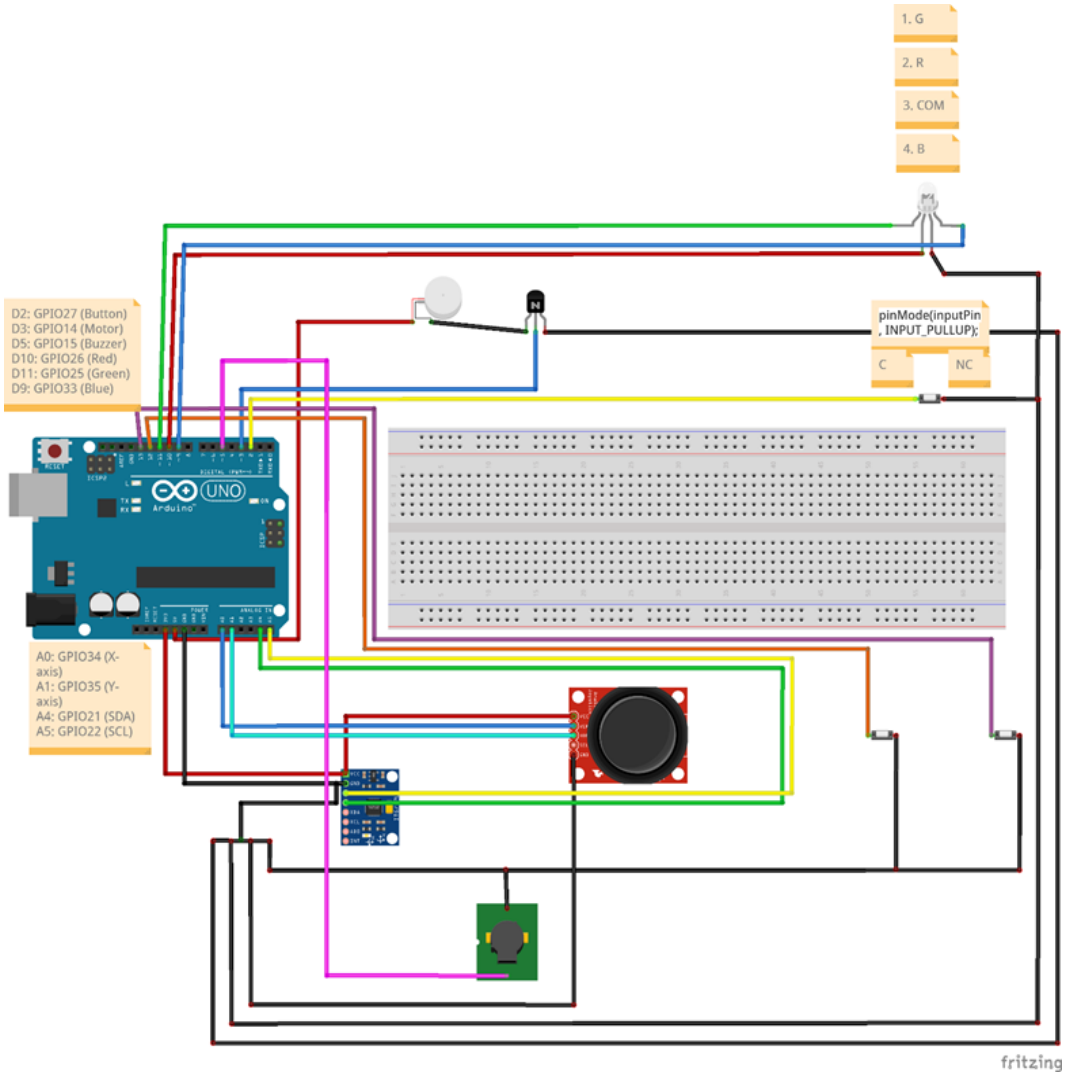


ESP32 Wi-Fi en Bluetooth Board - CP2102



LilyGO TTGO T-Energy ESP32-WROVER - met 18650 Batterijhouder

Appendix E – Fritzing schematic controller



Appendix F – Signed ERB + Consent form

Ethical Review Form

(Version 2.1)

This Ethical Review Form should be completed for every research study that involves human participants or personally identifiable personal data and should be submitted to ethics@tue.nl. For more information about how this process works please click here. Please check if you are using the correct form: Ethical Review Form (version 2.1). Please click here to obtain this latest version.

Part 1: General Study Information

1	Project title / Study name	M2.1 Preparation FMP
2	Name of the researcher / student	Jules van Gurp
3	Email of the researcher / student	j.a.m.v.gurp@student.tue.nl
4	Supervisor(s) name(s) *Additional explanation: Please write down the name of your direct supervisor. You can mention several supervisors if appropriate, but at least one supervisor should be mentioned.*	Erik van der Spek
5	Supervisor(s) email address(es) *Additional explanation: Please give the email address of the supervisor(s) mentioned in question 4.*	e.d.v.d.spek@tue.nl
6	Department / Group *Additional explanation: Please specify group if relevant e.g. JADS or HTI*	Industrial Design
7	What is the purpose of this application?	☐ Scientific study ☐ Bachelor education. Course:…….. ☒ Master education. Course:…….. ☐ Other (e.g. external, following external regulations):……
8	Research location *Additional explanation: Where will the data collection take place? On campus, in a company, in public space, online, etc.*	☒ Eindhoven University of Technology campus ☒ Other, name organization(s): Enversed VR Center, Torenallee 100-02 Eindhoven ☐ Public space ☐ Online
9	Start date data collection *Additional explanation: Please state when your data collection will start. Please note that you do not have to provide information about your complete (PhD) project, but only on this particular sub-study that you are submitting for approval in this form.*	20/05/24
10	End date data collection	30/06/24
11	Does your project receive external funding (e.g., NWO, relevant for special regulations from funders)?	☐ Yes. Name Funder: ☒ No

Ethical Review Form

12	Which internal and external parties are involved in the study? Think about sharing data or information between TU/e and other universities, commercial companies, hospitals, etc. *Additional explanation: Describe all internal and external parties that are involved in the study or project, including:* • *researchers or research groups at the TU/e who participate in the study;* • *(Researchers at) other universities/institutions that provide data/services, help analyzing the data, etc.;*	Internal parties • Researcher(s): Jules van Gurp • Supervisor: Erik van der Spek

Ethical Review Form

	• *(commercial) partners, companies, government bodies, municipalities, consultancy firms, hospitals or care institutions that provide data (e.g., contact details of participants, data for further analysis).* *Indicate which role each party plays: who defines the means and purposes in the study, who will supply the data (external parties?), who will process/handle the data, who will be able to access the data during and after research (only researchers at TU/e or also others)?*	External parties • Other universities/institutions: • Others: Enversed, a company based in Eindhoven. This research is part of a project that is being done in collaboration with them. However, they will only have access to the processed results and will not collect or assist in processing the data.
13	Have any special agreements already been made with an external party, such as a Non-Disclosure Agreement (NDA) or a data sharing agreement?	☐ Yes, namely: ☒ No ☐
14	Has your proposal already been approved by an external Ethical Review Board or Medical Ethical Review Board? *Additional explanation: For example, when you are collaborating with another university and the project has been approved by their Ethical Review Board, or when you received a WMO-waiver from a Medical Ethical Review Board.*	☐ Yes ☒ No
15	If yes: Please provide the name, date of approval and contact details of the ERB. Please also include the registered number for your project approval. Additionally, please send in the Ethical Review Form upon which ethical approval was granted together with this form.	-
16	If you process personal data that are likely to result in high privacy risks for participants, you need to perform a Data Protection Impact Assessment (DPIA). Have you done this for this or a very similar project? ***Please read the information below: a DPIA is not the same as a regular privacy impact assessment. More detailed questions on privacy will follow in the section below.*** *Additional explanation: A Data Protection Impact Assessment (DPIA) is a formal document that must be drafted under the guidelines of the General Data Protection Regulation (GDPR). Think of research with vulnerable people, high-risk medical research,* *The Dutch DPA (Autoriteit Persoonsgegevens) and our website provides more information about a DPIA.*	☒ Not applicable (no high privacy risks) ☐ Yes (the form is attached to the application) ☐ No

Part 2: Medical study

Ethical Review Form

1	Does the study have a medical scientific research question or claim? *Additional explanation: Medical/scientific research is research which is carried out with the aim of finding answers to a question in the field of illness and health (etiology, pathogenesis, signs/symptoms, diagnosis, prevention, outcome or treatment of illness), by systematically collecting and analyzing data. The research is carried out with the intention of contributing to medical knowledge which can also be applied to populations outside of the direct research population. If your research contains questions about health and health related parameters (such as well-being, vitality, feelings of anxiety or stress) but your research question is not primarily medical, then you can answer 'no' to this question.*	☐ Yes* ☒ No *If yes or in doubt, please contact Susan Hommerson via s.m.hommerson@tue.nl

Ethical Review Form

Part 3: Use of (medical) devices in the study

1	Does your research include a device? *Additional explanation: A device is a complete piece of physical hardware that is used to compute or support computer functions within a larger system. Devices can be divided into input-, output-, storage-, internet of things-, or mobile device.*	☒ Yes, not self-made ☒ Yes, self-made ☐ No
2	Please describe your device or link to an online description of the device	- A VR headset will be used together its accompanying controllers. This headset will likely be a Meta Quest 3. - A self-made wireless gaming controller (Appendix A) will be assessed in this study. This device is controlled by the LilyGO TTGO T-Energy ESP32-WROVER microcontroller (https://www.tinytronics.nl/en/development-boards/microcontroller-boards/with-wi-fi/lilygo-ttgo-t-energy-esp32-wrover-with-18650-battery-holder) and powered by a 18650 Li-ion Battery with a 3500mAh capacity. This battery is placed in the battery holder mounted on the microcontroller. The microcontroller also has a built-in protection circuit for the management of the battery. Furthermore, the battery is protected by a custom 3D-printed case that surrounds the battery holder. Other components include: two buttons, a small buzzer, a gyroscope/accelerometer module and a 3D-printed joystick. This joystick also houses another button and small vibration motor. All these components are mounted in a 3D-printed controller casing.
3a	Will you use a device that is 'CE' certified for **unintended use** (meaning you will use existing CE certified devices for other things than they were originally intended for) or use a device that is not 'CE' certified? *Additional explanation: You can find more information about CE certification here*	☐ Yes ☒ No
3b	If no: Please explain to what extent the device was assembled according to relevant standards and provide a risk assessment *Additional explanation: You can find more information about a risk assessment here*	All components operate using only low voltage levels. The vibration motor needs 5V, while all the others only need 3.3V. Furthermore, all components are secured very well into place within the casing to limit the damage a potential fall might cause. The only serious risk could be a damaged battery. However, the battery is already mounted very securely within its holder. Furthermore, this holder is fully protected by the additional battery casing. Therefore, a battery puncture is extremely unlikely.
3c	If yes: Do you use a device or software that has a medical purpose such as diagnosis, prevention, monitoring, prediction, prognosis, treatment or alleviation of disease or injury?	☐ Yes, my device or software currently has a medical purpose ☐ Yes, my device or software could have a medical purpose in the near future ☒ No ☐ I'm not sure

Ethical Review Form

Part 4: Information about the study		
1	What are your main research questions? *Additional explanation: You need to provide at least one clear research question.*	What is the usability of the custom controller? What is the experience of a player using this controller in an asymmetric VR game?
2a	Please check the box that indicates the relevant study population *Additional explanation: Please select which persons are eligible for your study.*	☐ Students ☒ General healthy population ☐ General population with specific feature, e.g., pregnancy, specifically ..... ☐ Patients, specifically ..... ☐ Other, specifically .....
2b	Age category of participants	☐ Younger than 12 years of age ☐ Older than 11 and younger than 16 years of age ☒ 16 years or older
3	Description of the research method (select all that applies)	☒ (Semi-structured) interviews ☒ Surveys

Ethical Review Form

	Additional explanation: Please specify your research method. Note that you need to provide information about the research method in an additional file that you attach to the ERB form. E.g., for interviews you provide the interview questions, for surveys you provide the survey questions, etc.	☒ Group workshops/roundtable discussions ☐ Diary studies ☐ Behavioral observations ☐ Building sensor data ☐ Wearable device (e.g. Fitbit watch, on-skin sensors) ☒ User testing ☐ Pilot study ☐ GPS tracking/location data ☐ Living Lab ☐ Other, namely .....
4	Description of the measurements and/or stimuli/treatments *Additional explanation: Think about your outcome measures and the variables you will be collecting and describe them in a way such that another person understands what the participant will experience. For example: Participants will perform task A and see pictures from database B, and we measure validated Scale 1.*	The participant will start the user test by getting information about the research verbally from the researcher. Then they will get an opportunity to read through the informed consent form, sign it, and ask questions. Once the consent form has been signed, the participants will get a short introduction to the different controls the custom controller offers. They will then perform some short tasks using it where they need to do simple things such as moving cubes around obstacles to a certain point on a screen. Once finished, a survey on MS Forms will be offered containing several questions. First of all, they will be asked what their hand of preference is and a 5-point Likert-scale where they can state their experience level with gaming controllers. Furthermore, they will need to fill in a Likert-scale questionnaire based on the ISO 9241-9 standard on device comfort as used in other research [1] (Appendix B), and they fill in the System Usability Scale (SUS) (Appendix C). Lastly, participants will be able to leave any remarks about the controller or their experience in the survey, or they can express them verbally to the researcher if they desire to do so, in which case they will be noted down in writing. In the next phase of the user test, the participants will play a short game against each other that is similar to the popular game Pac-Man. In this game, one participant will use VR glasses to play as Pac-Man. The other participants (2 to 4 participants, likely 2) use the custom controller to control characters on a screen and will try to catch the VR player to prevent them from reaching their goal. After a short while (approx. 5 minutes), the game will end and players will switch roles until everyone has played the VR role. The participants will then be offered another survey in MS Forms, which contains the Player Experience Inventory (PXI) (Appendix D). In this survey, they will also be able to answer some simple open ended questions about general remarks regarding the controller and game. Lastly, a short semi-structured group discussion will be held so participants can discuss improvements for the controller and game and state what they (dis)liked. An audio recording will be made of this discussion.

Ethical Review Form

		[1] Natapov, D., Castellucci, S.J. and MacKenzie, I.S. 2009. ISO 9241-9 evaluation of video game controllers. *Proceedings of Graphics Interface 2009* (CAN, mei 2009), 223–230.
5	Describe and justify the number of participants you need for this study. Also justify the number of observations you need, taking into account the risks and benefits. *Additional explanation: Think about if you need 3 or 30 participants for example, and why? Do they need to provide their input once, or several times, and why? If relevant, specify the duration of the study per participant and the compensation that is needed for the study.*	5 to 15 participants
6	Explain why your research is societally important. What benefits and harm to society may result from the study? *Additional explanation: What benefit will the results of your study have to society in general?*	This user test is being done to further examine the use of a custom video game controller. This device was specifically developed to be a less complicated alternative to traditional controllers such as a PlayStation or Xbox controller. The availability of this controller can make gaming more accessible to people with less or without experience with these more traditional forms of UI's. This research only concerns an iteration of the controller with "base" functionalities that should be usable for a variety of games. However, in a follow-up project different versions of the device will be made utilizing more non-standard game controller components. Not only can this lead to more novel gaming experiences, but it can also offer hardware asymmetry to the players. Furthermore, the product is designed to be used for asymmetric VR games and one such game will also be examined in this user test. Asymmetry in games can help less skilled players feel more competent. Asymmetry can make it harder for players to compare themselves with others, due to the differences in abilities that are offered to them. Furthermore, abilities can be given to only specific players, which can help them feel special and an essential part of the game. This aspect can also help make gaming more inclusive.
7	Describe the way participants will be recruited *Additional explanation: How will you recruit participants for your study? For example, by using flyers, personal network, panels, etc.*	☐ Survey link posted online, e.g., social media platforms ☐ On campus flyers ☒ Personal network ☒ Via a company, namely Enversed ☐ Via a hospital, namely …….. ☐ Via an organization …… ☐ By a Consortium Partner, namely …… ☐ Other, namely …….
8	Provide a brief statement of the risks you expect for the participants or others involved in the study and explain. Also take into consideration any personal data you may gather and associated privacy issues. *Additional explanation: Risks for the participants can be anything from risk of data breach to risk of safety or well-being (think about stress, extreme emotions, visual or auditory discomfort). Describe these possible risks and describe the way these risks are mitigated.*	The main personal data that will be gathered are interview recordings. However, these will be immediately deleted once they are transcribed. The other personal data in the form of handedness and video game controller experience will be detached from the rest of the data sets once the data has been processed into results. Therefore, all data will be anonymized. The only potential risk might be that

		participants experience some discomfort in the form of motion sickness from using the VR headset. Therefore, only teleportation based locomotion will be implemented in the game, since people are less likely to experience motion sickness when this movement type is used. Furthermore, participants will be informed beforehand that they should reconsider participating in the user test if they think they are prone to motion sickness. The researcher and the informed consent form will also highlight that participants are allowed to take off the VR headset at any point during the research if they desire to do so.

Ethical Review Form

Part 5: Self-assessment checklist

	Note: answers in the blue boxes indicate that your research is eligible for fast-track approval	Yes	No
1a	Does the study involve human material? (e.g., surgery waste material derived from non-commercial organizations such as hospitals)		x
1b	Will blood or other (bio)samples be obtained from participants? (e.g., hair, sweat, urine or other bodily fluids or secretions, also external imaging of the body)		x
2	Will the participants give their consent – on a voluntary basis – either digitally or on paper? Or have they given consent in the past for the purpose of education or for re-use in line with the current research question?	x	
3	Are the participants, outside the context of the research, in a dependent or subordinate position to the investigator? Additional explanation: Think about doing research on your own students or on your own employees. When there is a dependency or power imbalance between you and the research participants, you need to answer 'yes' to this question.		x
4	Does the study involve participants who are particularly vulnerable or unable to give informed consent? (e.g., children (<16 years of age), people with learning difficulties, patients, people receiving counselling, people living in care or nursing homes, people recruited through self-help groups)		x
5	Will participating in the research be burdensome? (e.g., requiring participants to wear a device 24/7 for several weeks, to fill in questionnaires for hours, to travel long distances to a research location, to be interviewed multiple times)?		x
6	May the research procedure cause harm or discomfort to the participant in any way? (e.g., causing pain or more than mild discomfort, stress, anxiety or by administering drinks, foods, drugs, or showing explicit visual material)		x
7	Will financial inducement (other than reasonable expenses and compensation for time) be offered to participants? Additional explanation: For an explanation of what is considered a reasonable compensation, see the topic participant fees from the HTI group		x
8a	Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g., covert observation of people)		x
8b	If yes: Will you be observing people without their knowledge in public space? (e.g. on the street, at a bus-stop)		x
9	Will the study involve actively deceiving the participants? (e.g., will participants be deliberately falsely informed, will information be withheld from them, or will they be misled in such a way that they are likely to object or show unease when debriefed about the study)		x
10	Will participants be asked to discuss or report sexual experiences, religion, alcohol or drug use, suicidal thoughts, or other topics that are highly personal or intimate? Additional explanation: Think about your research population. For some participants, particular topics can be considered sensitive or intimate, whereas the same topics will not be perceived as such by other participants.		x
11	Elaborate on all boxes answered outside of the blue boxes in part 5. Describe how you safeguard any potential risk for the research participant.		

Ethical Review Form

Part 6: Self-assessment on privacy

The following questions (1-11) concern privacy issues, as laid down in the General Data Protection Regulation (GDPR). The Data Stewards and – if necessary – privacy team of TU/e will assess these questions. In some cases, more information is required to assess the privacy risks. If this is the case, you will be notified that the Data Stewards team will contact you.

The GDPR defines 'personal data' as any information relating to an identified or identifiable natural person ('data subject'). Personal data also includes data that indirectly reveals something about a natural person. Personal data can lead to the physical, physiological, genetic, mental, economic, cultural or social identity of a natural person. There are two main categories of personal data: regular personal data and special category personal data.

If you are not sure whether some of these questions below should be answered with a Yes or No, please contact a Data Steward first through rdmsupport@tue.nl.

	Note: answers in the blue boxes indicate that your research is eligible for fast-track approval	Yes	No
1	Will the study involve discussion/collection/processing of **regular** personal data, or will you collect and (temporarily) store video or voice recordings for the purpose of conducting interviews? *Additional explanation: For example, name, address, phone number, email address, IP address, gender, age, video or interview recordings? If you are not sure whether your data contains personal data, please contact the Data Stewards Team (rdmsupport@tue.nl).*	x	
1A	If yes: Please describe which regular personal data you will collect in this study?	Interview recordings, right or left handedness, and experience with video game controllers	
2	Will the study involve discussion/collection/processing of **special category** personal data or other **sensitive data**? *Additional explanation: Examples of special category personal data are race, religion, health information, political views, genetic or biometric data for the unique identification of a person, sexual preference, etc. Health information concerns personal data of the physical or mental health of persons, including the provision of health care. Examples of other sensitive data is information such as communication data, financial records or credit scores, camera surveillance data, location/GPS data, internet-of-things data, employee monitoring, observing or influencing behaviour, criminal records, data of vulnerable persons (children, people with disabilities, refugees), BSN number etc. Please be aware that the use of special category personal data in research requires extra security measurements in order to safeguard the privacy of data subjects and to comply with the GDPR. Processing of this special category data is prohibited, except for specific purposes and under certain circumstances. If you need to process special category data, please consult the data stewards at rdmsupport@tue.nl.*		x
2A	If yes: Please describe which special-category personal data and/or sensitive data you will collect in this study?		

If you answered yes to either question 1 or 2, please answer the questions below. If you answered no to both questions, you can skip this part and continue onto part 7. Also, if an answer to any of the following questions is 'yes', please contact a Data Steward at rdmsupport@tue.nl

		Yes	No
3	Will your project involve the processing of personal data on a **large scale**? *Additional explanation: In general, any processing that involves more than 10.000 data subjects should be considered "large scale". However, if the data of approximately 1000 persons (or more) are involved, the data processing may still be considered large scale. In that case, besides the number of persons involved in the study, one should also assess (i) the amount of data collected from these persons taking into account the type/risk level of the personal data, (ii) the duration of the data processing, (iii) the geographic scope or extent of the processing. For example, if you would collect and process data across several European countries with 10+ socio-economic data items of 1200 individual persons for several years in a row, that is likely "large-scale processing". Other examples of a large-scale processing activity are:* • *Monitoring driving behavior of road users on Dutch highways* • *Collecting data of Covid patients* • *A hospital that processes patient data as part of its usual operations*		x

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	• *A transport company that processes travel information of people who travel by public transport in a certain city. For example, by tracking them through travel maps.*		
4	Does this processing activity involve the use of new or innovative technologies? *Examples of a new technology: combining fingerprints and facial recognition for physical access control, the use of bodycams in public spaces, the use of new technical methods in conducting research such as AI. This question also refers to new technologies that have not been deployed by TU/e so far.*		x
5	Does your study involve systematic (c.q. automated) monitoring of persons? *Additional explanation: Consider data processing activities that have the purpose of observing, monitoring or controlling individuals, for example in circumstances where the individuals are not aware by whom their personal data is collected and how it is used. Examples of such activities are using camera systems to monitor driving behavior on highways, monitoring email inactivity or employee phone use, certain applications of machine learning and artificial intelligence.*		x
6	Does the study involve collaborations (with third parties) in which data are shared or exchanged in order to link or combine data? *Additional explanation: This may often apply in a collaboration between the university and a commercial party, contract research, etc. It is important to assess this for all data in the entire project, not just your own data. An important consideration in this situation is whether the person whose data is involved could have expected that data from these different databases or sources of information were to be combined. For example, it is less likely for data subjects to expect that databases from different parties will be combined and the results are used for different purposes than one could reasonably expect; this may apply for example in a collaboration between the university and a commercial party.*		x
7	Will the study include data processing activities that prevent data subjects from exercising their rights or using a service or contract? *Additional explanation: Examples include processing operations carried out in public places that people cannot avoid (train station, airport, shopping mall, public university premises, etc.) or processing operations whose purpose is to allow or not allow data subjects to use a service or enter into a contract (examples: by refusing to pay a benefit, not being able to apply for a loan, etc.).*		x
8	Will the study process personal data to score, rank or profile persons? *Additional explanation: Examples: monitoring (highway) roads to give road users a "score" based on their detected driving behavior, a bank assessing its customers based on their creditworthiness, or an organization building behavioral and marketing profiles based on use of their website or navigating their website.*		x
9	Does your data processing include activities that involves composing "**blacklists**" – and, in particular, in relation to sensitive or special category data, such as communication data, financial records or credit scores, genetic data, biometric data, health data, camera surveillance data, location/GPS data, internet-of-things data, employee monitoring, observing or influencing behaviour, etc. *Additional explanation: This situation will not be a common occurrence in research, but you may indirectly be involved in this. In general, this typically concerns processing operations involving personal data relating to criminal convictions and offences, data relating to unlawful acts, data concerning unlawful or annoying behaviour or data concerning bad payment behaviour by companies or individuals are processed and shared with third parties (blacklists or warning lists, as used, for example, by insurers, hospitality companies shopping companies, telecom providers as well as blacklists relating to unlawful behavior of employees, for example in the healthcare sector or by employment agencies, etc.).*		x
10	Will personal data be transferred or shared outside the EU/EEA? EU data protection rules apply to the European Economic Area (EEA), which includes all EU countries and non-EU countries Iceland, Liechtenstein and Norway. *Additional explanation: The GDPR has drafted additional requirements for transfers data outside of the EU/EEA. Typically, additional safeguards must be implemented to protect the personal data of residents in the European Union. For example, if you collaborate with an American, Indian or Chinese university or other third party outside the EU/EEA, you must first check whether this is allowed and under which conditions this is allowed. Another typical example is storage of data on American providers of cloud (storage) services. Please contact the data stewards first to discuss this.*		x
11	Will any raw or anonymized personal data or any other sensitive data or research results from the project possibly be transferred to a high-risk country*? ***High risk countries**: China, Russia, Iran, Turkey, and North Korea.* *If personal data or other potentially sensitive data is exchanged with one of these countries, or if part of the data processing takes place in one of these countries: **an advice from the Data Protection Officer, the kennisveiligheidsteam (Knowledge Security team), and the CISO (Chief Information Security Officer) is ALWAYS required.***		x

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Part 7a: Processing of research data

1	Is consent your legal basis for processing the personal data in your study? *Additional explanation: What is a legal basis? One of main principles in the GDPR is to ensure that personal data is processed lawfully, fairly, and transparently. To comply with this principle, the processing of personal data also requires that you have a valid legal basis for the personal data processing activity.* *In research projects, the legal basis is often but not always consent. However, it is possible that it is not clear or not possible to establish whether to use consent as a legal basis.* *Some examples where consent may not be applicable as legal basis are covert research, data collection in public spaces, secondary data analysis of existing data, data that are transferred to you by a third party, consent is not possible or would require disproportionate effort, etc. In that case, please indicate which legal basis you think that applies or (preferably) contact a data steward first.*	☒ Yes and it will be obtained via an informed consent form. An informed consent template* is attached to this application. ☐ No, I will use another legal basis to process the data. Namely, …….. * You can download a suitable template **here**.
2	Where will the data come from?	☐ Data obtained from another party (secondary data use) ☒ New data collected only by my research team ☐ New data collected together with collaborators
3	Which of the following tools will you use to process personal data?	**Surveys** ☐ Qualtrics ☐ Limesurvey ☒ MS Forms ☐ Other, namely …….. **Interview/workshop recordings** ☒ Voice/video recorder ☐ Phone in a flight mode ☐ MS Teams ☐ Other, namely …….. **Transcription** ☐ Manual transcription ☒ Microsoft Office software (e.g. Word, Teams) ☐ Other, namely …….. **Statistical analysis** ☐ SPSS ☒ R ☐ Other, namely …….. **Other tools**, specifically Miro
4	Where will the data and in particular the personal data be stored during and after completion of the study? If you have already uploaded your Data Management Plan, you can refer to your Data Management Plan.	☒ SURF drive ☒ Onedrive ☐ Research Drive ☐ Network Drive

	Additional explanation: University supported-storage facilities are SURFdrive, SURF Research Drive, Ceph, departmental drives (this includes BE Project Drive), and the TU/e instance of Microsoft OneDrive. For most personal data, the use of SURF Research Drive, departmental drives (including BE Project Drive) and SURFdrive is required.	☐ Research Manager ☐ Other, namely ……
Part 7b: Safety and security measures		
1	Will you pseudonymize/anonymize the data? *Additional explanation:* *Anonymization: remove all direct identifiers (name, address, telephone number etc.) but also indirect identifiers (age, place of birth, occupation, salary) that, linked with other information, can lead to a person's identification. Anonymization to the point that a data subject is no longer identifiable means that the anonymized data is not considered to be personal data anymore.* *Pseudonymization: replacing the unique identifier of a data subject with an artificial pseudonym. This means that identification is still possible with the identification key. The identification key needs to be stored securely and separately from the pseudonymized data. If the data subject can be identified by combining data with additional information, the data is also called pseudonymous.*	☒ Yes ☐ No If yes, describe how: The main personal data that will be collected are interview recordings. Once these recordings have been transcribed, they will be immediately deleted. The demographic
2	Is access to (personal) data restricted? (Select all that apply)	☐ No ☐ Yes, via access control ☐ Yes, via password protection ☒ Yes, access only given to TU/e research team ☐ Yes, access only given to research team, including non-TU/e collaborators ☐ Other, specify…….
3	Who will have access to the data during and after completion of the project? (Select all that apply)	☒ Main researcher ☒ TU/e supervisor(s) ☐ External supervisors ☐ TU/e research team ☐ Other, specify…….
4	Will you store data for future research?	☐ No ☐ Yes, in a public data repository ☐ Yes, in a public data repository under restricted access ☒ Yes, in a TU/e-recommended storage (SURF Research Drive, Network Drive)
5	Will you share data outside the TU/e?	☐ No ☒ Yes, in a fully anonymized form ☐ Yes, raw or pseudonymized data* *If you selected this box, make sure that a suitable data agreement is put in place. You can contact the Data Stewards for support in preparing such an agreement
6	How long will data be stored after the end of the project?	This project will very likely have a follow-up project in the form of a Final Master Project starting next semester. Therefore, the data will be stored until

		February 2025.

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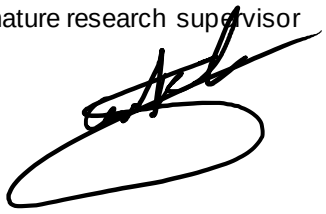
Part 8: Closures and Signatures

1	Enclosures (tick if applicable and attach to this form):	☒ Informed consent form (Appendix E) ☐ Informed consent form for other agencies when the research is conducted at a location (such as a school) ☐ Text used for ads (to find participants) ☐ Text used for debriefings ☐ Approval other research ethics committee ☒ The survey the participants need to complete, or a description of other measurements (Appendix B, C & D) ☐ Data Protection Impact Assessment checked by the privacy officer ☐ Data Management Plan checked by a data steward
2	Signature(s)	Signature(s) of applicant(s)  Date: 03/05/24 Signature research supervisor  Date: 03-05-2024

Appendix A – Picture of the custom controller

Appendix B – ISO 9241-9 Questionnaire

1. The force required for actuation was (1: too low – 5: too high)
2. Smoothness during operation was (1: very rough – 5: very smooth)
3. The mental effort required for operation was (1: too low – 5: too high)
4. Accurate pointing was (1: easy – 5: difficult)
5. Operation speed was (1: too fast – 5: too slow)
6. Finger fatigue (1: none – 5: very high)
7. Wrist fatigue (1: none – 5: very high)
8. General comfort (1: very uncomfortable – 5: very comfortable)
9. Overall the input device was (1: very difficult to use – 5: very easy to use)

Appendix C – System Usability Scale

(Strongly disagree – Strongly agree)

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

Appendix D – Player Experience Inventory

Constructs	Items	*Strongly disagree*	*Disagree*	*Slightly disagree*	*Neither disagree, neither agree*	*Slightly agree*	*Agree*	*Strongly agree*
		-3	*-2*	*-1*	*0*	*1*	*2*	*3*
Meaning	Playing the game was meaningful to me.							
	The game felt relevant to me.							
	Playing this game was valuable to me.							
Curiosity	I wanted to explore how the game evolved.							
	I wanted to find out how the game progressed.							
	I felt eager to discover how the game continued.							
Mastery	I felt I was good at playing this game.							
	I felt capable while playing the game.							
	I felt a sense of mastery playing this game.							
Autonomy	I felt free to play the game in my own way.							
	I felt like I had choices regarding how I wanted to play this game.							
	I felt a sense of freedom about how I wanted to play this game.							
Immersion	I was no longer aware of my surroundings while I was playing.							
	I was immersed in the game.							
	I was fully focused on the game.							
Progress Feedback	The game informed me of my progress in the game.							
	I could easily assess how I was performing in the game.							
	The game gave clear feedback on my progress towards the goals.							
Audiovisual Appeal	I enjoyed the way the game was styled.							
	I liked the look and feel of the game.							
	I appreciated the aesthetics of the game.							
Challenge	The game was not too easy and not too hard to play.							
	The game was challenging but not too challenging.							
	The challenges in the game were at the right level of difficulty for me.							
Ease of Control	It was easy to know how to perform actions in the game.							

	The actions to control the game were clear to me.							
	I thought the game was easy to control.							
Clarity of Goals	I grasped the overall goal of the game.							
	The goals of the game were clear to me.							
	I understood the objectives of the game.							
Enjoyment *	I liked playing the game							
	The game was entertaining							
	I had a good time playing this game							

* "Enjoyment" is not a construct of the PXI but it may be interesting to measure as well.

Appendix E – Informed Consent Form

Information sheet for research project "Video game controller for asymmetric VR-gaming"

1. Introduction

Eindhoven Technical University (TU/e invites you to take part in research project "Video game controller for asymmetric VR-gaming", because you got contacted by the main researcher and you willingly responded to take part in this research.

Joining this research project is your choice. Your participation is completely voluntary and does not pose any physical, legal or economic risks. You are not obliged to answer questions you are uncomfortable with, and you can withdraw from the research at any time without explaining why. Declining or withdrawing will not have negative impact for you.

Before you decide, please read the following information to understand what the research is about, what we expect from you and how we handle your personal data. After reading, you can sign up by completing the attached form.

If you have questions, feel free to contact the researcher via j.a.m.v.gurp@student.tue.nl. You can also discuss this information with people you trust.

2. Purpose of the research

The purpose of this research project is to check the usability of a custom video game controller made in collaboration with the company "Enversed". This device was developed to discover what the main functionalities of a controller intended for asymmetric Virtual Reality (VR) gaming could be. The person using the controller in such a scenario is not using VR, but they are playing a game together with someone who is. Furthermore, this study researches an example of such an asymmetric VR game that utilizes this custom controller. The gathered data will be used to make improvements to this product and to gain insights into how asymmetric VR games should be developed. These insights could assist in the actual eventual deployment of such controllers and games in the "Enversed VR Center" in Eindhoven. The project is managed by Jules van Gurp and the results of these research will be documented in his project report.

3. Controller in the sense of the GDPR

TU/e is in charge of handling your personal data for the research. You can contact TU/e at:

Technische Universiteit Eindhoven
De Groene Loper 3
5612 AE Eindhoven

4. What will taking part in the research project involve?

During this research you will be using a VR headset. You can always take of this headset in case you experience any discomfort such as motion sickness. You can also notify the researcher so they can help you take it off.

In the research project we will collect your personal data using the methods:

- Interviewing you about your experience using the controller and playing the asymmetric VR game. Notes of your answers will be written down and the interview will be recorded via audio. Also, we will make a transcript of the interview.
- Presenting you a questionnaire about your experience with the controller and the asymmetric VR game which you can fill in in writing.

For your participation you will not be compensated.

5. What personal data from you do we gather and process?

We collect and process the following personal data which is necessary for the project purpose:

Category	Personal data	Purpose	Retention period
Audio recording	*Voice recording of interview*	*To make a transcript of the interview*	*One month*
Demographics	*Handedness & level of experience with video game controller*	*These factors might influence the experience with the controller*	*One month*

Your data is retained only for the time period as specified in the table. Keeping your data for this period helps us to comply with scientific principles, such as producibility and verification. After this period, your personal data will be deleted or anonymized to ensure it can no longer be linked to you.

6. Stopping your participation

If you end your participation in the research we will not use your data anymore from that moment on.

For questions, ending your participation, or complaints, please contact the main researcher via j.a.m.v.gurp@student.tue.nl.

You have the right to request access, rectification, objection, erasure or adaptation of your data. Submit your request through privacy@tue.nl.

For concerns or questions about the handling of personal data e-mail the data protection officer of TU/e at dataprotectionofficer@tue.nl. You can also file a complaint with the Dutch data protection authority: the Autoriteit Persoonsgegevens.

7. Legal basis for processing your personal data

We process your personal data because it is part of the university's public task to conduct scientific research as stated in article 1.3 of the Dutch Wet Hoger onderwijs en Wetenschappelijk onderzoek. The TU/e always follows established codes of conduct for research integrity and the scientific standards.

8. Who has access to your personal data?

Access to personal data within TU/e

Only authorized employees involved in the research, like members of the committee that keeps an eye on the safety of project, have access to your personal data, but only if necessary for their tasks. The authorized employees will keep your personal data confidential.

For processing your personal data in this project, we will use the services of the following parties:

- Storage solution*: SURF ResearchDrive, Microsoft (Netherlands)*
- *Survey tool: Microsoft (Netherlands)*
- *Transcription tool: Microsoft (Netherlands)*
- *Data analysis tool: Miro (EU)*

With these parties TU/e has a suitable agreement in place to ensure specific obligations to protect your personal data are followed.

TU/e will process your personal data within the European Economic Area (EEA) by storing your data on a server inside the EEA.

9. How are your personal data protected?

TU/e has implemented appropriate technical and organizational measures to protect personal data. These measures include using centrally managed and verified research and storage tools. Additionally, data access is limited through authorization and authentication and organizational guidelines on the processing of personal data are being followed.

10. Confidentiality, storage of data and future research

The collected data will be stored on SURF ResearchDrive & Onedrive.

We will make sure that any published research results will not include confidential or identifiable information about you unless you explicitly agreed to it, for example if you want your name to be mentioned in publications.

We might use anonymized data for new purposes such as research or education. We will ensure the data cannot be linked to you and we will not disclose anything that makes you identifiable.

This research has been assessed and approved by the ethical committee of Eindhoven University of Technology.

***** Scroll down for the form *****

Consent form for participation

By signing this form, I confirm:

1. I have enough information about the research project from the separate information sheet. I have read it and I had the chance to ask questions, which have been answered to my satisfaction.

2. I take part in this research project voluntarily. There is no explicit or implicit pressure for me to take part in this research project and I understand I can stop my participation at any moment, without explaining why. I do not have to answer any question I do not want to answer.

3. I know my personal data will be collected and used for the research, as explained to me in the information sheet.

Furthermore, I consent to the following parts of the research project:

4. I consent to my answers being used for quotes in the research publications – without including my name.

   YES ☐ NO ☐

Name of Participant:	Name of researcher:
Signature:	Signature:
Date:	Date: