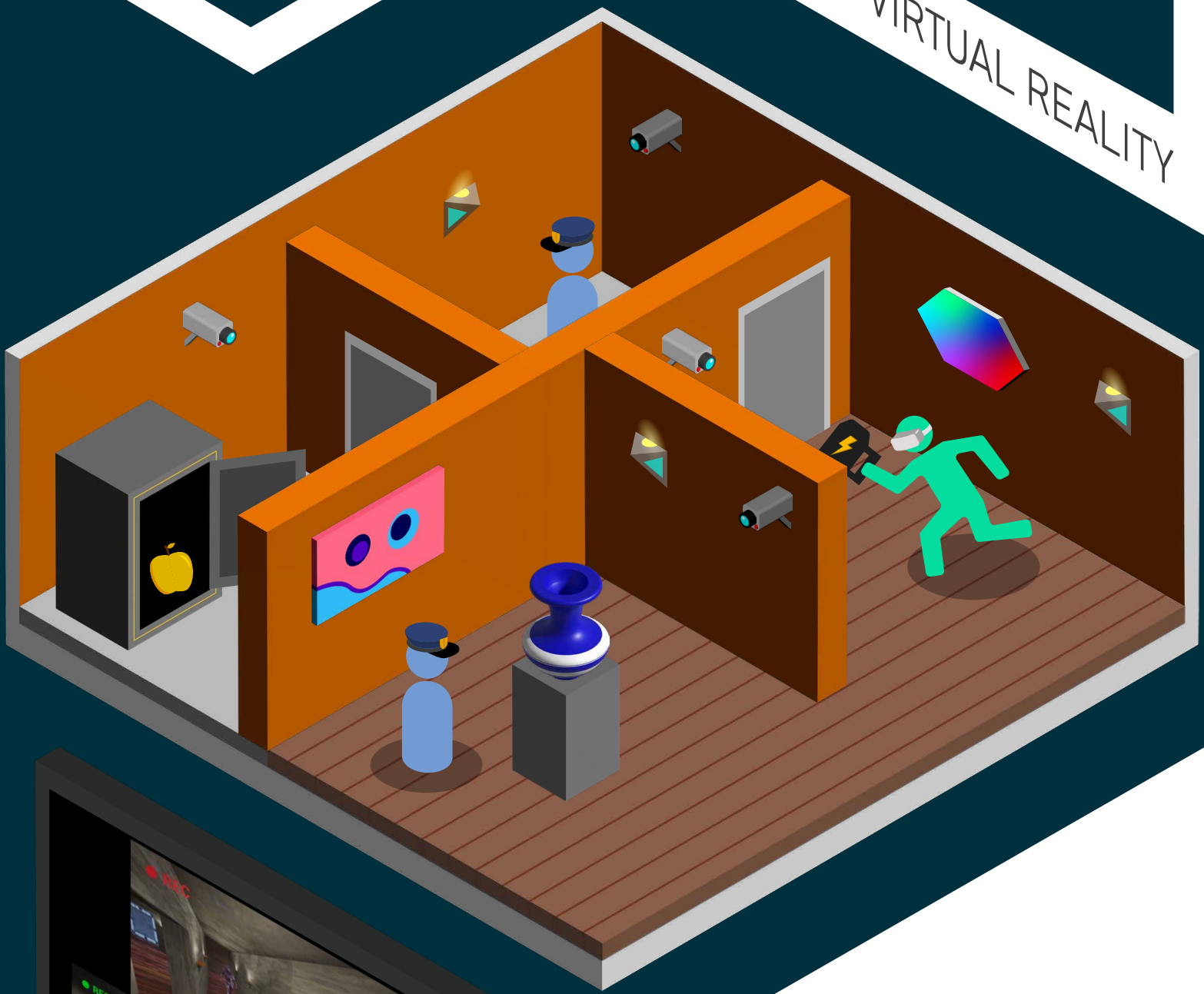
Heist EXtRavaganza

CO-LOCATED
ASYMMETRIC
VIRTUAL REALITY



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Final Master Project

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ENVERSED ENTERTAINMENT

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Introduction

Interest in Virtual reality (VR) has been rising for some time now, and for good reason. The technology offers its users novel experiences in which they can immerse themselves in the virtual world. However, VR head-mounted displays' (HMDs) immersive qualities can also isolate its wearer from the world around them. In co-located gaming experiences these characteristics can even lead to social isolation [6]. Bystanders, who are not wearing a HMD, can often only have a peek into the digital world via a 2D display. However, such a setting offers them no opportunities to interact with the virtual world.

Asymmetric VR (AVR) can turn these spectators into co-players. AVR lets one or more VR players play together with one or more non-VR players using different interface types to interact with the same game world [11]. The acknowledgment of co-located players, and by extension the physical world, may negatively impact the level of sensory immersion [51], and consequently, the spatial presence experienced by the VR player. However, if these interactions fit well into the game's context, loss in immersion may not even be a consequence [10]. The different tasks assigned to players can also induce roleplaying, increasing immersion [54]. Additionally, human to human interactions in general offer possibilities to increase social and co-presence [10]. Research suggests that social presence contributes more to creating satisfactory gameplay than spatial presence [9]. Furthermore, the addition of social interactions can create more joyful gaming experiences in general [33]. Providing players with complimentary abilities through the introduction of asymmetries also promotes teamwork in collaborative games [19] and assists in preventing more skilled or dominant players from simply commanding their teammates [60].

While AVR is still a somewhat emerging field of research, a good foundation has already been established describing how asymmetries can be created and leveraged through the implementation of specific mechanics [25,35,42,46]. What Harris et al. [25] first coined as the asymmetry of interface mechanic is what makes AVR what it is. Award-winning AVR games, such as Keep Talking & Nobody Explodes [50] and Acron: Attack of the Squirrels! [45], use a paper manual and smartphones as non-VR controllers, respectively. The use of non-standard interfaces can introduce novelty to a gaming experience and make it more accessible and inclusive. An interface such as a paper manual requires its user to be literate, but does not expect them to have prior experience with traditional gaming controllers. The complexity of interaction with an interface is influenced by the quantity and clarity of the affordances offered by it. The creation of gaming experiences utilizing a set of physical interfaces with varying levels of complexity can offer players the option to select a controller that fits their skill level or personal preferences. Some people also value being able to vary their participation level throughout a gaming session [31]. Different interfaces can each offer a different required participation level. By swapping controllers throughout a session, players can switch roles and thus vary their participation level. Furthermore, it lets them experience and interact with the same game in a different manner then before, increasing replayability.

While costs are coming down, experiencing VR at home can still be expensive. HMDs are costly and many games require additional powerful computing hardware to run them. These factors have contributed to the rise of VR arcades during the past few years. These locations let visitors experience VR without them needing to invest in the technology themselves [7]. This project has been done in collaboration with one such VR arcade, namely Enversed. Most of the VR games they offer can only be played by two players simultaneously (both VR), despite the groups visiting them often consisting out of more than that. Consequently, customers are waiting their turn while only being able to spectate others during most of their visit. Engaging these spectators in the same game world as the VR players could improve their experience. However, simply increasing the number of co-located VR players can be undesirable for several reasons. Players risk colliding with each other in room-scale VR without very accurate spatial tracking and virtual representations of other players' location. Secondly, additional VR players require more HMDs, increasing costs. Furthermore, motion sickness is a symptom commonly induced by VR [30,44], making it undesirable for many people to be in VR for extensive periods of time. AVR can engage larger groups of visitors simultaneously in a shared experience while offering people the opportunity to take a break from VR.

The project described in this report has the aim of making co-located VR games a more social and shared experience through the extensive exploration of asymmetry of interface. It investigates how a set of interfaces can be created for AVR with the goal of creating a highly asymmetric gaming experience to promote enjoyment and social engagement. Design guidelines based on literature are set up to assist in the creation of a coherent set of interfaces.

Background

Asymmetry in play

Asymmetric games are “a genre of games where there are two or more groups of players with different objectives and gameplay mechanics” [18]. Research comparing symmetric and asymmetric gameplay suggests that the latter can increase social presence, connectedness, and engagement [13,24]. Various Mechanics of Asymmetry exist that designers can implement in their games: asymmetry of Ability/Challenge, Interface, Information, Investment, Goal, and Responsibility [46]. These different types of asymmetry can have a variety of benefits in multiplayer games. They can make games more inclusive by letting players choose roles that fit them [23]. Asymmetry of Ability/Challenge can make it more difficult for less experienced players to compare themselves to more skilled ones. In asymmetric cooperative games, asymmetry of Ability/Challenge and Information can make every player necessary to achieve team goals, making them feel useful [60]. Asymmetry of Information also has the added benefit that it can encourage communication, thereby enhancing social interaction [25,49,60].

Through the implementation of these various Mechanics of Asymmetry, certain Dynamics of Asymmetry can emerge between players in the form of interdependence. There are three forms of directional dependence: Mirrored, Unidirectional, and Bidirectional [25,46]. Mirrored dependence occurs when “the nature of each player’s reliance on each other is identical” [25]. Therefore, this form is very uncommon in fully asymmetric games. Unidirectional dependence arises when one player relies on the other, but not vice versa. Bidirectional dependence is when multiple players rely on each other, but in different ways. High levels of player interdependence can offer benefits such as increased communication and reduced frustration [16]. Additionally, it can improve the sense of social connectedness [61]. Lower levels of interdependence can foster an atmosphere of competitiveness, even in collaborative games [16,24]. Despite players having to work together, lower levels of interdependence can, for example, lead to more competitive players trying to see who can reach the end of a level first.

Asymmetric interfaces

AVR makes use of asymmetry of interface and games such as Keep Talking & Nobody Explodes [50], Acron: Attack of the Squirrels! [45], Takelings House Party [15], and Panoptic [53] have proven its potential. AVR has the ability to improve presence and enjoyment levels for both HMD and non-HMD players [20,37,61]. Additionally, it can even make VR gaming experiences more enjoyable and engaging for spectators [31,61], as it offers spectators a projection of the virtual world. Furthermore, non-VR players are more sensorially available to receive and provide social cues to spectators. A VR player’s face and sight is mostly blocked by a HMD, so social interactions such as facial expressions cannot be exchanged with spectators.

Most existing AVR games and research let non-VR players interact with the virtual world using more widespread forms of gaming interfaces such as gamepads, 2D displays, or smartphones [15,28,31,34,35,45,49,53]. The success of some Keep Talking & Nobody Explodes [50] with its paper manual interface shows great promise in how the characteristics of non-standard gaming interfaces can encourage social interaction through increased asymmetry and contribute to an enjoyable shared gaming experience. However, aside from this example, no commercially available AVR games seem to exist using non-conventional interfaces.

Some research investigates how alternative interfaces can improve social engagement and enjoyment for both HMD and non-HMD players [20,21,47,61]. However, the quantity of knowledge around this topic seems to be limited. ShareVR [20] highlights how VR and non-VR players can interact in interesting ways through the use of physical props and a moveable handheld display used as a “window into the virtual world”. Astaire [61] goes in a different direction and turns the players themselves into interfaces by letting a VR player dance with a non-VR player. Both these projects show how thinking outside of the box when creating interfaces can enhance co-located AVR experiences. However, all of these examples are designed for 2 players while no literature seems to investigate the concept of providing every player with their own unique interface in groups of 3 or more people.

Figure 1 *Nintendo Labo Blaster [41]*

Nintendo Labo [41] was perhaps not that commercially successful, but it still displays how alternative interfaces can create incredibly interesting and novel experiences, without the need for these interfaces to be technologically complex. Labo uses cardboard add-ons for the Nintendo Switch’s Joy-Con-Controller. For some of these interfaces the input modalities of the controller do not drastically change, but its form and haptics do. The Labo Blaster for example is a cardboard shotgun that is controlled by making a pumping action and pressing a trigger. The cardboard is not necessary to use the Joy-Cons as a shotgun, since their motion-sensing capabilities can also detect a pumping action when being done in the air, and one of its triggers could also be

used to replace the paper trigger. However, the prop's aesthetics and feel help to tell a more convincing and enjoyable story. Alt.ctrl.GDC [62] is a part of the Game Developers Conference and showcases unique alternative interfaces. 996 Tech [36] is a game presented there where players need to race each other while sitting on toilets and steer using plungers. This game could have easily be controlled with a gamepad, but that would have likely made it drastically less enjoyable and novel. An interface's form can be used as a tool for transmedia storytelling [27]. A game's story can partly be told by a digital medium in the form of the game itself, but also by physical mediums such as an interface or even a set of them.

Design guidelines

To assist in the creation of a set of unique interfaces for AVR, some design guidelines were set up based on literature research. The design goal of the interfaces was to make co-located VR games a more social and shared experience.

Research suggests that cooperative AVR games create a higher sense of co-presence and social presence in players compared to competitive ones [28]. Furthermore, a sense of team competence can have an effect on the perception of individual competence [52]. Therefore, collaborative games can make less skilled players feel more competent.

Additionally, it is advisable that at least one interface provides a projection of the game to spectators. In the cases where more people are present compared to roles available, a projection can be a way to engage these additional people [20,31].

It is also recommended to have tight coupling between players' roles through high interdependency and inclusion of each other in their respective gameplay loops. Tight coupling and high interdependency can create improved levels of social connectedness, and encourages more social interaction [29,39,61]. However, players should not be made dependent on each other just for the sake of interdependence, as this can lead to what Harris & Hancock [24] call "tedious reliance". A teammate's action is better perceived when it is no irrelevant task, but a challenge they actually have to overcome themselves to make a meaningful contribution to the team [20,24].

Research further suggests that players appreciate varying levels of participation and dependence throughout a gameplay session [24,31].

Lastly, it is advisable to make the interfaces and their aesthetics fit the context of the game, since this can contribute in telling the game's story and thus engaging and amusing players [40]. Taking inspiration from pervasive games, it can help with extending the gaming experience and the magic circle of play into the real world where non-HMD players can be included socially [38].

Action "Boom!"	Social "Let's Play Together"	Mastery "Let Me Think"	Achievement "I Want More"	Immersion "Once Upon a Time"	Creativity "What If?"
Destruction Guns. Explosives. Chaos. Mayhem.	**Competition** Duels. Matches. High on Ranking.	**Challenge** Practice. High Difficulty. Challenges.	**Completion** Get All Collectibles. Complete All Missions.	**Fantasy** Being someone else. somewhere else.	**Design** Expression. Customization.
Excitement Fast-Paces. Action. Surprises. Thrills.	**Community** Being on Team. Chatting. Interaction.	**Strategy** Thinking Ahead. Making Decisions.	**Power** Powerful Character. Powerful Equipment.	**Story** Elaborate plots. Interesting characters.	**Discovery** Explore. Tinker. Experiment.

Figure 2 *Yee's Gamer Motivation Model [58]*

Player profiles

Player profiles can assist in designing interfaces that appeal to a variety of player types. Players are not a homogenous group, so investigating different game-related preferences can help tailor a game to a broader audience [26,55,58]. Many researcher have attempted to segment gamers into profiles [4,17,22,57]. One of the first and best-known attempts at classifying gamers is the Bartle taxonomy of player types. Bartle [4] describes 4 types of players: Killers, Achievers, Socializers, and Explorers. However, this taxonomy has received criticism [22]. Some argue that it is overly simplistic. Another point of criticism is that players can have multiple motivations for play simultaneously, and the magnitude of these factors can vary for every individual.

Yee used Bartle's work as a reference to develop the Gamer Motivation Model [56]. This model consists of 6 main motivational factors: Action, Social, Mastery, Achievement, Immersion, and Creativity. Each of these factors includes 2 sub-factors (Figure 2). A notable difference between the frameworks is Yee's inclusion of Immersion, which is an important factor in why people play VR games. This model also does not give the impression that one factor is mutually exclusive with another.

However, it is important to mention that while earlier work from Yee [55,59], on which the model is partly based, has been more clearly validated and peer-reviewed, the same cannot be said about the current model. Nonetheless can it serve as a useful base for considering various motivations for play in an effort to make games more inclusive for different types of players.

Developing a set of different interfaces and roles also has the unique advantage that one interface can focus more on certain motivational factors, while another focuses on others. However, it is almost impossible to

design an interface that caters to only one specific motivational factor without heavily limiting its interaction possibilities. Such a limitation should also not be the goal, since no gamer has only one motivation for play. Nonetheless, these categories can still assist in making the interfaces more distinct from each other, thereby increasing asymmetry.

Reflecting on my M2.1 Project

During my M2.1 project, I also developed interfaces for AVR, in the form of the AsymDroid controllers (Figure 3). An accompanying 3-player AVR game was develop together with these controllers (Figure 4). They showed great promise in making VR more inclusive and social through asymmetric play. This project was also done in collaboration with the company Enversed, and they were very satisfied with the work delivered. However, the fact that this controller was intended for use with a variety of AVR games caused its input modalities to be quite generic and not that alternative compared to more traditional gaming controllers. Asymmetry was what made the experience of using these controllers unique and significantly contributed to enjoyability. However, the controllers themselves did not necessarily create an asymmetric experience, the AVR did. Furthermore, the play sessions showcased that most of the social interactions were between the two non-VR players, since they had to cooperate. I felt like asymmetry of interface could be explored further to harness its full potential in making VR a more social and enjoyable experience to a wider audience. Therefore, I set the goal of making a set of various interfaces to offer every player a own unique role.

Figure 3 *The two AsymDroid controllers developed during my M2.1*

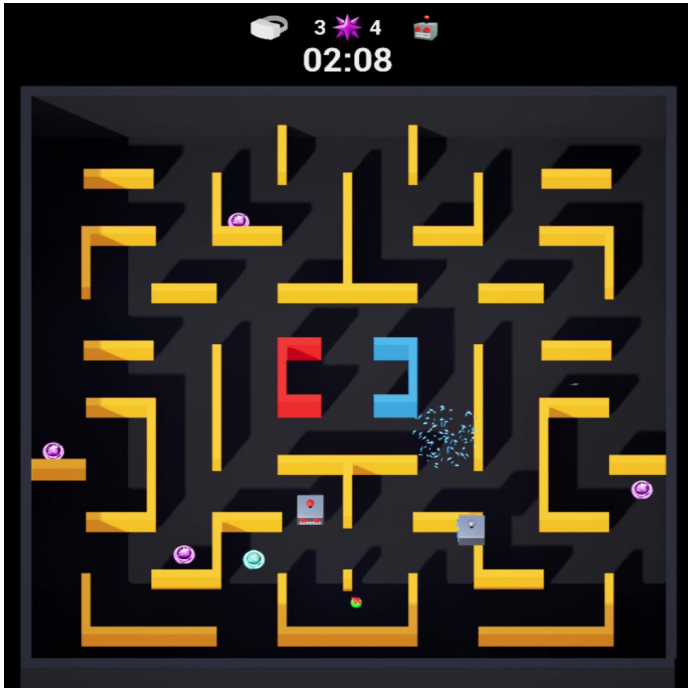

Figure 4 *The AsymDroid game seen from the perspective of the non-VR players*

Design Process

This project followed a double diamond design process [14]. During the Discovery phase, extensive effort was put into creating a solid base of understanding around the topic of asymmetry in play and asymmetric interfaces. Furthermore, benchmarking was done by looking at commercially available alternative interfaces, but also ones from literature and Alt.Ctrl.GDC [62] (Appendix A). Literature about player profiles was also gathered to assure that the various interfaces would be distinct from each other and attractive to a wider audience. This knowledge was then used during the Define phase to set up design guidelines for the interfaces and an accompanying AVR game. Additionally, based on literature and the AsymDroid play sessions, the decision was made to make the accompanying game cooperative so more social interactions between non-VR and VR players would be facilitated. The key findings from the literature research and benchmarking can be found in the background section of this report.

This project was done in collaboration with the company Enversed, since they were interested in discovering how AVR can engage spectators in the VR games they offer to visitors of their VR centre. They assisted by me having biweekly meetings with their CCO Tim van der Grinten. These conversations offered me feedback from an expert and gave me insights into how my concepts would be interesting from a market perspective.

First iteration

To diversify my initial concepts, I sketched out ideas for interfaces that each focussed on generating one of the motivational factors from the Gamer Motivation Model. None of the concepts focussed on the Immersion factor, as I assumed the VR role would naturally cater to players interested in it. The ideas were not necessarily created in the context of specific game concepts.

Action

One of Action's sub-factors is excitement, which relates to fast-paced activities and thrills. Therefore, I thought interfaces that facilitated a lot of fast movement would suit this category. Some concepts involved players running around the play area to press various buttons or deliver modular controller parts to multiple co-players, as these parts needed to be shared. Other ideas were more stationary but still encouraged movement. For instance, players could spin crank wheels really fast, or two people could work together to move handles up and down, similar to operating a pump trolley. Players could also smack a hammer on plates as seen in Cosmic Crew [43] from Alt.Ctrl.GDC, or use their feet to generate force while feeling resistance, akin to using a foot pump.

Social

The concepts in this category mainly focused on communication. An interface might include a display showing various projections of the VR world, each from a different perspective. Its user had to communicate the displayed information to other players. Additionally, this user could be equipped with a microphone to speak directly to the VR player, making them the main line of communication between the virtual and real worlds in scenarios where non-VR players are not physically near the VR player. Another idea involves auditory information provided through a speaker, which users must then relay to others. Social interfaces might also include shared control mechanisms. For instance, two players could synchronously pull a rope in a specific rhythm to power something in the virtual world. This concept took inspiration from button spinner toys.

Mastery

One of this category's sub-factors is Strategy. Therefore, one concept was a board that represented the virtual world. On it a variety of pawns could strategically be placed. The idea was that its user had to think ahead when placing these pawns as it could influence which resources would be available to the VR player in certain parts of the map. Moving camera pawns could maybe change what parts of the virtual world could be seen by other non-VR players. Perhaps even parts of the board could be physically manipulated to transform the virtual terrain. The other sub-factor is Challenge. Therefore, interfaces that have to be controlled very precisely could be interesting. A force feedback push-pull lever was an option. Something similar to Gilliam's Great Escape [32] from Alt.Ctrl.GDC where a golfing game was played with the lever from a toaster was also deemed interesting.

Achievement

Power is one of Achievement's sub-factors. Therefore, I thought that interfaces that project importance and impact might be interesting. For example, the aesthetics of a red toggle switch with a cover over it could embody importance. Another option was something akin to a dynamite plunger providing resistance when pushing it down. The other sub-factor is Completion. If the resistance of this plunger interface would increase throughout a game, it could give perhaps give a sense of progression, relating to completion. Perhaps an interface could evolve throughout a game. Perhaps the cover of the aforementioned toggle switch would only unlock after the VR player performed a certain action. Perhaps another player could find powerups, making them available to the achievement focussed player.

Creativity

One of Creativity's sub-factors is Design, focussing on expression and customization. Therefore, one direction was using blocks, 3D tracked pens, or even sand with which terrains or objects could be created in the real world and then replicated in the virtual. Other options also included the Discovery sub-factor. These interfaces were modular, so players could customize and experi-

ment to find out what worked best, or what they preferred. Other ideas purely focussed on Discovery and had players move around the play area to find or scan tokens. Doing this could perhaps provide co-players with information or powerups. Another example took inspiration from ShareVR's [20] "window into the virtual world". A player could walk around with a display to see the VR world from different perspectives.

Feedback

My coach highlighted that many of these concepts lacked a clear gameplay loop. When would its user know when to perform actions and how would these affect others' loops? From Enversed I also received feedback that interfaces that involved moving around the play area were not ideal. The risk of collisions between players is still notable, even if players' locations are tracked and projected to VR-players. They noted that VR players can be so immersed that they do not always notice spatial cues such as sound. Therefore, sudden movements or them moving backwards can be risky. Additionally, physically larger interfaces were less interesting to them, since these could permanently claim one of their play booths, instead of being easily moved and stored when not in use.

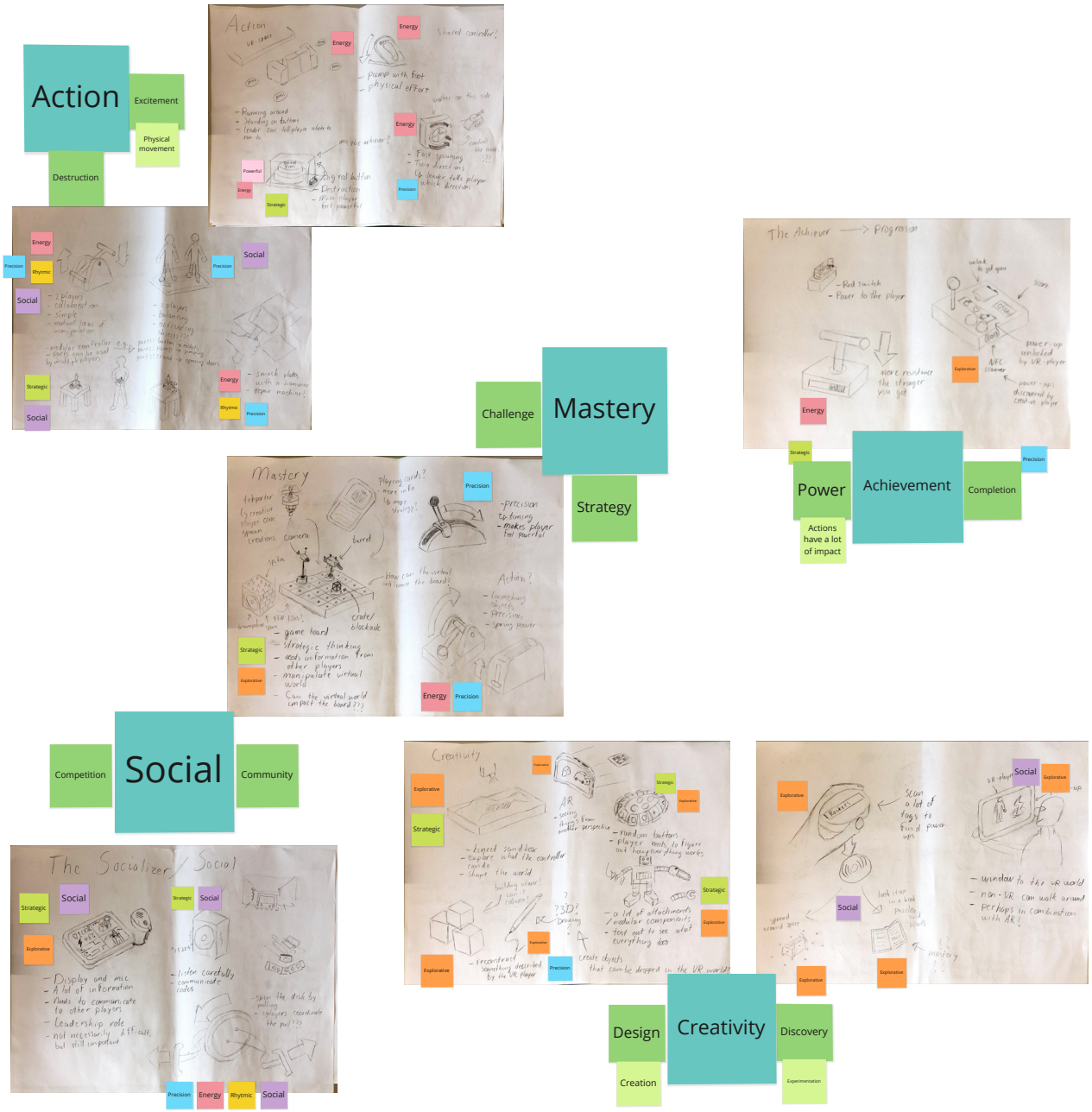

Figure 5 *The various sketches from my first iteration per motivation factor (interaction categories next to sketches will be discussed later in this report)*

Second iteration

In this ideation round I came up with 3 game concepts with each 4 interfaces. The ideas for some of these interfaces were inspired by the previous iteration. Placing these interfaces in the context of a game assisted in sketching a clearer picture of the various gameplay loops and how their users would interact with and be dependent on each other. Dawes et al. [11] identify 5 AVR subgenres. For 3 of these VR and non-VR players interact cooperatively: “Lifeline”, “Order Simulation”, and “Perspective Puzzle.” Each concept was based on one of these subgenres. How the participation levels per role could vary throughout the game was also considered along with if the interactions with these interfaces and others were continuous or only at discrete moments. The concept that evolved into the final iteration will be discussed here, while descriptions of the other 2, “Factory (Order Simulation)” and “Puzzle Adventure (Perspective Puzzle)” can be found in Appendix B.

Heist (Lifeline)

In this first concept, the VR player had to be guided through a heist by their co-players. The first non-VR role was inspired by the earlier strategy board concept with its accompanying pawns. This player could for example place mines, distractions, smoke bombs, or blockades on a grid to assist in various ways. They should also think ahead about where to place an escape vehicle or cameras. Each grid tile also would have an LED to provide feedback about for example the whereabouts of guards. The second role would then be provided with a display and headphones to see and hear the VR world through these cameras. Another player would be provided with a “detonator gadget” that could be used to activate the distractions and bombs placed by the strategic player. This interface had components as the earlier discussed crank wheel, detonator plunger, and covered toggle switch. Additionally, it had a number pad and LCD screen that could perhaps be used to fill in secret codes communicated by other players to open doors. An internal vibration motor could also function as a form of radar to warn the VR player. Lastly, one interface was a paper manual similar to Keep Talking & Nobody Explodes [50]. This interface could be used to decipher codes or contained other valuable information. This player could for example tell the VR player which colour wire to cut to disable an alarm system.

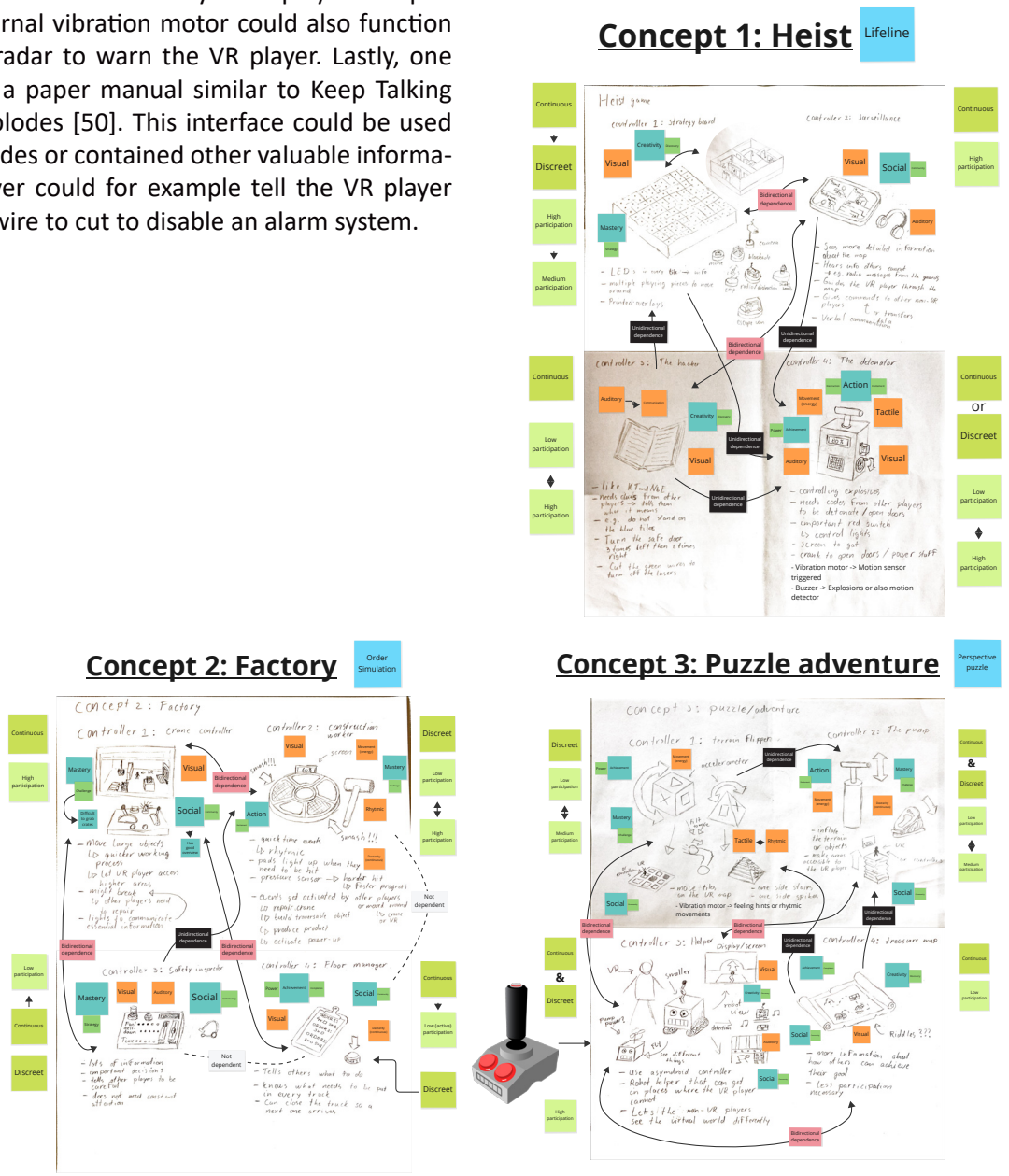

Figure 6 *Sketches of the 3 game concepts with notes on how the various roles can inderdependent, if the interactions are continuous or only at discreet moment, and the participation level per role*

Co-design

At this point in the process, I was curious whether there were some interfaces that perhaps could facilitate completely different types of interesting interactions that I had not yet discovered. Therefore, I was interested in generating additional ideas for interfaces together with people that had a good understanding of VR gaming and how certain game mechanics can be implemented to create desired dynamics between players. Therefore, I set up a co-design session with 3 of Enversed's VR developers.

Due to time constraints, the co-design session lasted only about an hour. I began with a brief introduction to AVR, including examples of AVR games, types of asymmetry, and my three second-iteration game concepts with their respective interfaces. Participants were provided with materials for sketching and were asked to propose one additional interface for each of my concepts. During the second round they were given a copy of the AVR Game Genre framework (Appendix C) [11] to assist them in coming up with one idea for an AVR game concept with an accompanying alternative interface. In the final round, they exchanged sketches with other participants and generated one additional interface idea for each of the others' game concepts. Discussions between rounds were audio-recorded to capture their descriptions.

Results

The sketches and descriptions from participants can be found in Appendix D. They expressed finding it difficult to come up with alternative interfaces and thus often incorporated ones they were familiar with. They did still apply them in an asymmetric manner. In hindsight, taking elements from methods such as the Magic Machine Workshop [2] could have encouraged more imagination. Nonetheless, two elements from their concepts were later incorporated into my design.

Firstly, one participant created an interface in the form of an actual safe for the Heist game. Purely looking at this interface's input/output modalities, it was simpler version of my "detonation gadget" concept. However, the aesthetics of the rotary input in the form of the crank wheel were changed to mimic a safe dial. If the player turned it, they could open the virtual safe. Such a concept could utilize haptic feedback, like that provided from a vibration motor, to mimic the clicks you feel can feel when opening an actual safe. Such changes could make my interface feel like it is in object located both in the physical and virtual world, increasing immersion and the size of a shared magic circle.

Another interesting concept was made for my Puzzle Adventure game. This interface consisted out of a tablet and a stylus. The tablet would display a top down view of the map and the stylus could be used as a laser pointer into virtual world. I thought this was an interesting form of non-verbal communication between VR and non-VR players. Additionally, drawing on the map reminded me of the Alt.Ctrl.GDC game Gambling Paradise [3]. In this game players need to make notes on a printed out map to guide an AI teammate through a casino heist. I thought that being able to draw on a visual representation of the game world could be an interesting way to assist non-VR players to understand this world. Furthermore, it adds a strategic element as the ability to make notes can encourage players to think ahead.

Categorizing Asymmetric Interactions

When presenting my concepts to Tim from Enversed, I received positive feedback, but he thought that the interfaces were too game specific. They preferred more abstract interfaces that do not necessarily aesthetically conform to the theme of a specific game. Therefore, I was advised to categorize the various forms of interaction that made these interfaces distinct from each other. These categories could then be used as a guideline when designing sets of interfaces.

I understood their desire for more abstraction, as this could make these interfaces usable for a variety of games. However, I did not want this to come at the cost the interfaces' aesthetic theming, as this could disconnect them from the virtual world and the story being told. Furthermore, I deemed designing a set of interfaces that could work well together for a variety of games out of the scope of this project. I preferred creating a set that works really well with one game, as I thought this would give me more interesting insights into how such interfaces can influence a group's social dynamics.

However, I did acknowledge that such a proposed categorization could be a very useful tool to assist designers in considering a variety of interactions. It could help make interfaces feel more distinct from each other so users experience having a unique role and being an essential part of a team.

First I came up with 6 interaction categories: Energetic, Precise, Explorative, Strategic, Rhythmic, and Social. However, after applying these categories to all my interface concepts from my previous 2 iterations, the ideas from the co-design session, and some of the alternative interfaces from Alt.Ctrl.GDC (Appendix D & E), I dropped the latter two categories. Rhythmic was removed as I realized that it was a sub-category of Precise. Social was dropped as this was not an interesting interaction style just by itself. Interfaces that purely facilitate social interactions such as a microphone are significantly less interesting if its user does not have to overcome some kind of challenge to gather or think about the information being communicated. In this project where the goal is to make AVR games more social, these types of interactions are very desirable. However, social interactions are mostly something between players, not between player and interface.

Energetic

How well a player performs energetic interactions is dependent on much energy they can put into the interface. An example could be needing to shake a motion sensing interface or having to run around a room pressing various buttons as fast as possible. These examples focus on kinetic energy. However, potential energy interactions can also be applied to interfaces. A player having to turn a crank to wind up a spring as tightly as possible while feeling an increasing level of resistance could be an example. This action could then result in launching a virtual object as far or fast as possible. What's interesting about these interactions is that the input value is limited by the human physical ability. A joystick as input has a clear limit. The limit is how much it can be moved either side. However, if you put someone on an exercise bike and use the pedals as input, then the limit is how fast the pedals can be turned. In this case the limit can vary from player to player, but also be influenced by exhaustion levels, depending on the intensity of the interaction. However, these interactions are mentally not challenging.

Precise

Performance levels for interactions in this category do not increase by doing actions necessarily faster or with more force. For these interactions it is more important with which specific speed or force an action is performed. Balancing or controlling components or whole interfaces are included in this category. For some of these interactions the same components as for energetic ones can be used. A wheel can be turned as fast as possible for energetic interactions, while if it is rotated more slowly and controlled, for example when steering a car, it can be precise. When inputs need to be performed in a specific rhythm or they need to be timed or coordinated well, then they can also be precise.

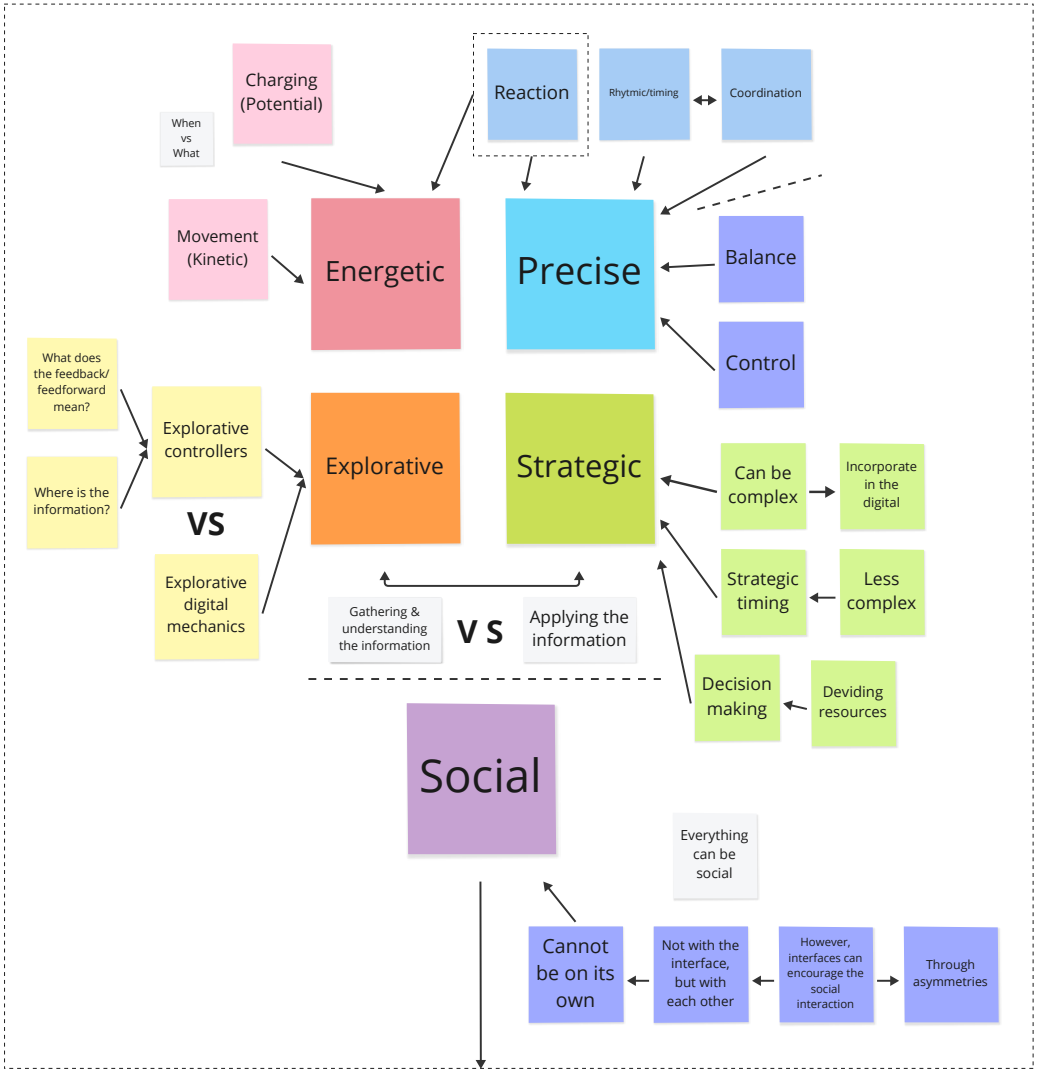

Figure 7 *Exploration of a possible framework for categorizing interactions with asymmetric interfaces*

Explorative

The latter two categories are more information related and can be mentally more challenging. Explorative interactions concern gathering and understanding information. Interfaces of which the output channels present a lot of information can fit this category. A paper manual containing a lot of text and visuals would be an example. A player could have to go through all this text to find secrets or use it to understand other information their team already possesses. Interfaces including monitors showcasing projections of the VR world and controls to change these projections also fit in. However, interfaces offering a lot of input modalities with no clear affordances can also offer explorative interactions. In such a scenario the interface can first offer its user barely any information, but through experimentation, they can gather it. Perhaps shaking it might result in something, or maybe three buttons need to be held simultaneously to perform a hidden action.

Strategic

In this last scenario, the player already has information, but needs to decide how to use it. The focus is on thinking ahead and decision-making. Interfaces allowing users to note down their ideas could encourage forward planning. Interfaces with numerous sliders and knobs could facilitate resource management mechanics, forcing players to make decisions. However, these interactions require players to also be provided with sufficient information to base their decisions on, which can make them quite complex.

Strategic timing also falls into this category. “Normal” timing is reactive, such as pressing a button as quickly as possible after a light appears or a teammate shouts a cue. These interactions mostly adhere to the precise category, but some argument can be made for energetic, as performance partly depends on physical speed. However, performance primarily relies on how quickly someone can mentally process a signal. Additionally, someone can react too quickly, which should not be the case for energetic interactions. Strategic timing is proactive. It involves making a conscious decision based on information and planning. For example, choosing to use your only smoke bomb to get past a specific guard.

Interactions do not necessarily need to completely fit within one of these categories. This framework is not definitive. It is only a guideline for designers to think about a variety of interactions and how they can be expressed in interfaces.

Third iteration

Dutch Design Week

Based on these categories I made some changes to both my Heist and Puzzle Adventure concepts to make at least one interface fit each category. The Factory concept was dropped as I saw less opportunities for dependencies. The theme of the heist concept was also specified to a casino heist, to make the story around the concept more enticing. I wanted feedback one how people perceive controllers in these categories. Enversed invited me to present the game from my M2.1 during Dutch Design Week at their VR centre, which offered me the opportunity to present my ideas to a wider audience. Since visitors also got to play my game, they already had an understanding of what AVR is. After some play sessions I explained my 2 new game concepts and the various interfaces to players.

People thought the Energetic category could be confusing and did not saw a lot of opportunities for it to be used the game's context. However, some parents did appreciate the simplicity of the interaction, as this might be ideal for younger children. One child also preferred one of these interfaces, as for the heist concept, the interface looked like a gun. Having to do a heist together also seemed to be significantly more enticing than the generic puzzle adventure concept. The strategic concepts were appreciated as people thought that it always gave you something to do or think about. What people enjoyed most about the precision concepts was that they gave you something to feel and manipulate.

Final changes

Based on this feedback the choice was made to continue with the heist concept. Additionally, for the final prototypes, the Energetic and Precise concepts would be combined. This choice was made due to people expressing concerns that a purely energetic role might not have much to do. Furthermore, combining them

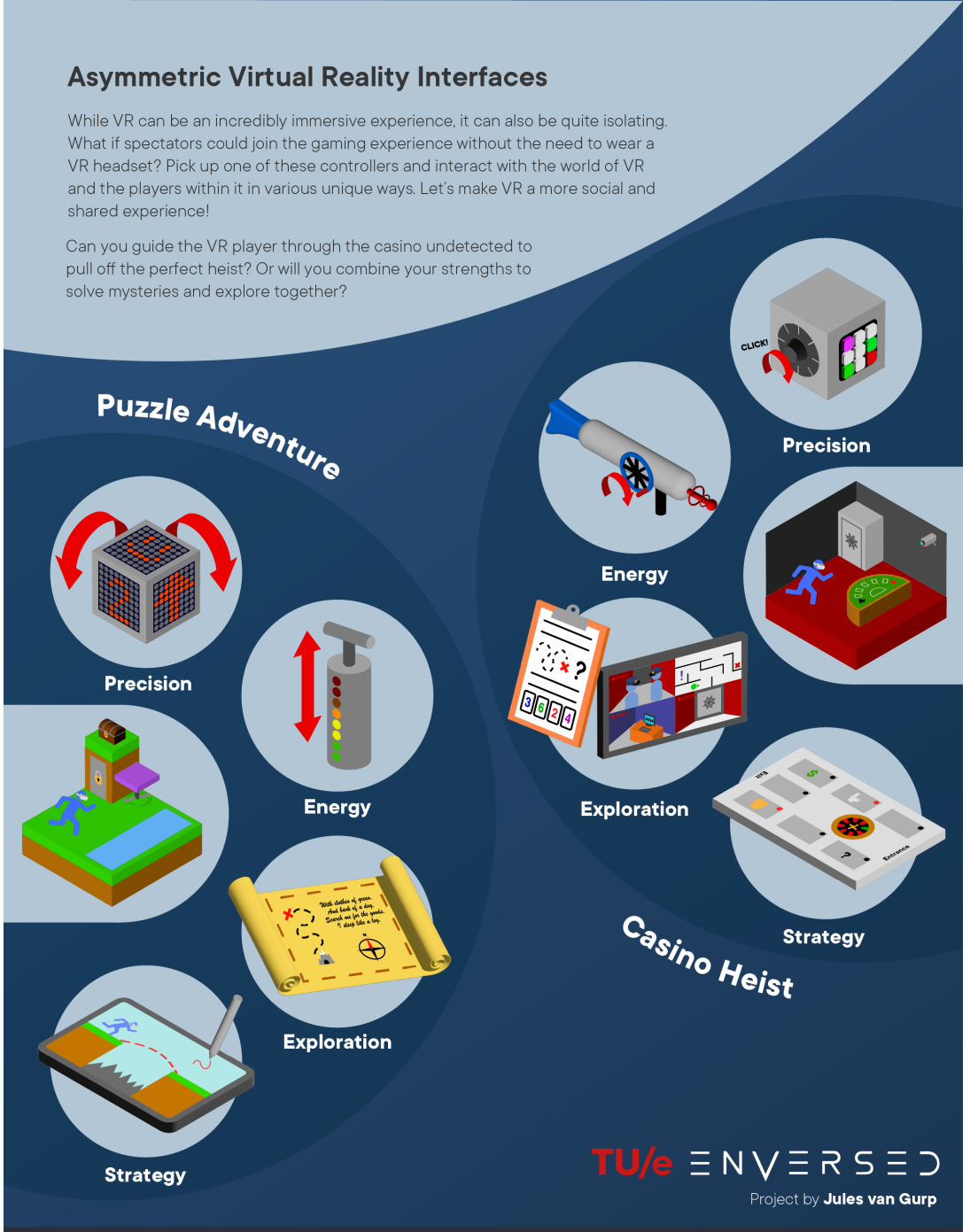

Figure 8 *The DDW poster showing my concepts*

could speed up the prototyping process. Certain interface components could be used for both interaction types anyways, such as a rotary input. Outlines of how the team would have to work together and how they traversed through the casino were outlined on a possible game map (Figure 9). The various components for the interfaces were also determined (Appendix F). For the strategic concept I already switched to a map with buttons on it, instead of the board with tiles in a grid pattern and various pawns. I deemed it impossible to develop the latter concept in time considering I also had to create the others and the game. During development I also switched from a casino to a museum, since more 3D assets were available fitting this theme.

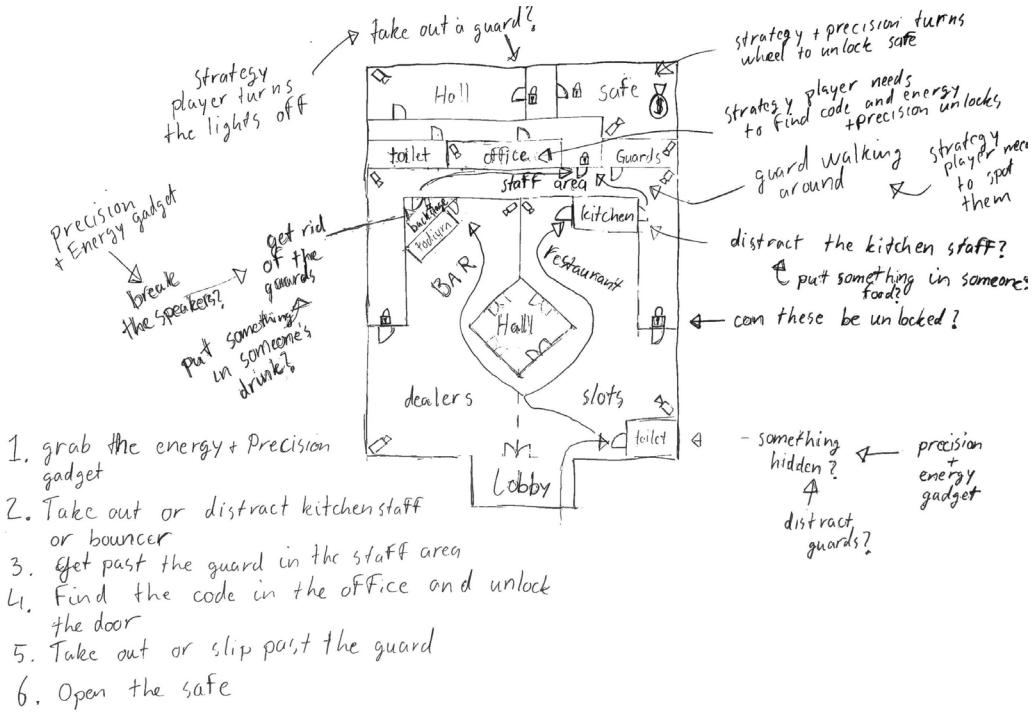

Figure 9 *Rough sketch of what a playthrough of the game could look like*

Heist Extravaganza

The final prototype was named Heist Extravaganza. In this AVR game 4 players have to cooperate to infiltrate a museum called “Le Musée des Extravagances” during the night. They have to retrieve the mythical apple of the Hesperides to save the world. Each player has a unique role and interface. They have to all use their unique abilities and knowledge to avoid or take out the various guards on patrol, hack door locks, find hidden codes, disable a laser system, unlock the safe door, identify the correct apple, and finally escape. The game was developed in Unreal Engine 5.4.4. Free 3D assets were used from the Unreal Engine Fab marketplace to make the world feel more lively.

Fox

This role is played by the VR player. They have hidden themselves in the restroom and come out at night to find the golden apple. They are guided through the museum by the other players. The Fox carries along the Super Gadget, which is a virtual representation of the Engineer’s physical interface. The gadget can be identified by the lighting bolt symbol on the side of both the Fox’s and Engineer’s version. The Fox can place the gadget on various Super Gadget interaction points that trigger minigames for the physical version which have to be completed for the Fox to continue. This role focusses mainly on exploration and immersion.

Mastermind

This player is provided with a paper manual full of information about the museum and the planning of the heist. The text is written as if it are the notes of the Mastermind and if read aloud takes the players through the story of the game. This role was designed with explorative interactions in mind. The player is presented

Figure 10 *The Fox seen from the perspective of the cameras (top), and the view of the Fox holding the virtual Super Gadget from the perspective from the Fox themselves (bottom)*

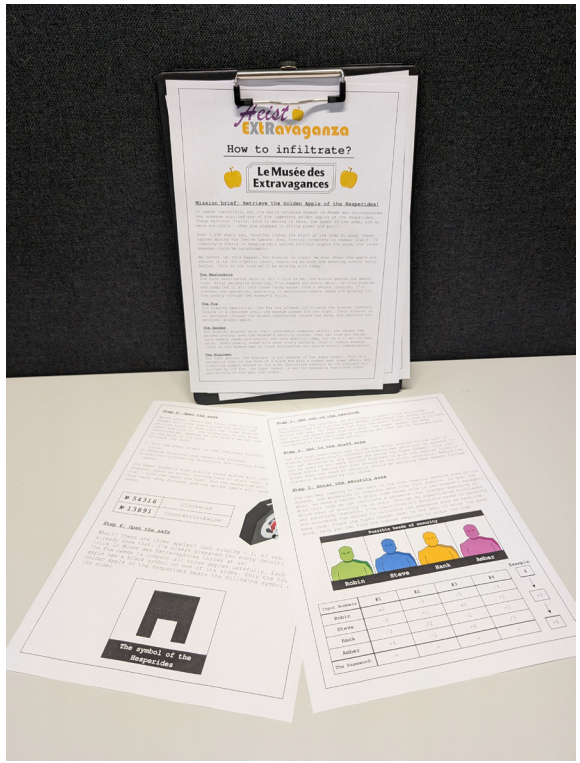

Figure 11 *Some of the pages of the Mastermind’s interface in the form of the paper manual*

with a lot of information and has to identify what is important and communicate this to their co-players. The manual also includes some simple puzzles requiring input from others. Some of the puzzles' results can assist the Engineer. The role was designed not to be difficult, specifically for people with less experience with traditional gaming interfaces. The entire manual can be found in Appendix G.

Hacker

This interface consists out of a laser cut top down map of the museum with whiteboard paper over the rooms so notes can be made on it, but also easily erased. There are 10 small red buttons spread out on the map that can be pressed to "hack" the museum's security cameras. The 3 last selected camera feeds are projected on a monitor. Next to each button is a RGB LED in a 3D printed transparent casing that indicates whether this camera was most recently selected (red), 2nd most (green), or 3rd (blue). The most recently selected camera can be panned using a slide potentiometer, and zoomed using a rotary one. These camera movements can also be seen by the Fox in the virtual world. The monitor is intended to also be viewed by the other non-VR players for more effective communication and especially to provide them with a projection of the VR world, as this can make them feel more involved when they have no specific task assigned [20,31].

This interface was developed focussing on strategic interactions, as its user is intended to plan out how the Fox can get past the guards. The ability to make notes should assist in this. Additionally the player is provided with a big red POWER button that can be pressed to take a guard out with a limited amount of sleeping gas, and it can be used to control a lamp. The player has to figure out when to turn this lamp off and on the get past another guard. Additionally, the panning and zooming can be used to find info in some rooms that needs to be communicated to the Mastermind.

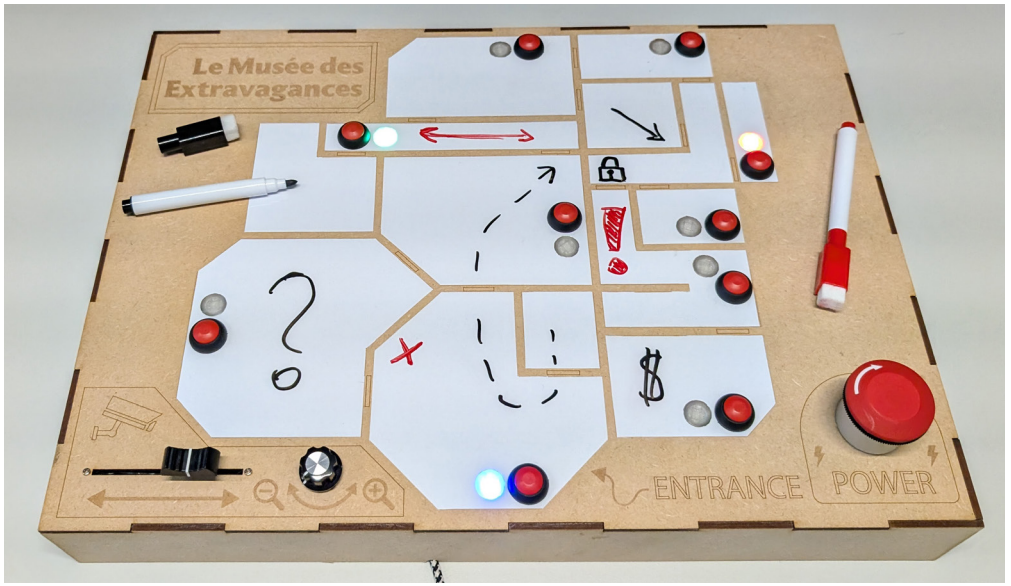

Figure 12 *The Hacker's physical interface with notes on it*

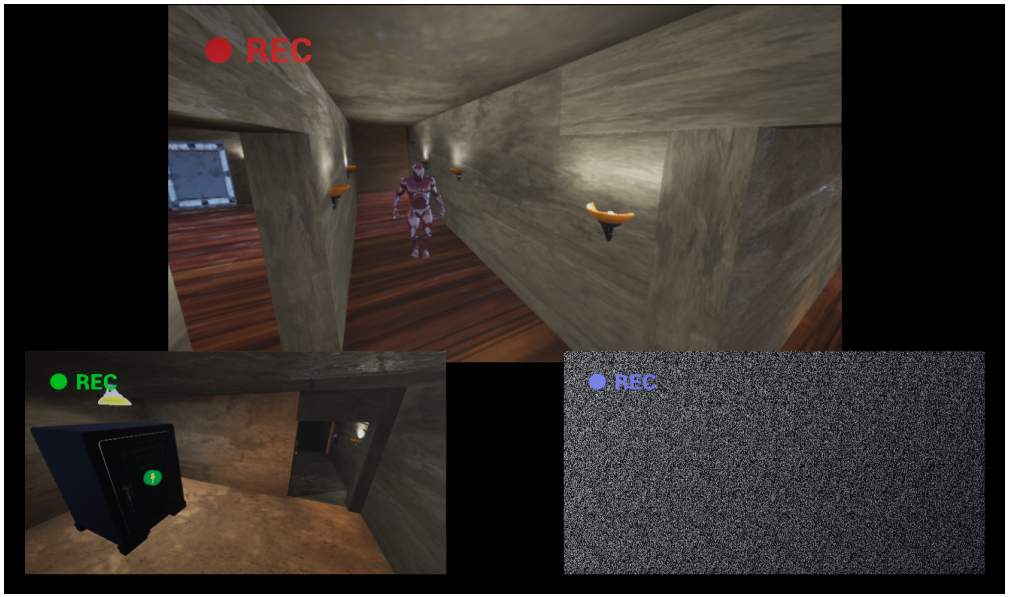

Figure 13 *The Hacker's view of the camera feeds as displayed on the monitor*

Engineer

The interface for this role is the Super Gadget. The Fox carries its virtual representation around. This design choice was made to implement a form of transmedia storytelling and pervasive gaming. This interface focusses on energetic and precise interactions. One component is the wheel. During some parts of the game the wheel has to be rotated as fast as possible to for example hoist the VR player and apple up into a ventilation shaft. For these interactions there is a rotating handle on the outside of the wheel to assist in turning it faster. However, there is also smaller grip in the middle of the wheel that can be grabbed for more precise rotations. It being closer to the centre makes the leverage smaller, which makes it easier to feel the clicks from the rotary encoder that is used to read the inputs. Additionally, grabbing it like this lets the player use their wrist and fingers for precise controls, instead of their elbow and shoulder such as with the other grip. Aside from the haptics from the rotary encoder, a vibration motor is also incorporated to simulate stronger clicks during a minigame where the Engineer has to precisely rotate the wheel to open the safe. Haptics can be especially interesting asymmetric interfaces, as it can only be felt by the person holding them.

On top of the gadget is a short row of LEDs that provide its user feedback on how fast they are rotating the wheel. These are also used when deactivating the laser system, as the player has to spin the wheel to keep a moving LED in the middle of the row. Additionally, a song comes out of the gadget through a passive buzzer when the wheel is rotated at the start of the game. This action distracts one of the guards. Lastly, on one side is a number pad and LCD screen. The screen gives instructions and is used for a minigame where the number that shows up needs to be pressed as quickly as possible. It is also used to fill in a password to open a door.

The casing was designed in Fusion 360 and 3D printed using PLA. The wheel's handle was printed using PETG as it is more wear resistant to friction. The Engineer's and Hacker's prototype are both controlled using a ESP32-WROVER microcontroller, but only the former is powered using Li-Po battery. Both communicate with Unreal Engine through serial communication and are programmed using C++ in the Arduino IDE. The Super Gadget connects to a PC using Bluetooth Classis, while the Hacker's interface utilizes a USB cable.

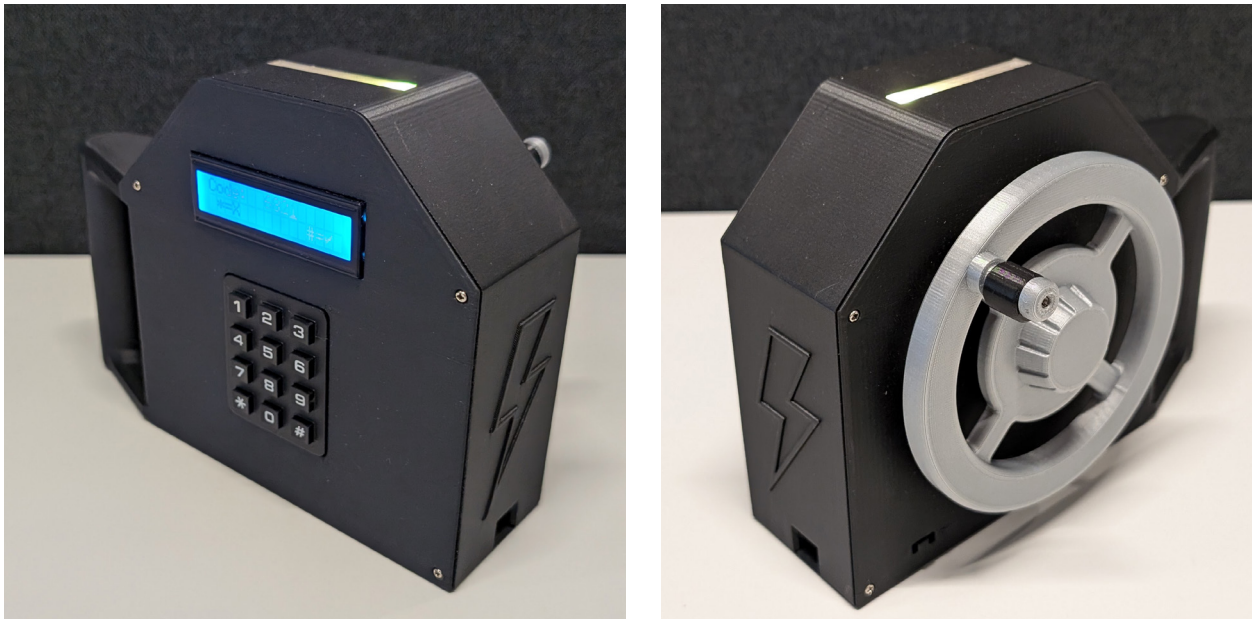

Figure 14 *Both sides of the Engineer's physical Super Gadget interface*

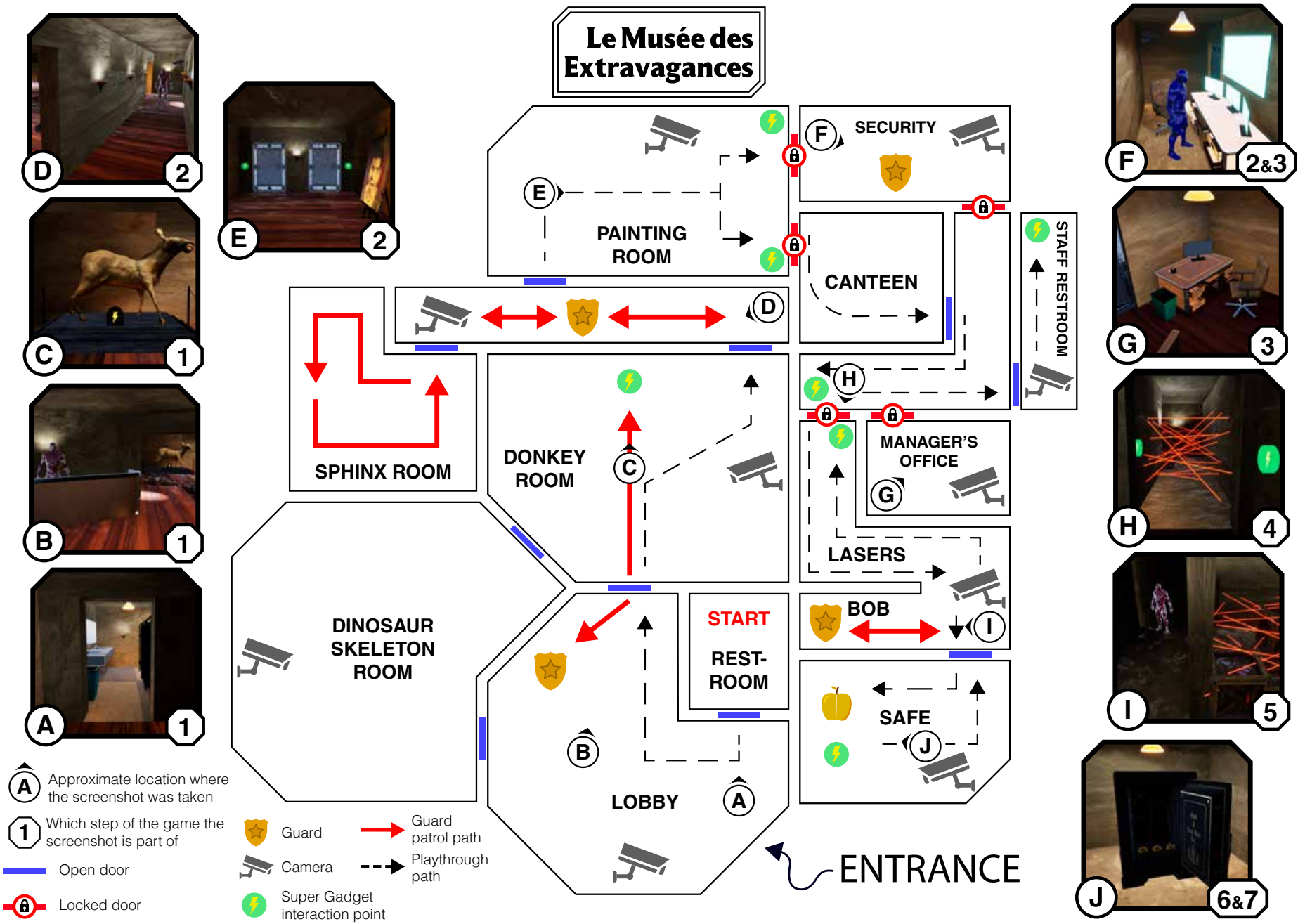

Figure 15 *Overview of the game in the form of a map and screenshots from the game. The letters underneath the screenshot indicate where on the map it was taken. The numbers underneath the screenshots indicate which part of the game (see Table 1) the screenshot is part of.*

Game steps	Designed tasks per role and type of dependency between them (→ unidirectional ↔ bidirectional)	
Step 1: Get out of the restroom	**Fox:** Wait for the Hacker to take out the guard with the sleeping gas.	**Mastermind:** Tell the Hacker about the sleeping gas and the Engineer to distract the guard.
	Hacker: Look at the cameras to see when the guard is next to the Super Gadget underneath the donkey statue and then press the big red POWER button to release the sleeping gas.	**Engineer:** Rotate the wheel to play music so the guard gets lured to the donkey statue under which the virtual Super Gadget is hidden.
Step 2: Get to the staff area	**Fox:** Grab the Super Gadget underneath the Donkey statue and slip past the guard. Place the Super Gadget on the correct Super Gadget interaction point next to the two doors.	**Mastermind:** Tell the others to be on the watch for guards and tell the Hacker that they should go through the door that leads to the canteen while other is the security room.
	Hacker: Discover the patrol route of the guard and tell the Fox to go when the guard is momentarily in the Sphinx room. Find out behind which door is which room and tell the Fox to place the gadget correctly.	**Engineer:** Once the Fox has placed the virtual gadget correctly, use the number pad to quickly press the numbers appearing on the screen to hack the door's lock. This should open the door so the Fox can continue.
Step 3: Enter the security area	**Fox:** Grab the gadget and place it on the Super Gadget interaction point next to the door that leads to the lasers. The Engineer can then fill in the correct code. Optionally assist the Hacker by communication on which the door the sign "Manager's Office" is placed.	**Mastermind:** Communicate that the code should be in possession of the Manager and that the password needed to open the door changes depending on which head of security is present. When the Hacker finds the code and identifies the head of security, calculate the password.
	Hacker: Locate the manager's office and zoom in on the desk to find the code in one of the drawers and communicate it to the Mastermind. Also find the head of security in the security room and tell the Mastermind which colour he is to identify him.	**Engineer:** Wait for the Fox to place the Super Gadget and the Mastermind to calculate the password. Fill in the correct password on the physical Super Gadget to open the door.
Step 4: Avoid the lasers	**Fox:** Grab the gadget and place it on the interaction point on the laser system control panel. Get to the other side of the hall once the Engineer has temporarily disabled the lasers to permanently disable the lasers by pressing the power button located there.	**Mastermind:** Give the Engineer instructions on how to use the Super Gadget to disable the lasers and tell the Fox that there the laser system power button should be at the end of the hallway.
	Hacker: Watch how the lasers get disabled.	**Engineer:** Quickly, but precisely turn the physical Super Gadget's wheel to keep the moving LED on top of the gadget in the centre. As long as the LED does not touch either end of the LED-strip, the lasers will stay disabled. Do this until the Fox powers the lasers off.
Step 5: Get past Bob	**Fox:** Slip past the guard called Bob once the Hacker has turned off the light across from Bob's post.	**Mastermind:** Tell the Hacker that they can control the light to slip past Bob.
	Hacker: Press the big red POWER button to turn off the light and tell the Fox to quickly slip past Bob. Turn the big red POWER button to turn the light back on again so Bob does not get suspicious and goes after the Fox.	**Engineer:** Wait for the others.
Step 6: Open the safe	**Fox:** Place the gadget on the Super Gadget interaction point on the safe. Look at the back of the safe to find the serial number. Do not communicate the one on the side of the safe, since this one is incorrect.	**Mastermind:** Tell the Fox to look at the back of the safe for the serial number and use it to determine if the Engineer should start turning the wheel clockwise or counter-clockwise until they feel a vibration. They should then turn it the other way and repeat this until the safe opens.
	Hacker: Wait for the safe to open.	**Engineer:** Grab the inner knob of the Super Gadget's wheel to more accurately feel the clicks and follow the Mastermind's instructions to open the safe.
Step 7: Grab the apple	**Fox:** Grab the three apples to look for the symbols on them and compare them to the one described by the Mastermind. Pick the apple with the correct symbol on it.	**Mastermind:** Describe the correct symbol to the Fox.
	Hacker: Wait for the Fox to select the correct apple.	**Engineer:** Wait for the Fox to select the correct apple.
Step 8: Get the hell OUT of there!	**Fox:** Grab the apple and Super Gadget and slip past Bob to get to the staff restroom. Place the gadget on the Super Gadget interaction point that only just appeared. This point is underneath the opening to the ventilation shaft.	**Mastermind:** Tell the Hacker to find the staff restroom and the Fox to place the gadget and apple on the interaction points. Explain to the Engineer that they have a grappling hook.
	Hacker: Identify the location of the staff restroom and direct the Fox to it, but also use the big red POWER button to let the Fox slip past Bob.	**Engineer:** Rotate the wheel as fast as possible to hoist the apple and Fox up into the ventilation shaft using the Super Gadget's grappling hook.

Table 1 *Overview of all the designed tasks per role and how the roles and dependent on each other during the game*

User Evaluation

Method

Procedure

In this user test 2 groups of 4 people participated which were recruited through personal contacts. Within the groups, people already knew each other beforehand.

Participants were asked to decide among themselves who would assume which role. The researcher clarified that gameplay-related assistance would only be provided under one condition: if the players specifically requested help and the researcher determined that they were “stuck”. The manual guided the players through the game. Audio recordings and notes of observations were made during the game and these were later turned into a transcript. After completing the game, participants were asked to fill in a digital questionnaire including the Player Experience Inventory (PXI) [1] and the Social Presence in Gaming Questionnaire (SPGQ) [12]. Furthermore, participants had to fill in some open-ended questions related to their experience with the game in general, their specific role, and the interactions with their co-players. Additionally, the players had to rank the game’s 4 roles based on personal preference. Afterwards, a semi-structured group interview (Appendix H) was done and audio recorded, which was later transcribed.

Analysis

A deductive thematic analysis [8] was performed on the transcripts and the questionnaire’s open-ended questions (Appendix I). The PXI results were analyzed using one-tailed one-sample t-tests to compare each measurement’s mean score against PXI benchmark data [63]. For measurements with positive t-values, right-tailed tests were conducted, while left-tailed tests were used for negative t-values. The Enjoyment measurement was excluded from these tests due to the absence of benchmark data; its results were analyzed descriptively. The results from the SPGQ were analyzed and explored through the use of summary statistics (Table 2 & Table 3).

	Empathy	Negative feelings	Behavioural engagement
Mean	3.125	0.271	3.109
Standard deviation (s)	0.461	0.377	0.430
Min	2.143	0	2.625
Max	3.571	1	3.875

Table 2 *The mean and standard deviation for each of the subscales of the SPGQ (scale ranges from 0 to 4)*

	Empathy		Negative feelings		Behavioural engagement	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Mastermind	3.571	0	0	0	3.125	0.354
Fox	3.143	0	0.083	0.118	3.125	0.530
Hacker	3.429	0.202	0.333	0.471	2.938	0.088
Engineer	2.5	0.505	0.667	0.471	2.75	0.177

Table 3 *The mean and standard deviation for each of the subscales of the SPGQ per role (scale ranges from 0 to 4)*

	Mean	SD	min	max
Mastermind	3.625	0.518	3	4
Fox	1.5	0.756	1	3
Hacker	3	1.069	1	4
Engineer	1.875	0.641	1	3

Table 4 *The 4 roles ranked by the participants based on the question “Could you rank the various roles based on how enjoyable they seem to you?” (1 is highest, 4 is lowest)*

	Mean	SD
Mastermind	2.83	0.24
Fox	3	0
Hacker	2.5	0.71
Engineer	2.67	0.47

Table 5 *The mean and standard deviation of the PXI Enjoyment score per role (scale ranges from -3 to 3)*

Results

General experience

The results of the PXI can be seen in Figures 16 & 17. The mean scores for all psychosocial consequences were higher than those of the benchmark data, except for Autonomy (M = 0.58, SD = 1.12), which scored significantly lower, t(5) = -1.91, p < 0.05. However, Curiosity (M = 2.25, SD = 0.75) scored significantly higher, t(5) = 3.43, p < 0.05. For the functional consequences, all mean scores were higher than those of the benchmark data, except for Audiovisual Appeal (M = 1.71, SD = 1.29). No differences were significant. The Enjoyment (M = 2.75, SD = 0.39) score is exceptionally high.

A high level of social presence was reported, as reflected in the mean scores for two of the SPGQ subscales: Empathy (M = 3.13, SD = 0.46) and Behavioural Engagement (M = 3.11, SD = 0.43) (Table 2). The mean score for the subscale Negative Feelings (M = 0.27, SD = 0.38) was exceptionally low, which in this case is desirable. Participants elaborated in the interviews that the game's social aspect positively influenced their enjoyment of it. They liked communicating, collaborating, and engaging in banter with their co-players. Participants expressed that they felt part of a team and enjoyed that they, but also the other roles, seemed to contribute and be important to this team. They indicated that these moments where they felt like they were crucial to the team were some of the nicest. One player describes such moments as, "This is my moment, I cannot mess this up".

The high PXI mean score for Goals & Rules (M = 2.54, SD = 0.69) and participant's comments reflect that the game was very clear to them, perhaps too much. The Mastermind's manual guided the player's through the game well, since the researcher only had to hint the Mastermind to read part of the manual again once. This hint was the only assistance players received, except for when the game needed to be paused when a technical issue occurred. Players expressed a desire for less guidance, since this could offer them more freedom in solving problems their way. Less information provided players with opportunities to come together to solve problems.

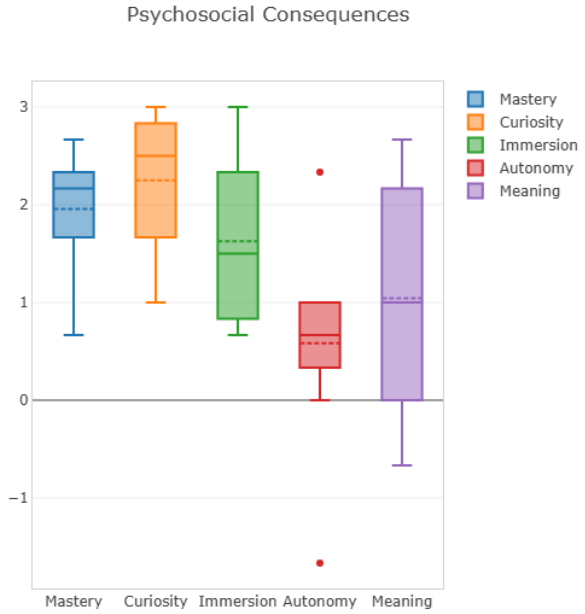

Figure 16 *A boxplot showing the psyshosocial consequences results from the PXI*

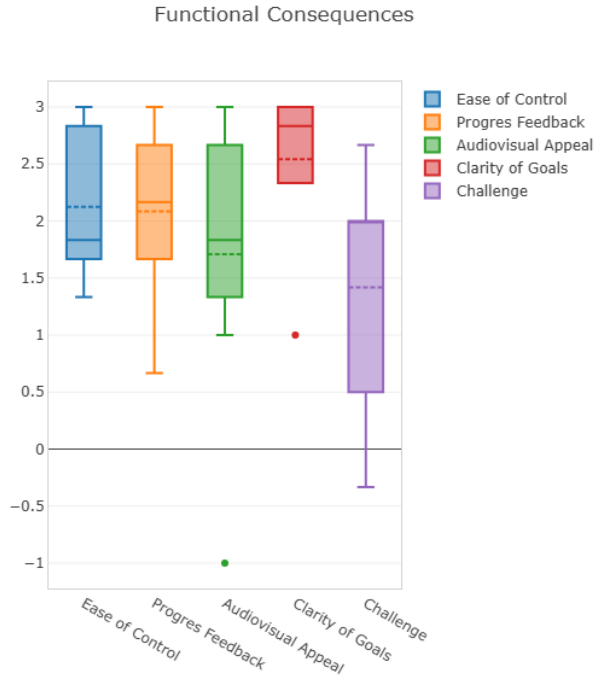

Figure 17 *A boxplot showing the functional consequences results from the PXI*

Less guidance might also cause players to make more mistakes. However, moments when things went wrong were described as some of the most fun and memorable, since they could be chaotic and exciting, while also encouraging the team to come together to discuss possible solutions. Both groups found it enjoyable when their Engineer failed to disable the laser system multiple times. A team member remarked: "You're so cocky about it and then it goes completely wrong." Despite the co-players laughing when the Engineer failed, they also offered assistance and encouragement. The Mastermind for example tried to clarify the instructions. Both Engineers also indicated this to be their most memorable moment. One reflected, "That's why it was so memorable, because it went so wrong", while the other remarked, "I wanted to do well, but it didn't. That made it extra nice when I did."

Players did note that the social setting created an environment where it was okay to make mistakes. They remarked that it helped that they were no complete strangers to each other. One player stated that they felt chill and comfortable. Furthermore, participants indicated that they appreciated that the game did not punish them too much for failing.

The roles

While some roles appeared more interesting to most players than others, all roles seemed enjoyable, albeit in different ways. One player stated: “Of course, it’s a personal choice, but I think it’s fun either way.” The ability to choose your role was also valued. Some players for example indicated that they preferred not be the Mastermind, because they did not feel like reading or were bad at communicating clearly. Other players did not desire to play as the Engineer, since they thought it required fine motor skills or were not that into quick time events. Furthermore, someone appreciated that the roles were “not hierarchical”. Additionally, players appreciated the look and feel of the Hacker’s and Engineer’s interface.

Mastermind

The Mastermind role was ranked lowest by the participants (M = 3.63, SD = 0.52) (Table 4). Nonetheless, the PXI score from these players report a high Enjoyment score (M = 2.83, SD = 0.24). The Mastermind players enjoyed that the manual allowed them to tell the story and participant remarked that it was well written. One player especially tried get into the role of Mastermind by mimicking the voice of this supposed “Mastermind”, and enjoyed doing this. The group members also remarked that this acting improved their experience and sense of immersion. They liked coordinating the other players and making them pay attention, while being able to see what the others were doing, which made them feel part of the effort. However, the main reason this role was perceived as the least interesting by the participants, was that they thought that Mastermind did not have to actually overcome a lot of personal challenges. They desired a more interactive and less linear manual. It was suggested to make the exploration of the document more of a challenge in itself. One of the Masterminds described that they desired to do more “actual Masterminding”, and having to go back and forth between parts of the document in response to perhaps even unexpected events could help in achieving this goal.

Fox

The Fox’s mean rank was highest out of all roles (M = 1.5, SD = 0.76). The mean PXI Enjoyment score (M = 3, SD = 0) was also greatest for this role. The immersiveness of VR made it attractive, especially for people less familiar with it. Participants acknowledged that the actual actions they had to perform were perhaps more interesting for the other roles. The Fox players indicated that their least enjoyed moments were when they had to wait while the others were busy, especially since they could not always see what they were talking about. However, they did like that during these moments they could look around the museum and attempted to interact with the objects within it. One Fox player specifically expressed a desire for more objects to be interactable. These interactions did not even necessarily need to serve a greater purpose to the progression of the game. This Fox player noted that it could already be fun for the others to see them walk around or make a mess with random objects, since the others could see them through the cameras. Another participant replied: “Yeah, throw it at the camera.” The virtual representation of the cameras were used by both Fox players as a communication tool. One player attempted to present the symbol on one of the golden apples to the camera, instead of verbally describing it to the others. However, this group’s Hacker told this Fox to not show it to them, as “That’s not fun!” The other Fox made hand gestures and waved at one the cameras while waiting for the Engineer to open the safe. This unexpected social interaction turned into an enjoyable moment, since it made the Hacker and Mastermind laugh.

Hacker

The Hacker role had the third highest mean rank (M = 3, SD = 1.07), but still has a good mean PXI Enjoyment score (M = 2.5, SD = 0.71). The Hacker players enjoyed being able to control not only how they, but also the Mastermind and Engineer saw the virtual world. The ability to make annotations on the map was also appreciated, since they expressed that it assisted them in thinking ahead, and in the creation of a sense of orientation, especially at the start of the game. Some participants remarked that this role seemed less interesting to them, since they thought that most of the time the Hacker did not really have a specific task, aside from communicating what they were seeing to the Fox. However, the Hacker responded that the ability to explore and make notes about the museum was sufficient to stay entertained throughout the duration of the game. During one game, the Mastermind pressed the big red POWER button on the Hacker’s interface. This Hacker reflected negatively on this unexpected interaction, since it resulted in a decrease of their sense of agency. They noted on this incident: “from a gameplay perspective, why am I even here?”

Engineer

The Engineer role was ranked second (M = 1.88, SD = 0.64) and its mean PXI Enjoyment score (M = 2.67, SD = 0.47) does not differ much from those of the other roles. The Hackers enjoyed the minigames they had to perform with their interface. They valued that it required skill and sleight of hand. That some quick time events were more difficult was appreciated, since it made it extra rewarding when they did finally succeed. The completion of their personal challenges also felt crucial to the team effort. Players further indicated that they did not have much to do in between minigames. Therefore it was valuable that they could see and hear what the others were doing and discuss it with them, making them still contribute to the team effort. One Engineer exclaimed, “When it was my turn, I was like YES! Let’s go!” This highlighted how the anticipation of waiting for a moment to be important made it feel more special and exciting. Nonetheless, both Hackers

noted that they would have liked to play more music, allowing them to interact with their interface between minigames. One Hacker suggested that playing music could alert guards, adding an element of fun by enabling them to mess with teammates or create chaos. Another idea was to use the Super Gadget's buttons to send alerts to its virtual representation, turning it into a communication tool between the Engineer and the Fox.

Discussion

The Asymmetric Experience

This project aimed to make co-located VR games a more social and shared experience through the extensive exploration of asymmetry of interface. The results from the SPGQ show that Heist Extravaganza was successful in achieving this goal. The comments from the participants show that their asymmetric roles made them feel like an essential part of a team, which they describe as significant contributing factor to their enjoyment of the game. Another goal of this project was to see if a highly asymmetric set of interfaces can promote enjoyment in AVR games. The enjoyment scores from the PXI also show this to be possible. That scores for both scales are high might be since social engagement and enjoyment are heavily linked [33]. Players expressed that moments when things went wrong were some of the most enjoyable, as this created chaos, but also brought them together to find solutions. However, they also remarked that this was only fun because they felt like they were in an environment where it was okay to make mistakes. These comments highlight that one of the most essential parts of making a social and enjoyable asymmetric gaming experience, is making sure players find themselves in social environment where everyone is comfortable.

Shared vs Personal Interfaces

Seeing each other interact with their interfaces helped non-VR players feel more involved during moments where they themselves had no specific tasks assigned, which matches research on this topic [31]. In a game such as Heist Extravaganza the different interfaces and asymmetric roles can make it difficult for all players to feel equally involved at all times. Some interfaces simply better support constant participation, where for others momentary interactions are more interesting. Some people enjoy variety in their participation level [31], so "shared" interfaces can be ideal. If a player desires to do so, they can choose to assist others while they have no personal tasks assigned. However, they do not have to, since others can also interact with that interface.

However, designers should be very considerate about what part of which interface is considered shared to whom. Part of the Hacker's interface (the monitor displaying the camera feeds) was designed to be shared with others. However, one Mastermind player pressed the Hacker's big red POWER button, which was designed and perceived by the Hacker as their personal interface. This event caused this player to experience a decrease in sense of agency and importance to the team. Therefore, while shared interfaces can be good for involving players socially, it can also lead to the opposite effect if one's sense of agency over their role is violated.

Thoughtful contributions

When players are dependent on each other, they have to overcome their own challenges, otherwise the relying player can see it as Tedious Reliance [24]. However, the player that performs a "mindless action" might also not experience a sense of accomplishment or feel that they truly contributed to the team effort. The player in the role of Mastermind did not have to overcome many personal challenges, contributing to this role being perceived as the least interesting on average. One Mastermind desired that information had to be exchanged back and forth more often, creating additional bidirectional dependencies [25]. Harris & Hancock [24] propose "rhythms of interdependence" similar to "interest curves" [48]. While interdependence between players can encourage social interaction and improve engagement [16,24,29,61], a lack of variance can also lead to making this dependence feel less exciting. As the Engineers highlighted, having these momentary interdependencies feel more crucial can make them feel more exciting and special.

Interactive Physical-Virtual Artifacts

The decision was made to give some of the interfaces the appearance of artifacts from the virtual world, in which the VR player immersed themselves. Inspiration was taken from pervasive games that "extend the gaming experience into the real world" [5]. Especially in VR games the magic circle of play is often confined to the digital space, but pervasive game can assist in breaking it free and extending it into the physical where non-VR players can be included socially [38].

Interactive artifacts that in appear in some form both in the virtual and real world are also tools for transmedia storytelling. Even for the VR player, the story of the game already starts to be told the moment they see the physical interfaces, so before they have even put on the HMD. Presenting a story to players should not be undervalued as storytelling is one of the oldest tools to engage and amuse an audience [40]. The mere sighting of such artifacts might spark curiosity in players who question how the interface and its user is going to fit into the story that they themselves will also be part of.

Research indicates that some VR players experience an increased feeling of vulnerability and anxiety in co-located AVR settings. People get "very vulnerable being the immersed person" [31]. One VR player reflected on previous VR experiences and compared it to playing as the Fox: "there's people outside and they can see me playing a game and standing here, being silly. Sometimes I think that feels awkward, but in this case,

I think it felt chill." This highlights that perhaps making everyone an immersed person through storytelling and taking their focus away from the VR player and onto a personal interface might help reduce this sense of vulnerability and anxiety.

Furthermore, these interactive artifacts can serve as a communication tool between both worlds. In this game the Hacker role could control cameras that served as a window into the virtual world. Spectator screens are not necessarily something new for VR. However, having a virtual representation in the form of 3D model of a security camera at the exact location in digital space where this "window" was located did have an interesting effect. It unexpectedly also served as a point of reference for the VR player to communicate back to the physical world. During play testing one VR player attempted to show symbols to their co-players through this camera, while it was intended for this communication to be done verbally. Another VR player waved and made gestures with their virtual hands in the direction of one of the cameras, receiving a response of laughter from two co-players. One Engineer player pointed that pressing buttons on their physical "Super Gadget" interface could perhaps display notifications on its virtual counterpart, which was carried by the VR player. These examples show that interactive physical-virtual artifacts can be an alternative to verbal communication between VR and non-VR players and perhaps offer another dimension to their social interactions.

Another example of one such artifact was another part of the Hacker's interface, namely the map of the museum. This map was a dimensionally accurate representation the VR world on which its user could draw erasable annotations. One Hacker player indicated that they at first found it difficult to orient themselves while controlling the cameras, despite seeing on the map where the cameras were located. Luckily, they quite quickly got the hang of it and expressed that ability to make notes contributed to this. Therefore, these interactive artifacts can also serve a purpose in making non-VR players better understand the virtual world, leading to more effective communication.

Perhaps for the terminology it is worth differentiating between two forms these artifacts can take. One is the true Interactive Physical-Virtual Artifact, such as the Engineer's Super Gadget. In this form the physical interface's aesthetics mimic an object taken from the virtual world, almost as if it is a copy. However, it can still be interacted with in the real world and influence the virtual. The second form could be described as an Interactive Cross-Reality Artifact, such as the Hacker's camera system. In this form, the cameras in the virtual world, and the controls, map and monitor in the real world, are part of a larger interactive system. In this latter form the actual physical part of the interface does not act is if it is located in the virtual world. The aesthetics communicate that the physical is in different location than the virtual, but are still connected.

Limitations & Future work

While the results from the user test give an insight into how players experienced Heist Extravaganza and the various roles, testing with more players is necessary to statistically compare the roles. Testing with employees of Enversed was also done, but was not included in the results as this session only had 3 players. Due to difference in setup, it was deemed not correct to be included in the other results. In this scenario one player had to play 2 roles simultaneously, which proved to be difficult as this player had to divide their attention. Additionally, more technical issues occurred, perhaps due to a difference in hardware. However, Enversed did highlight that they saw great potential in the concept and discussions are ongoing that a more stable version of Heist Extravaganza could be displayed at their VR center to further investigate how this asymmetric experience is perceived.

As highlighted by user test participants, the game, and especially the Mastermind role, could also be improved by making it less linear. This change will likely lead to players making more mistakes, but this is desirable, as it offers them opportunities to socially come together to find solutions. However, when implementing this change a socially comfortable environment needs to be maintained where it is acceptable to make mistakes. Furthermore, having variety in how the game can be played over multiple play sessions gives players the opportunity to switch roles, increasing replayability.

In future steps it might also be worth investigating how more aesthetically abstract asymmetric interfaces can be created, as these could be usable for a wider variety of AVR experiences, making them more commercially viable. Perhaps the categorization of asymmetric interactions done in this project could assist in the guidance of such designs. However, more research has to be done to further develop this framework.

Conclusion

Conclusion

This project aimed to make co-located VR games both enjoyable and a more social and shared experience through the extensive exploration of asymmetry of interface. The resulting design, Heist Extravaganza, shows that asymmetric interfaces can contribute to a highly enjoyable and socially engaging cooperative AVR experience. The various roles made players feel as an essential part of a non-hierarchical team. In the context of the game, every role was enjoyed, but some more than others. It is important that players overcome their own challenges to contribute to their team. Heist Extravaganza can still be improved by making the players' interaction possibilities less linear, but it was a good first step in the discovery of the extensive use of asymmetry of interface in the context of AVR.

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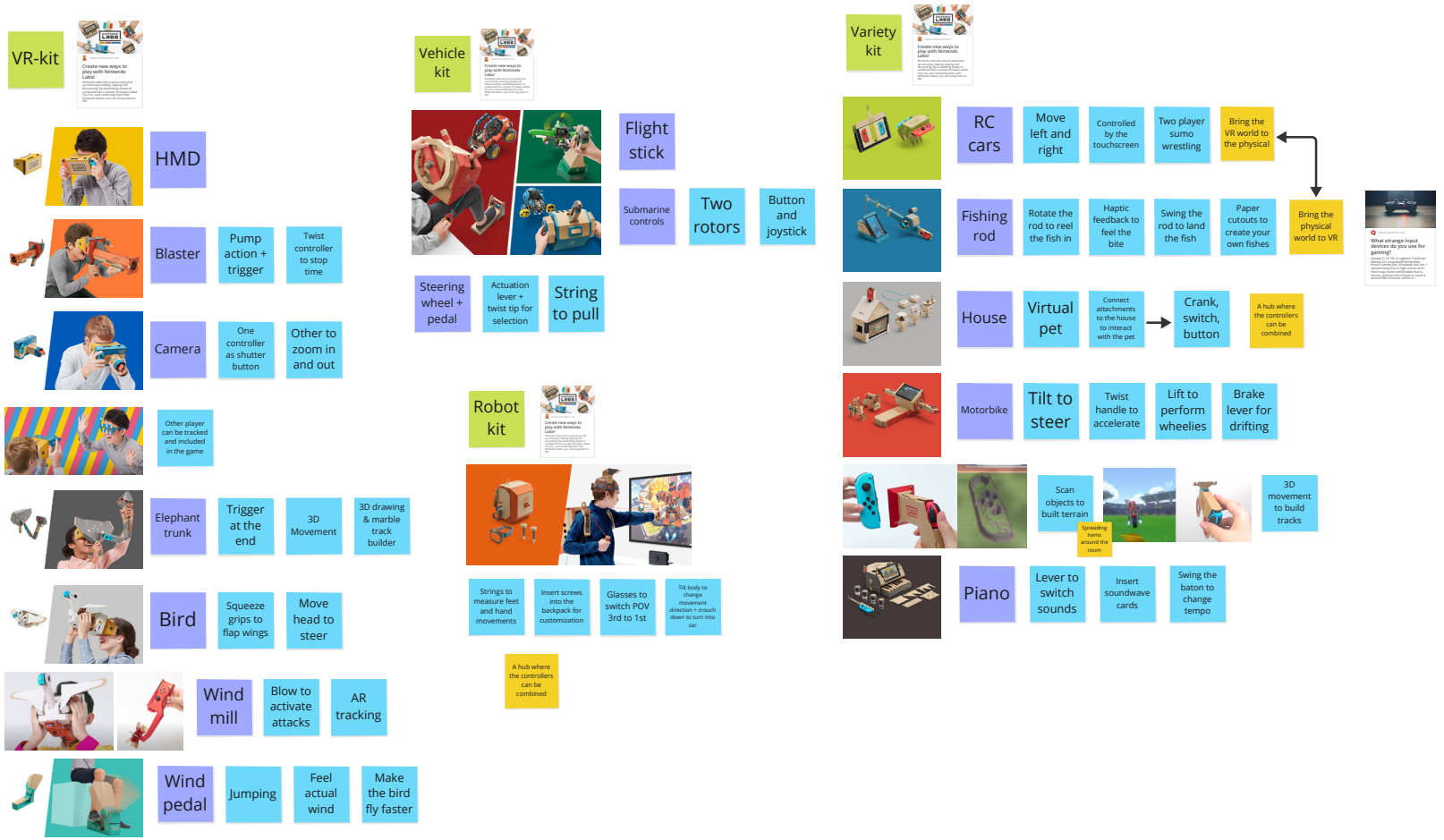
Appendix

Appendix A1 – Benchmark



Appendix A2 - Benchmark

Appendix B - Descriptions of second iteration concepts

Factory (Order Simulation)

In this concept players had to work together to run a factory. The VR player had to run around on the work floor, moving smaller objects around. Another player would be given a monitor and control panel with levers and buttons. They would be able to control a crane to move larger objects and pallets. However, the levers could perhaps get stuck at certain moments. The second interface would be backlight silicon plates and a rubber hammer. These plates could be smashed quickly, akin to Whack-A-Mole, to repair the other player's control panel and get the lever unstuck. The hammer player would also get a virtual robot avatar that could be moved around by the VR and crane player to be placed next to factory machines to also repair these or speed up production. The third interface would contain a lot of LEDs, a speaker, and warning lights to provide its user with information about the machines. This could for example highlight if machines were about to break and needed maintenance or if they were finished producing items. This player could also move sliders to reduce machine wear, at the cost of production speed, or adjust the speed of conveyer belts. The last interface would be a clipboard with product orders on it. This player could then communicate what had to be produced and loaded into trucks, giving them somewhat of a manager role. This player also had a big red button they could press to order the trucks to leave.

Puzzle Adventure (Perspective Puzzle)

In the final concept players had to work together to navigate a world full of puzzles and find secrets. The VR player would actually walk around in this world together with a small robot helper controlled by another player. The interface used for this could have been a monitor and the AsymDroid controller developed during my M2.1 project. The monitor would display a 1st person view from the perspective of the robot. Another player would be given a hand or foot pump to inflate virtual platforms to make certain parts of the world accessible to the VR player. This pump could also be used to power a rotor on the robot character to make it fly. Another player would be given a cube with an accelerometer in it that could be used to manipulate the virtual terrain or move/balance large objects. The last player would be given a treasure map with all kinds of secrets on it. This interface could be used to assist the other players in navigating the map and finding treasure.

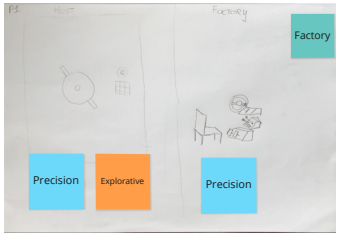
Appendix C – AVR Game Genre framework as presented to the participants of the co-design workshop

Mechanics		
Competitive or Cooperative	Describes whether a game is competitive or cooperative. If a game is both, note which players (VR or non-VR) are cooperative and which are competitive.	
Number of Players	Includes the number of players for each platform.	
Asymmetric Mechanics		
Goals	Defines how the goal of the game differs between VR and non-VR players. The goal is the main mechanic that determines if a player wins or loses a game.	
Abilities	Determines the moves that VR and non-VR players can take to help them reach their goal.	
Challenge	Describes how players must use the abilities that they have to reach their goal.	
Interface	Explains how the interfaces and controllers between VR and non-VR players differ. This mechanic is universally asymmetric across all AVR games.	
Information	Outlines what information a player has access to as they play a game. Information may or may not be asymmetric between VR and non-VR platforms.	
Dynamics		
Dependence	Determines if and how players rely on the actions of one another to effectively play a game. Three types of directional dependencies are used: Mirrored dependence: Players rely on each other in the exact same manner. Unidirectional dependence: One player depends on the other to act; however, this dependence is not reciprocated. Bidirectional dependence: Both players rely on each other in different ways.	
Synchronicity and Timing	Delineates the timeframes in which VR and non-VR players act respective to one another. Five types of directional dependencies are defined: Asynchronous timing: It does not matter to the other player when one player takes an action. Sequential timing: One player must complete an action before the other. Expectant timing: A player may trigger an action if the other is ready and waiting. Concurrent timing: Both players must continuously take an action at the same time. Coincident timing: Both players must take a specific action at the same discrete time.	
Aesthetics		
Theme	Explains how players perceive the game world. This may include descriptors such as narrative, fantasy, sensation, fellowship, etc.	
Roles	Describes the asymmetries in how players perceive each other's position in the game world.	

Appendix D - Results from the co-design workshop

P1

Heist



- Controller with parts that mimic things you can find on a safe
  - Number pad
  - Large lever
  - Rotation key
- Perhaps modular?
- The VR player can interact with it

- Forklift/EPT driver
  - Stick on steering wheel
  - Mimic real life

P2

Heist

Factory

Puzzle

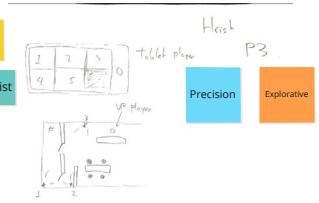
Heist
- Getaway driver
  - Can drive around the bank to look out of police
  - Has to get the VR player out of the bank
- Hacker quick time events on tablet

Factory
- EPT driver
- Switching around the direction of the production lines

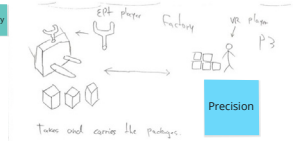
Puzzle Adventure
- Laser pointer
  - Control monster in the VR world
  - Give directional feedback to VR player
  - Use tablet to see and interact with the world (top-down)

P3

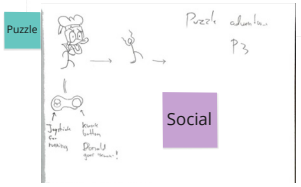
Heist



Factory



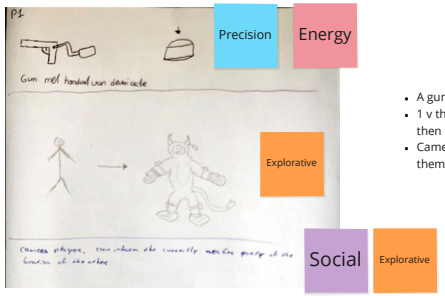
Puzzle



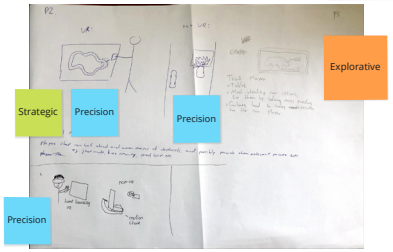
Heist
- Tablet where cameras can be selected
- Warning VR player about guards

Factory
- EPT driver
- Takes and carries the larger package or multiple packages around

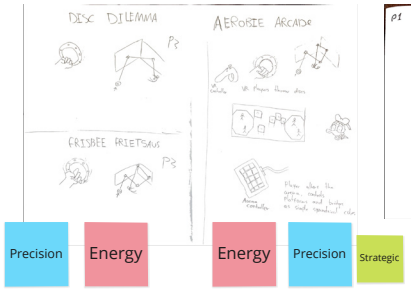
Puzzle Adventure
- A big red Quack! button to scare the VR player

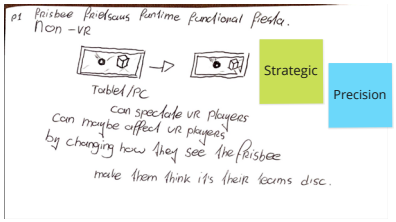


- A gun that needs to be charged before aiming
- 1 v the rest game where this one person is weak but then turns into a monster
- Camera player can assist this one person by telling them where the others are



- Racing game where one person is racing, and the other has a top down view of the map. This player can warn the VR player about obstacles
- The VR player uses hand tracking or a motion chair for extra realism

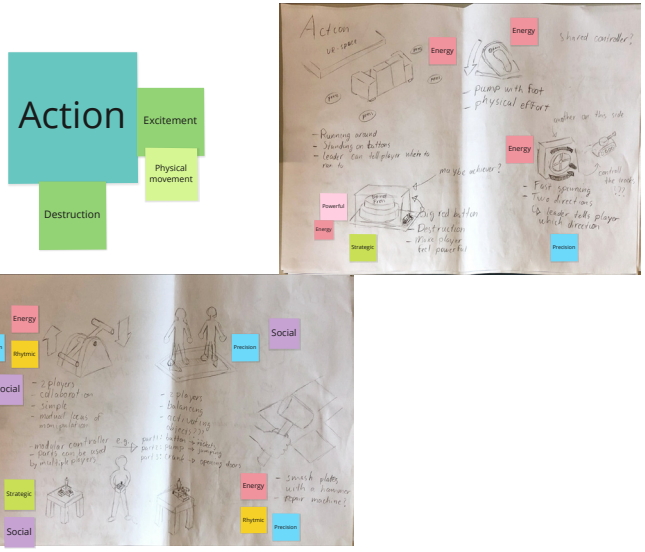


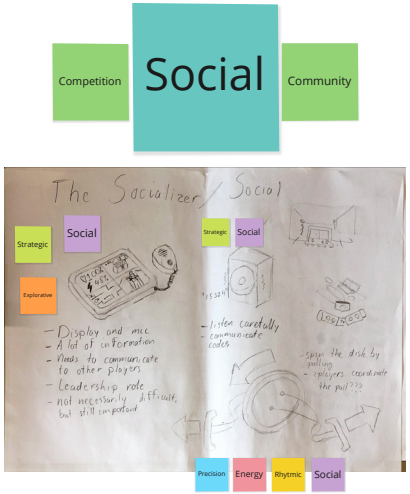


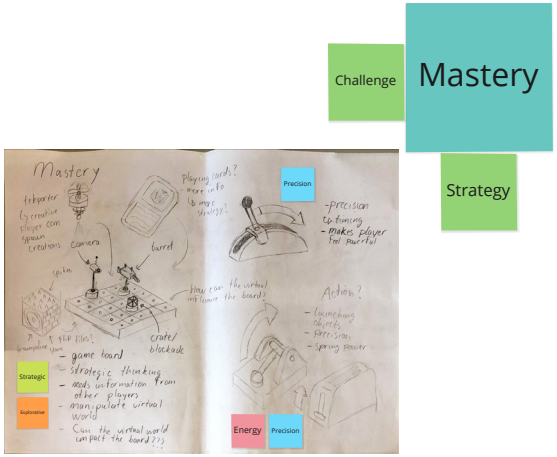
- Non-VR player can change which team the frisbee is from mid air so you can get killed by your own frisbee

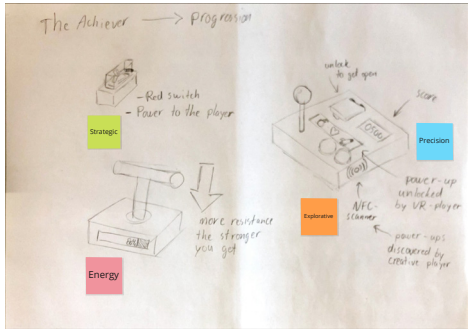
- VR players need to throw frisbees at each other
- Non-VR players have an interface with cubes sticking out of it that can be moved to manipulate the VR world

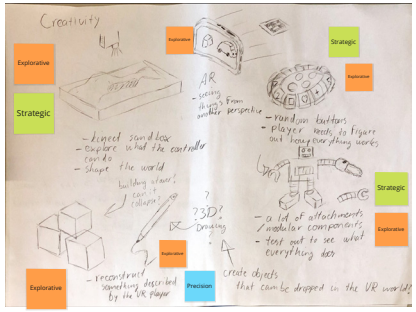
Appendix E1 – First iteration concept interactions categorized

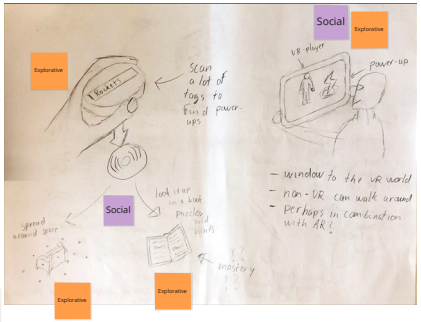












Power
Actions have a lot of impact

Achievement

Completion

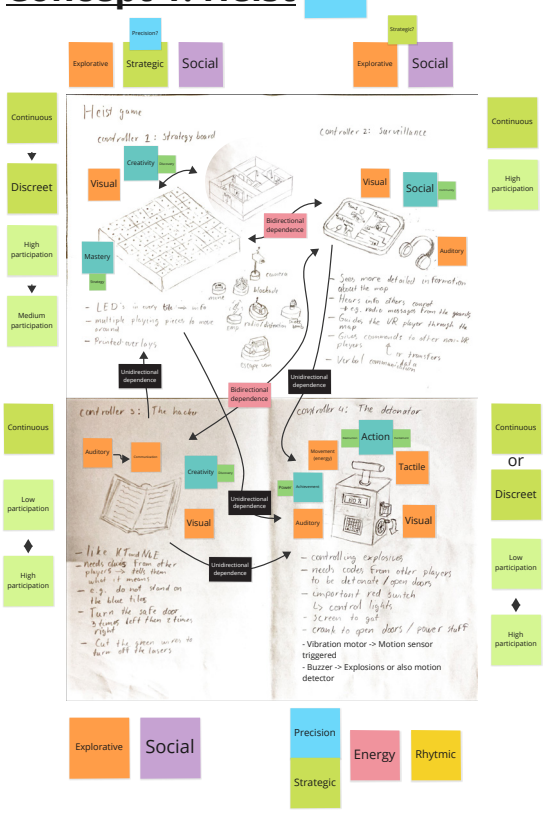
Design
Creation

Creativity

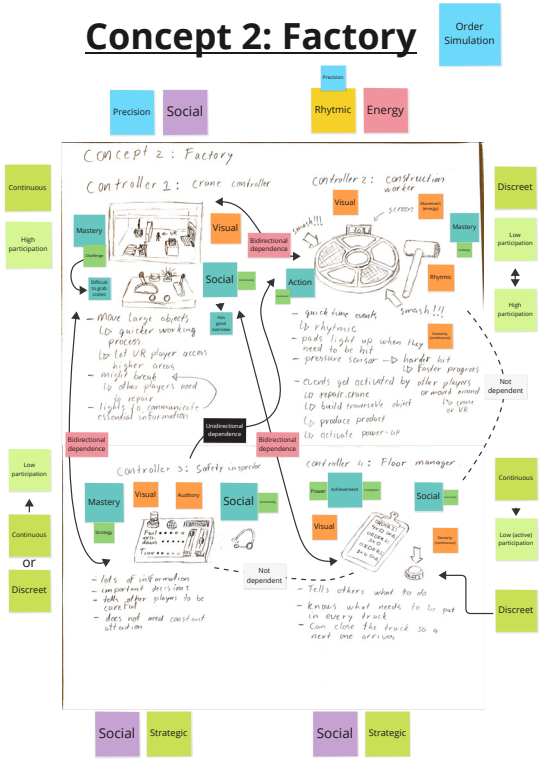
Discovery
Experimentation

Appendix E2 – Second iteration concept interactions categorized

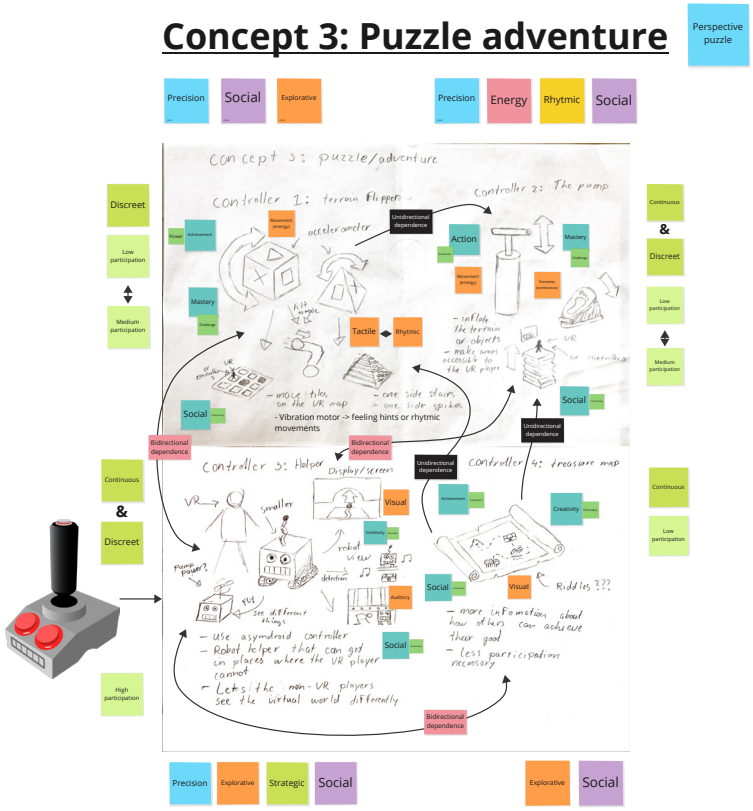
Concept 1: Heist



Concept 2: Factory



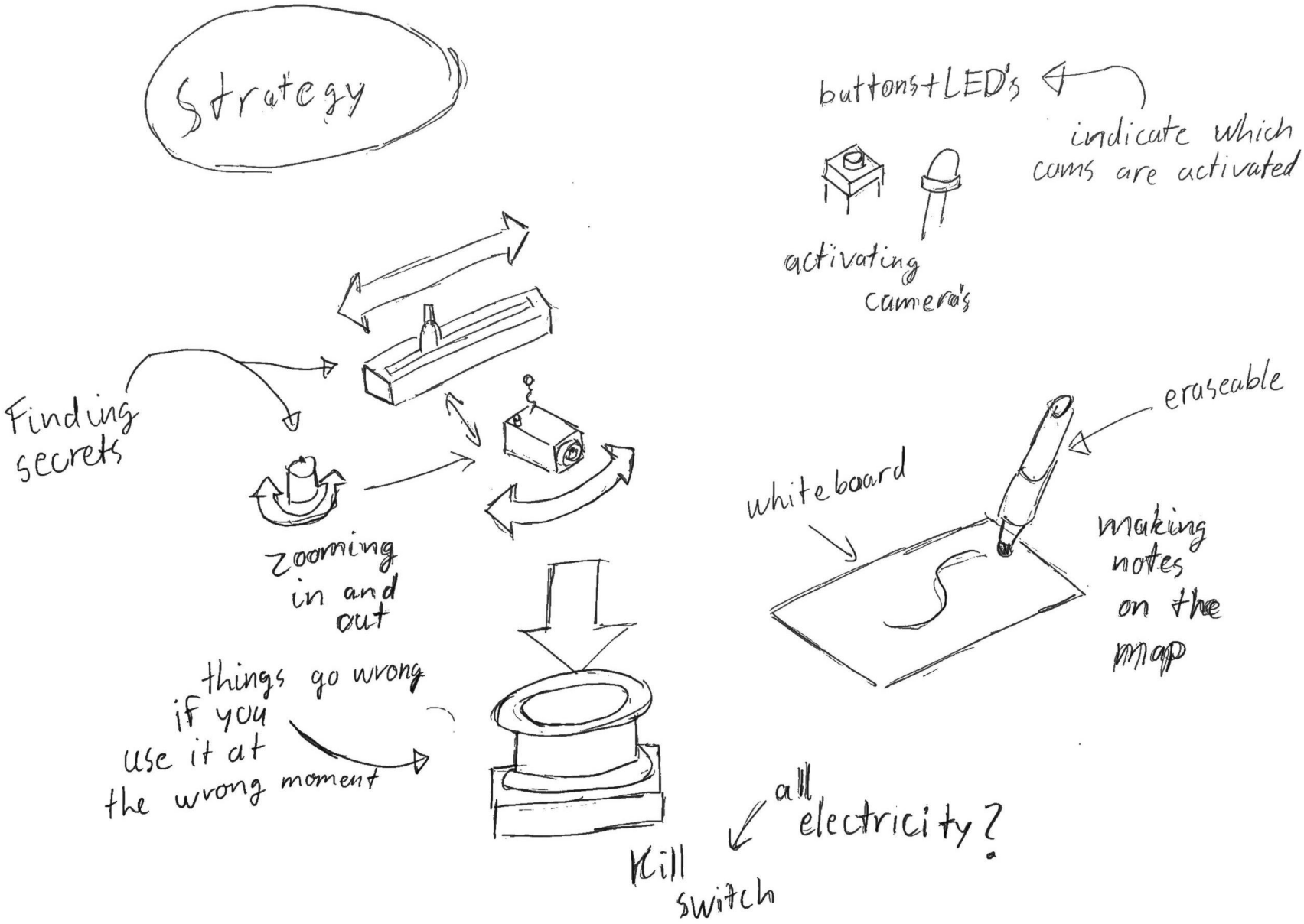
Concept 3: Puzzle adventure



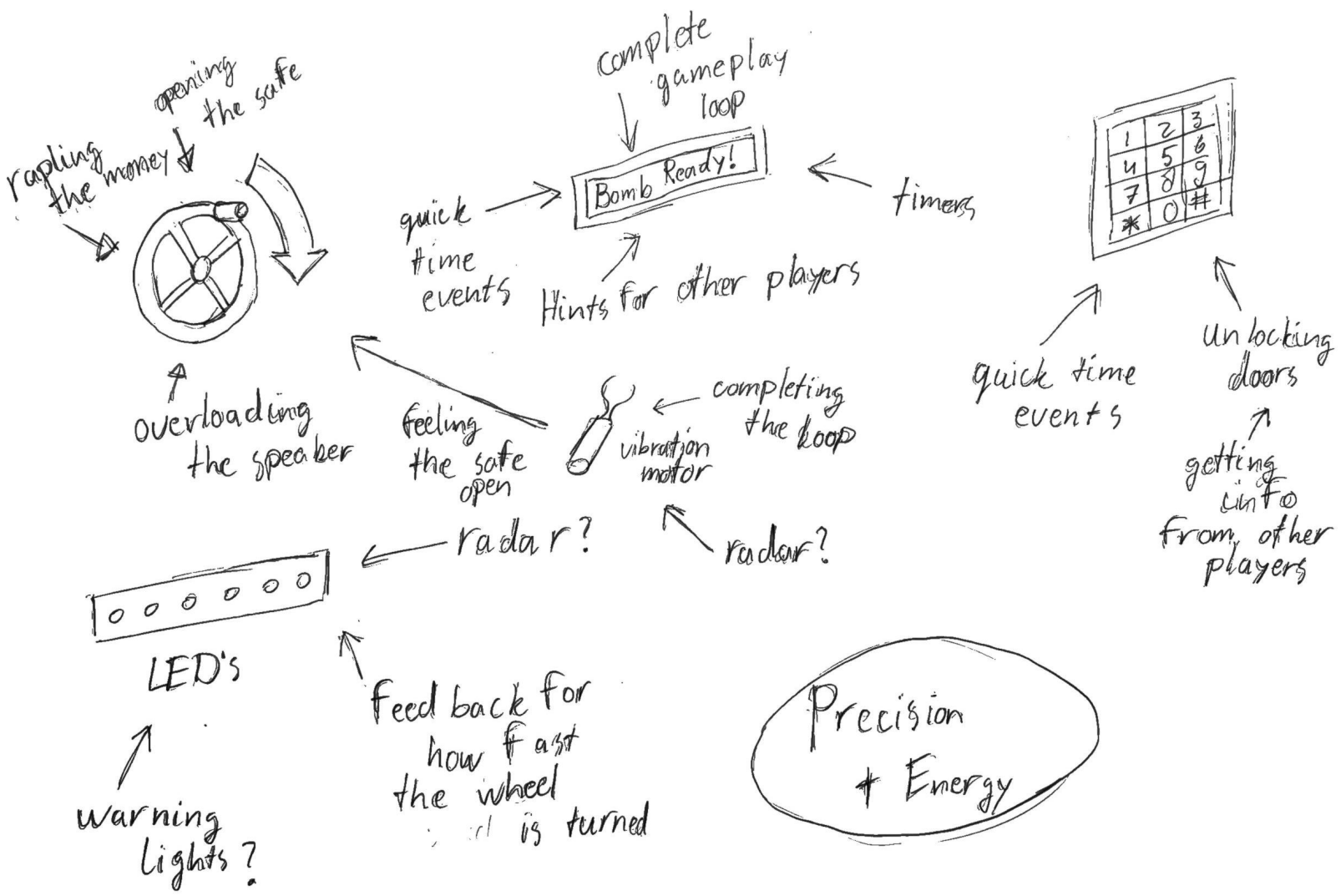
Appendix E3 – Alt.Ctrl.GDC interactions categorized

CTRL ALT GDC

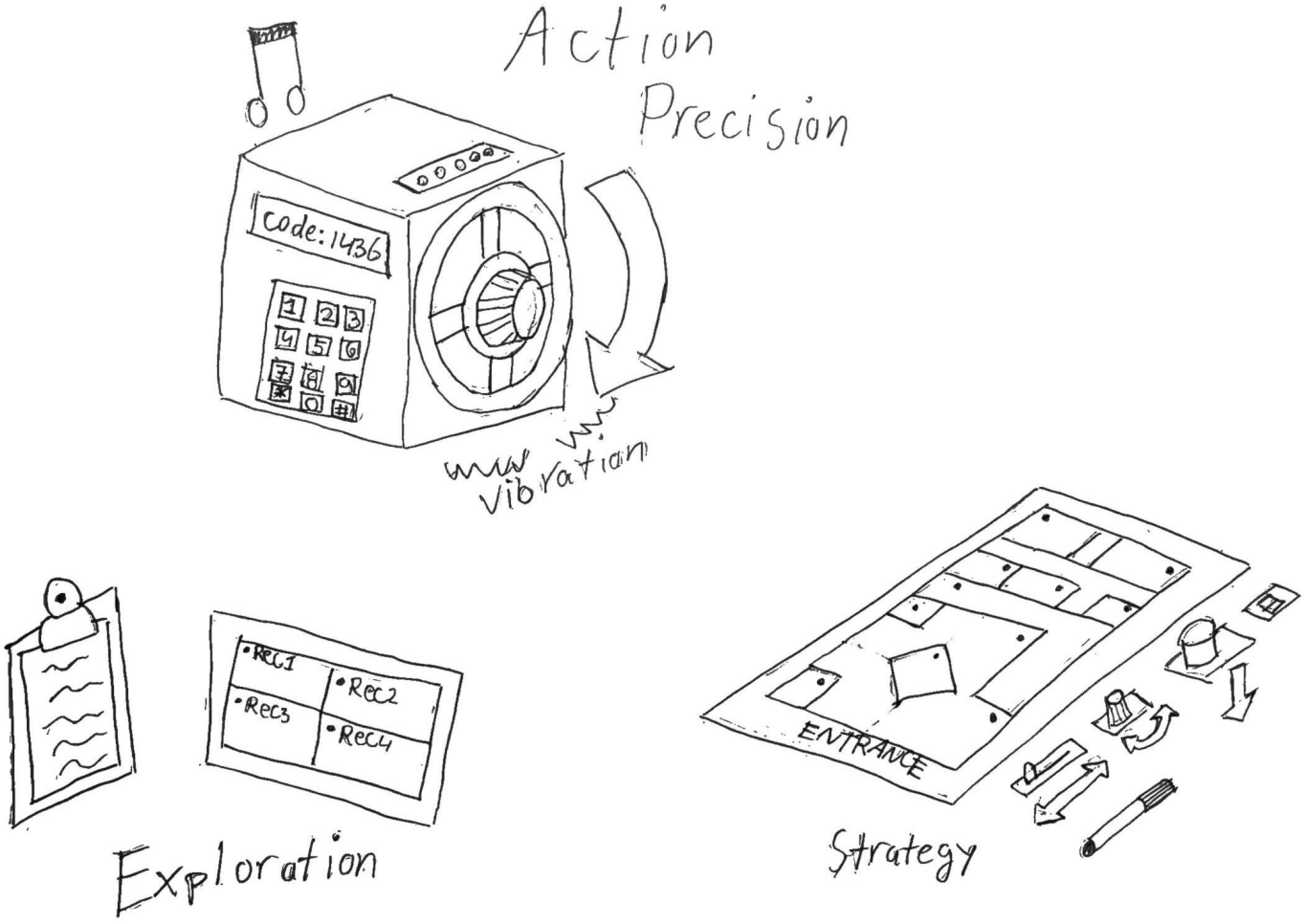
Appendix F1 – Sketches determining the components for the interface



Appendix F2 – Sketches determining the components for the interface



Appendix F3 – Sketches determining the components for the interface



Appendix G1 - Heist manual

Heist ExtRavaganza

How to infiltrate?

Le Musée des Extravagances

Mission brief: Retrieve the Golden Apple of the Hesperides!

It seems impossible, but the world-renowned museum *Le Musée des Extravagances* has somehow acquired one of the legendary golden apples of the Hesperides. These mythical fruits, said to belong to Hera, the queen of the gods, are no mere artifacts — they are steeped in divine power and peril.

Over 3,000 years ago, Heracles risked the wrath of the gods to steal these apples during his Twelve Labors. Now, history threatens to repeat itself. If humanity's hubris in keeping this sacred artifact angers the gods, the consequences could be catastrophic.

We cannot let this happen. Our mission is clear: we must steal the apple and return it to its rightful owner, restoring balance and averting divine retribution. This is the team we'll be working with today:

The Mastermind
The role description says it all — this is me, the brains behind the operation. After extensive scouting, I've mapped out every detail of this mission and compiled it all into these handy notes. From a secure location, I'll oversee the operation, assisting in monitoring camera feeds and guiding the Fox safely through the museum's halls.

The Fox
Our stealth specialist. The Fox has already infiltrated the museum, cleverly hiding in a restroom until the museum closes for the night. Their mission is to navigate through the museum undetected, locate the safe, and retrieve the mythical golden apple.

The Hacker
Our digital wizard. With their remarkable computer skills, the Hacker has gained control over the museum's security system. They can view and manipulate camera feeds and control one very specific lamp, but we will get to that later. Additionally armed with some trusty markers, they'll create annotations on the museum map to track discoveries and ensure smooth communication.

The Engineer
Our tech genius. The Engineer is the creator of the *Super Gadget*. This is a versatile tool in the form of a black box with a number pad, power wheel, and lightning symbol marked on its side. Controlled remotely by the Engineer but carried by the Fox, the Super Gadget is key for bypassing restricted areas and solving on-the-spot challenges.

Step 1: Get out of the restroom

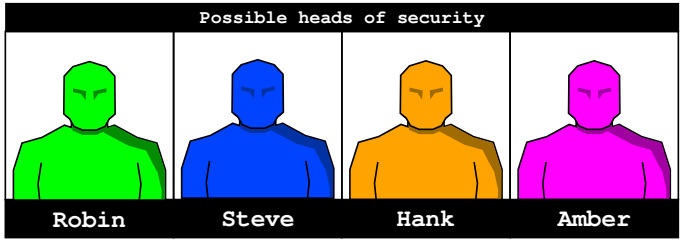
Just outside the restroom, we anticipate a guard to be stationed. Therefore, the Fox hid the Super Gadget underneath the donkey statue during the day. The Engineer can turn the power wheel to play a lullaby and lure the guard away from his post. The super gadget has been equipped with one cartridge of sleeping gas that can be released with the Hacker's big red POWER button.

Step 2: Get to the staff area

The Fox must make their way to the two doors located to the left of Pierre Croissantière's infamous Screaming Man painting. Be careful to not get detected by any guards and bring the Super Gadget! This tool can be used by our very skilled Engineer to pick the digital locks of these doors. Behind one door should be the staff cafeteria. Behind the other door the head of security should be watching fake camera footage cleverly displayed by our Hacker.

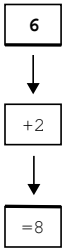
Step 3: Enter the security area

The hallway leading to the safe is the most heavily secured area of the museum, and accessing it requires more than just stealth. To open the door, we need a secret 4-digit code known only to the museum's manager. With this code we can calculate a password that changes depending on which head of security is on duty. Through my unparalleled brilliance and extensive research, I've identified all possible heads of security and uncovered the method to calculate the password once we have the base code. Place the Super Gadget next to the door to enter the password. Here you can find the tables required to crack the code:



Input Numbers	#1	#2	#3	#4
Robin	x2	−3	/5	−4
Steve	−2	+1	x5	+2
Hank	/3	/2	−1	+1
Amber	+4	−1	+6	/5
The Password:	=	=	=	=

Example:

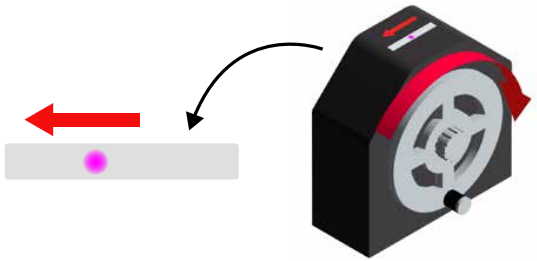


Appendix G2 - Heist manual

Step 4: Avoid the lasers

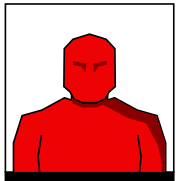
Once we've cracked the code and entered the security area, we'll face another challenge: a laser security system guarding the hallway. Fortunately, our Engineer can remotely disable the lasers using the Super Gadget. The Fox must place the Super Gadget on top of the control panel for the system. However, time is critical — the Engineer can only keep the lasers disabled for a limited period. The Fox will need to act quickly, navigating through the hallway while the lasers are down. Near the end of the hallway is a big red button. If pressed, it will permanently deactivate the laser system, allowing safe passage.

A **blue** light will pop-up on top of the Super Gadget once it is ready to start disabling the lasers. The Engineer can then disable the system by starting to turn the wheel with sufficient speed. The light will turn **purple** while the lasers are off, but it will also start moving. Turn the wheel in the opposite direction as the movement of the light to keep it in the center. If the light moves too far to either the left or right, the lasers will be enabled again.



Step 5: Get past Bob

If we've made it this far, only one real obstacle remains: Bob.
Bob is the most trusted and longest-serving member of the Musée des Extravagances' security team. His years of dedication have honed his instincts, but they've also taken a toll on his eyesight. This gives us a small advantage — if we use it wisely. Thanks to countless hours of effort, our Hacker has gained control over one crucial element of the museum's power grid: a single lamp that illuminates part of the hallway near Bob's post. Using the big red POWER button, the Hacker can turn off this lamp, momentarily shrouding the area in darkness. This will give the Fox just enough time to slip past Bob. However, caution is key — if Bob senses something is amiss, he'll be on high alert, and our chances of success could plummet. Timing and precision are everything here!



Bob

PS: The Fox must not forget to bring the Super Gadget with them — it's essential for what comes next.

Step 6: Open the safe

We're almost there! The final step is to open the safe, and the Super Gadget will once again prove its worth. The Engineer must use their skilled hands to grab onto the inner knob of the Super Gadget's power wheel and turn it. The direction of the first turn, clockwise or counterclockwise, depends on the safe's serial number, which can be found on the back of the safe.
To crack the safe:

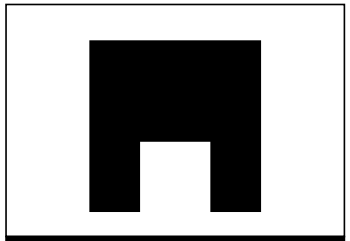
1. Turn the wheel slowly in the indicated direction until you feel a click.
2. Reverse direction and repeat the process.
3. Continue alternating directions and turning slowly until the safe opens.

The Super Gadget's high-quality sound system will indicate when the Engineer makes an error, forcing them to start over. Precision is crucial — turn the wheel too fast, and the mechanism will reset!
Stay calm, stay focused, and the golden apple will soon be within reach.

№ 54316	Clockwise
№ 13891	Counterclockwise

Step 7: Grab the apple

What?! There are three apples? Just kidding — I, of course, already knew that. I'm always prepared for every deceitful trick Le Musée des Extravagances throws at us!
The Fox needs to inspect all three apples carefully. Each apple has a black symbol on one of its sides. Only the true Golden Apple of the Hesperides bears the following symbol on its side:



The symbol of the Hesperides

Appendix G3 - Heist manual

Step 8: Get the hell OUT of there!

Be quick Fox! Grab the correct apple and your trusty Super Gadget and head for the extraction point. You remember when I said Bob was our last real obstacle? Well, I was right! We need to get past him one more time. You know the drill by now!
The extraction point is located in the restroom of the staff area. There's a hole in the ceiling where the Super Gadget can be placed. Once it's in position, the Engineer can use the power wheel to hoist the apple up with the Super Gadget's built-in grappling hook. Lastly, our invaluable team member Fox can be hoisted up.

Step 9: Celebrate!

Okay, this is the last and most important step: **Celebrate**! We did it! All of you have proven your worth, and please remember: I couldn't have done it without you! We have saved the world by retrieving the Golden Apple of the Hesperides – at least, I think we did.
To be entirely honest, I'm not one to believe in gods, but hey, it's probably better to be safe than sorry. Rest assured, I'll make sure the apple returns to its rightful owner.
You can truly be proud of yourselves! This is a heist for the history books!

Thank you for playing!

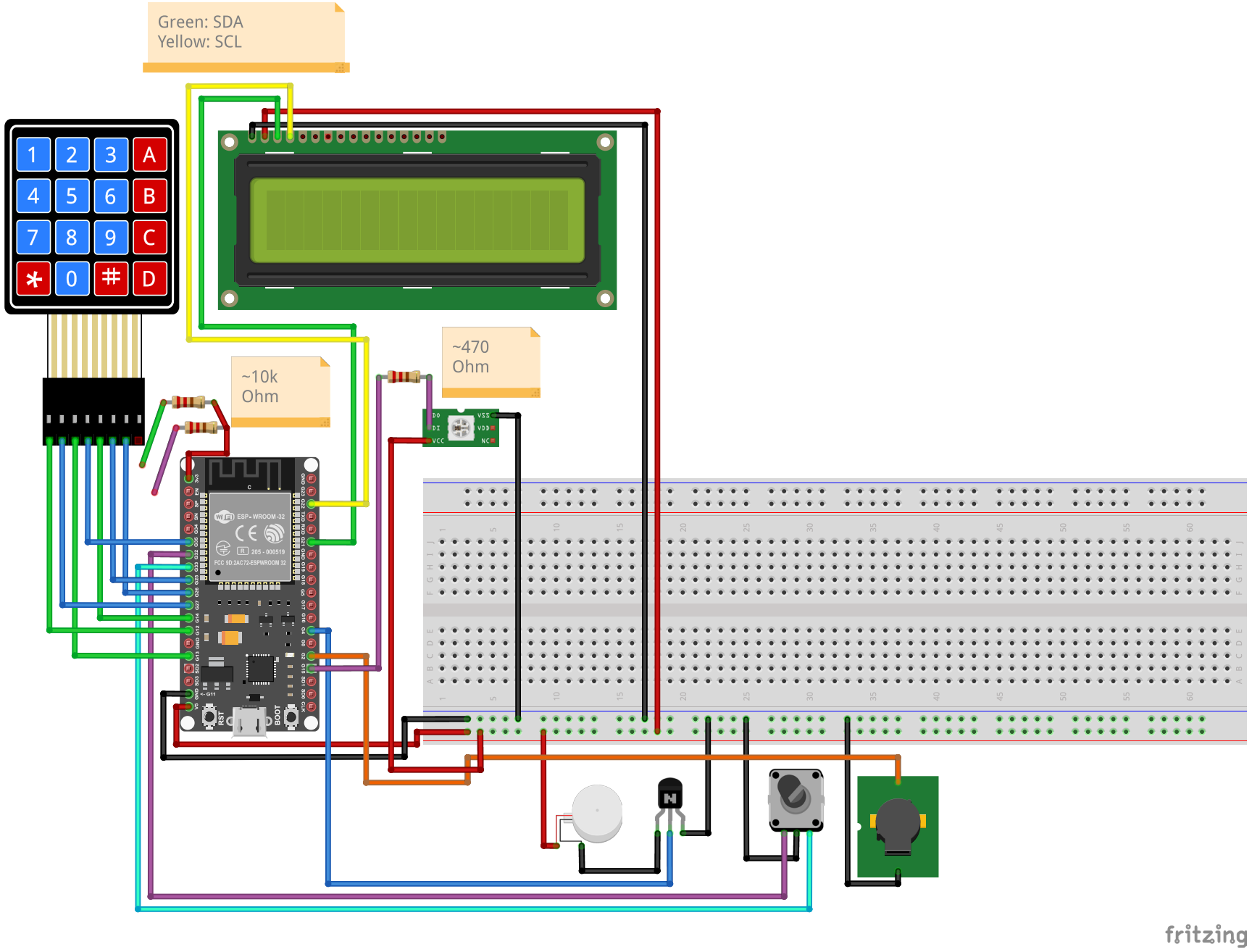
Appendix H - Interview questions

Interview questions user test Heist Extravaganza

1. How would you describe your experience playing this game?
2. What did you enjoy most while playing the game? Why?
3. What did you dislike most while playing the game? Why?
4. What was your most memorable moment while playing the game? Why?
5. How would you describe your relationship with the other players during the game?
6. How did the interactions between you and your co-players influence your experience?
7. How would you describe your experience playing your role specifically?
8. Which role seemed most enjoyable to you? Why?
9. Which role seemed least enjoyable to you? Why?
10. If you could change one thing about your role, what would it be?
11. If you could change one thing about the game in general, what would it be?
12. Is there anything else you would like to say about the game that I have not given you the chance to?

Appendix I - Visual clustering of some of the larger themes that were already made in Taguette

Appendix J - Schematic of electronics Super Gadget



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	Physical interfaces for co-located asymmetric virtual reality gaming
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 Studios, 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.*	04/10/24
10	End date data collection	08/01/25
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. *<u>Additional explanation</u>: 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: - I will handle and process all data. • Supervisor: Erik van der Spek

	• *(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 • Others: Enversed Studios: - The explorative research will be performed with some of the virtual reality developers employed by Enversed Studios. This project is done in collaboration with this company. They will have access to the processed and pseudonymized 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	
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*	
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
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.*	- How should a set of physical interfaces for co-located asymmetric virtual reality gaming look like? - What game mechanics can be created using these interfaces to encourage social interactions between co-located players and facilitate an enjoyable shared experience?
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, specifically VR developers ☐ 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.*	- Notes and audio recording of semi-structured group discussion around the topic of physical interfaces for co-located asymmetric virtual reality gaming. To provide the participants with more context around the topic, they will also be shown sketches of examples of ideas for such interfaces created by the researcher. - Participants will be asked to come up with a short description for a concept of an asymmetric virtual reality game. They will be provided with the Asymmetric Virtual Reality Game Genre framework (Dawes et al., 2024) to assist them in coming up with different for mechanics, dynamics and aesthetics for such a concept. They are also encouraged to sketch out their ideas. These concepts will also be discussed afterwards. - Lastly, participants will be asked to generate some ideas for physical interfaces that could be used in their game concepts. They are encouraged to sketch out their ideas. These concepts will be shared and discussed in the group. Dawes M, Rackliffe K, Hughes AL, Hansen DL. Asymmetric VR Game Subgenres: Implications for Analysis and Design. *Multimodal Technologies and Interaction*. 2024; 8(2):12. https://doi.org/10.3390/mti8020012
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.*	2 or 3 developers: - The amount of participants will be limited due to the number of developers that are available. However, this limitation should not be a problem, since this workshop is mainly explorative, and not necessarily for validation. - The study will only be one session with a duration of 1 to 1.5 hours. Participants will not be compensated.
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?*	Virtual reality gaming is often an isolating and individual experience. Providing co-located spectators with physical interfaces opens up the opportunity for them to join the experience and thus become co-players. These interfaces or controllers can let these co-players manipulate or perceive the virtual world in a different manner then the VR player. Social interaction between all these different kind of players can be encouraged if the right gaming mechanics are designed. Such a scenario can make VR a more social and enjoyable experience even for people who are sensitive to motion sickness, which is often induced by VR. This aspect makes the technology more inclusive and no additional VR head-mounted displays (HMDs) are needed to let more people join in. HMDs can be expensive.

Ethical Review Form

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 Studios ☐ 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.*	No serious risks are expected since no sensitive personal data will be collected and no sensitive or personal topics will be discussed. All data generated from the workshop will be fully pseudonymized.

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?	Voice recordings	
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

	• *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 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 - Offline version of Taguette thematic analysis tool (https://www.taguette.org/) - Miro for further thematic analysis of processed and pseudonymized data (https://miro.com)

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

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	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: No direct or indirect identifiers will be collected, aside from voice recordings. However, these voice recordings will be deleted within two weeks after they have been transcribed. The comments and sketches of certain participants will be grouped together with the use of an artificial pseudonym (e.g. P1, P2, P3).
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……. **The non-TU/e collaborator, Enversed Studios, will only be shown the processed and pseudonymized data.**
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* **The non-TU/e collaborator, Enversed Studios, will only be shown the processed and pseudonymized data. The only personal data collected will be voice**

		recordings, and these will NOT be shared with Enversed Studios. These recordings will even be deleted shortly after the analysis. *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?	The data will be deleted within two months after finishing the project.

Part 8: Closures and Signatures

1	Enclosures (tick if applicable and attach to this form):	☒ Informed consent form ☐ Informed consent form for other agencie when the research is conducted at a locatio (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 ☐ 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)  Jules van Gurp Date: 01/10/24 Signature research supervisor  Date: 02/10/2024

Information sheet for research project "Physical interfaces for co-located asymmetric virtual reality gaming"

1. Introduction

Eindhoven University of Technology (TU/e) invites you to take part in this research project which aim is to explore the questions: '*How should a set of physical interfaces for co-located asymmetric virtual reality gaming look like?*' & '*What game mechanics can be created using these interfaces to encourage social interactions between co-located players and facilitate an enjoyable shared experience?*'. You receive this invitation because the researcher is collaborating with your employer, Enversed Studios. For your participation you will not be compensated.

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 project 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 us (contact details below). You can also discuss this information with people you trust.

2. Who are we?

This research project is conducted by:

Technische Universiteit Eindhoven (TU/e) De Groene Loper 3 5612 AE Eindhoven	Jules van Gurp

In collaboration with the following parties:

Enversed Studios Achtseweg Zuid 241 5651 GW Eindhoven	No access to personal data

How to contact us?

Jules van Gurp	j.a.m.v.gurp@student.tue.nl
Privacy Operations	privacy@tue.nl
Data Protection Officer	dataprotectionofficer@tue.nl

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

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

- Group discussion about physical interfaces for co-located asymmetric virtual reality gaming and to write down your answers/record your answers via audio/video. Also, we will make a transcript of the group discussion.
- Letting you sketch out and note down ideas regarding physical interfaces for co-located asymmetric virtual reality gaming and concepts for asymmetric virtual reality gaming.

▪

4. 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 and type	Personal data	Purpose	Retention period
Audio recording	*Voice recording of group discussion*	*To make a transcript of the group discussion*	*Two weeks after the voice recordings have been fully transcribed*

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. Unless you explicitly agree to the use of your identifiable information in publications (for example your quotes or your name).

5. Stopping your participation and your rights

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 researcher via the contact details as provided in the table under section 2.

For concerns or questions about the handling of personal data, you can e-mail the data protection officer as indicated in the table under section 2. You can also file a complaint with the Dutch data protection authority: the Autoriteit Persoonsgegevens.

You have the right to request access, rectification, objection, erasure or adaptation of your data. Submit your request through team Privacy Operations via the contact details as provided in the table under section 2.

6. Legal basis for processing your personal data

The TU/e processes your personal data to conduct scientific research, which is the university's public task as stated in article 1.3 of the Dutch Wet Hoger onderwijs en Wetenschappelijk onderzoek. The TU/e always follows the applicable codes of conduct for research integrity and the scientific standards when conducting research.

7. Who has access to your personal data?

Only authorized employees involved in the research have access to your personal data if this is necessary for their tasks. The authorized employees will keep your personal data confidential.

Other parties/processors that have access to the data are listed in the table below:

Party/processor	Why access?	Processing within the European Economic Area?
Microsoft (Netherlands)	*Storage solution & Transcription tool*	*Yes*
Miro	*Data analysis tool*	*Yes*

TU/e has a suitable agreement with these parties to protect your personal data. We will not share your personal data with any other party, unless we are required to do so by law.

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

server inside the EEA. In addition, TU/e has implemented appropriate technical and organizational measures to protect your personal data. These measures include using centrally managed and verified research- and storage tools.

8. Future research

During the research project, your personal data may also prove useful for new, socially important research. In such case, we would like to reuse your data for the new research. This will only happen if (1) your personal data is truly necessary, (2) the recognized ethical standards for scientific research are followed, and (3) the new research objectives align with the current research objectives. If your personal data is used in future research, we will take all reasonable steps to inform you about this. You can object to the use of your personal data for new research.

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 an adult

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 personal data, audio taken of me, sketches and notes of my ideas, and answers or quotes I gave during the research, to be used by the researcher in publications and/or in presentations – without including my name.

   YES ☐ NO ☐

Name of Participant:

Signature:

Date:

Name of researcher:

Signature:

Date:

From: Mulder, Maartje on behalf of Ethics
To: Gurp, Jules van
Cc: Spek, Erik van der
Subject: RE: ERB form + Informed Consent Form
Date: Thursday, 3 October 2024 10:48:20
Attachments: image001.png

Dear Jules,

Your application (ERB2024ID377) has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

With kind regards,
Maartje Mulder

TU/e

040-2475032
Secretary Integrity and Ethics Office
Secretary BoE EngD

From: Gurp, Jules van <j.a.m.v.gurp@student.tue.nl>
Sent: woensdag 2 oktober 2024 14:11
To: Ethics <Ethics@tue.nl>
Subject: ERB form + Informed Consent Form

Dear Ethics Board,

In the attachments you can find the signed ERB form with the informed consent form as an appendix. Everything should be minimal risk.

Kind regards,

Jules van Gurp

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	Physical interfaces for co-located asymmetric virtual reality gaming
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 Studios, 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.*	09/12/24
10	End date data collection	08/01/25
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: - I will handle and process all data. • 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 • Others: Enversed Studios: - This project is being done in collaboration with Enversed Studios. However, only fully processed and anonymized/pseudonymized results will be presented to them.
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		
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 be a Meta Quest 3. - For this research two "gaming controllers" were developed (Appendix B). These devices were made using 3D printed and wooden laser-cut parts. They should not present any risks to their users since they are not wearable and only use operating voltages of 5V and below. They are both controlled using an ESP32 microcontroller.
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 electronic parts are properly closed off to users and like aforementioned only operate using low voltages. Furthermore, no parts require high a current. Additionally, the controllers have no sharp edges and are quite light, so these factors should also not pose any risks to its users.
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
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.*	- How do the physical interfaces designed for asymmetric virtual reality contribute towards a social and enjoyable co-located multiplayer gaming experience? - How do users experience the different roles that the varying types of physical interfaces offer them?
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, specifically…… ☐ Patients, specifically …….. ☐ Other, specifically ……

Ethical Review Form

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 research procedure will start by giving the participants a short introduction and by letting them read and sign the informed consent form. - The participants will then play a collaborative asymmetric VR game specifically designed for this research and the accompanying controllers. The game is designed for 4 players with each their own specific role and accompanying interface. Participants may decide among themselves who will use which interface. One player will wear a VR head-mounted display. The second will have a paper manual and monitor. The third will use a 3D-printed controller with a small LCD screen, a keypad, and a wheel that can be turned as an input method. The last controller will be a laser-cut map of the game world with buttons and LED's placed on top. The game will likely take around 30 minutes to play. - Once the participants are done playing the game, they will be asked to fill in two questionnaires in MS Forms. The first of the these two questionnaires will be the Player Experience Inventory (PXI) (Appendix C). The second questionnaire is the Social Presence in Gaming Questionnaire (SPGQ) (Appendix D). After they have finished filling in the questionnaires, a semi-structured group interview will be held with all participants simultaneously. An audio recording will be made of this group interview.
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.*	~8-12 Participants - In this research participants will need to be play a videogame that is designed for 4 players. It will likely only be possible to test the game with 2 or 3 groups due to the length of the game and time constraints of the project. - The study will only be one session with a duration of 1 to 1.5 hours. Participants will not be compensated.
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?*	Virtual reality gaming is often an isolating and individual experience. Providing co-located spectators with physical interfaces opens up the opportunity for them to join the experience and thus become co-players. These interfaces or controllers can let these co-players manipulate or perceive the virtual world in a different manner then the VR player. Social interaction between all these different kind of players can be encouraged if the right gaming mechanics are designed. Such a scenario can make VR a more social and enjoyable experience even for people who are sensitive to motion sickness, which is often induced by VR. This aspect makes the technology more inclusive and no additional VR head-mounted displays (HMDs) are needed to let more people join in. HMDs can be expensive.

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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 ……... ☐ 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.*	No serious risks are expected since no sensitive personal data will be collected and no sensitive or personal topics will be discussed. All data generated from the workshop will be fully pseudonymized.

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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?	Voice recordings	
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

	• *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 - Offline version of Taguette thematic analysis tool (https://www.taguette.org/) - Miro for further thematic analysis of processed and pseudonymized data (https://miro.com)

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: No direct or indirect identifiers will be collected, aside from voice recordings. However, these voice recordings will be deleted within two weeks after they have been transcribed. The comments of certain participants will be grouped together with the use of an artificial pseudonym (e.g. P1, P2, P3).
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* **The non-TU/e collaborator, Enversed Studios, will only be shown the processed and pseudonymized data. The only personal data collected will be voice recordings, and these will NOT be shared with Enversed Studios. These recordings will even be deleted shortly after the analysis.**

		*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?	The data will be deleted within two months after finishing the project.

Part 8: Closures and Signatures

1	Enclosures (tick if applicable and attach to this form):	☒ Informed consent form (Appendix A) ☐ Informed consent form for other agencie when the research is conducted at a locatio (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 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)  Jules van Gurp Date: 08/12/24 Signature research supervisor  Date: 08/12/24

Appendix A – Informed Consent Form

Information sheet for research project "Physical interfaces for co-located asymmetric virtual reality gaming"

1. Introduction

Eindhoven University of Technology (TU/e) invites you to take part in this research project which aim is to explore the questions: '- *How do the physical interfaces designed for asymmetric virtual reality contribute towards a social and enjoyable co-located multiplayer gaming experience?*' & '*How do users experience the different roles that the varying types of physical interfaces offer them?*'. You receive this invitation because the researcher is collaborating with your employer, Enversed Studios. For your participation you will not be compensated.

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 project 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 us (contact details below). You can also discuss this information with people you trust.

2. Who are we?

This research project is conducted by:

Technische Universiteit Eindhoven (TU/e) De Groene Loper 3 5612 AE Eindhoven	Data controller

In collaboration with the following parties:

Enversed Studios Achtseweg Zuid 241 5651 GW Eindhoven	No access to personal data

How to contact us?

Jules van Gurp	j.a.m.v.gurp@student.tue.nl
Privacy Operations	privacy@tue.nl
Data Protection Officer	dataprotectionofficer@tue.nl

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

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

- You will be asked to play a collaborative asymmetric virtual reality game together with 3 other participants. Each player will get their own unique physical interface to interact with and perceive the game. You will have to choose amongst yourselves who plays which role. The duration of the game is approximated to be around 30 minutes.
- Once you have finished playing the game you are asked to fill in two questionnaires in Microsoft Forms: The Player Experience Inventory (PXI) & the Social Presence in Gaming Questionnaire (SPGQ).
- Lastly, a semi-structured group interview will be held during which you will asked questions regarding your experience playing the game, the use of the various interfaces, and your interactions

with the other participants. The researcher will make notes of this interview and audio will be recorded so a transcript of the interviews can be made.

4. 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 and type	Personal data	Purpose	Retention period
Audio recording	*Voice recording of group interview*	*To make a transcript of the group interview*	*Two weeks after the voice recordings have been fully transcribed*

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. Unless you explicitly agree to the use of your identifiable information in publications (for example your quotes or your name).

5. Stopping your participation and your rights

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 researcher via the contact details as provided in the table under section 2.

For concerns or questions about the handling of personal data, you can e-mail the data protection officer as indicated in the table under section 2. You can also file a complaint with the Dutch data protection authority: the Autoriteit Persoonsgegevens.

You have the right to request access, rectification, objection, erasure or adaptation of your data. Submit your request through team Privacy Operations via the contact details as provided in the table under section 2.

6. Legal basis for processing your personal data

The TU/e processes your personal data to conduct scientific research, which is the university's public task as stated in article 1.3 of the Dutch Wet Hoger onderwijs en Wetenschappelijk onderzoek. The TU/e always follows the applicable codes of conduct for research integrity and the scientific standards when conducting research.

7. Who has access to your personal data?

Only authorized employees involved in the research have access to your personal data if this is necessary for their tasks. The authorized employees will keep your personal data confidential.

Other parties/processors that have access to the data are listed in the table below:

Party/processor	Why access?	Processing within the European Economic Area?
Microsoft (Netherlands)	*Storage solution, Transcription tool & Survey tool*	*Yes*
Miro	*Data analysis tool*	*Yes*

TU/e has a suitable agreement with these parties to protect your personal data. We will not share your personal data with any other party, unless we are required to do so by law.

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

server inside the EEA. In addition, TU/e has implemented appropriate technical and organizational measures to protect your personal data. These measures include using centrally managed and verified research- and storage tools.

8. Future research

During the research project, your personal data may also prove useful for new, socially important research. In such case, we would like to reuse your data for the new research. This will only happen if (1) your personal data is truly necessary, (2) the recognized ethical standards for scientific research are followed, and (3) the new research objectives align with the current research objectives. If your personal data is used in future research, we will take all reasonable steps to inform you about this. You can object to the use of your personal data for new research.

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 an adult

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 personal data, audio taken of me, and answers or quotes I gave during the research, to be used by the researcher in publications and/or in presentations – without including my name.

YES ☐ NO ☐

Name of Participant:

Signature:

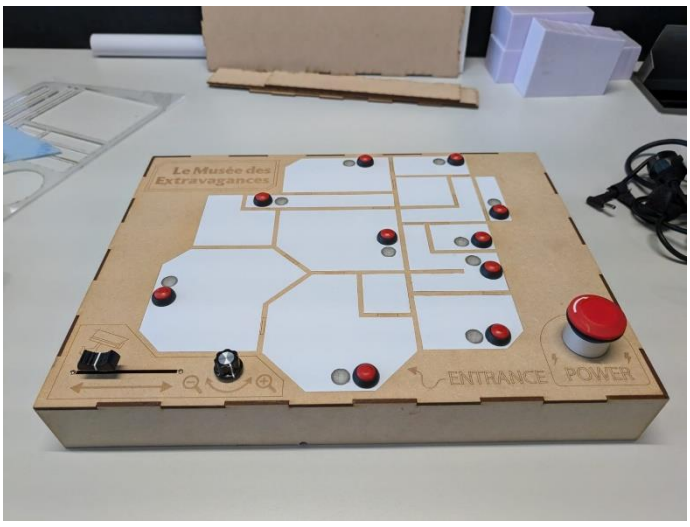
Date:

Name of researcher:

Signature:

Date:

Appendix B – Two of the self-made controllers made for this research



Appendix C – 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 D – Social Presence in Gaming Questionnaire

4. GEQ - Social Presence Module

Please indicate how you felt while playing the game for each of the items,
on the following scale:

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4
< >	< >	< >	< >	< >

1	I empathized with the other(s)
2	My actions depended on the other(s) actions
3	The other's actions were dependent on my actions
4	I felt connected to the other(s)
5	The other(s) paid close attention to me
6	I paid close attention to the other(s)
7	I felt jealous about the other(s)
8	I found it enjoyable to be with the other(s)
9	When I was happy, the other(s) was(were) happy
10	When the other(s) was(were) happy, I was happy
11	I influenced the mood of the other(s)
12	I was influenced by the other(s) moods
13	I admired the other(s)
14	What the other(s) did affected what I did
15	What I did affected what the other(s) did
16	I felt revengeful
17	I felt schadenfreude (malicious delight)

From: Severens, Marjolein on behalf of Ethics
To: Gurp, Jules van
Subject: RE: ERB form User Test
Date: Wednesday, 11 December 2024 13:06:43

Dear Jules,

Your application (ERB2024ID580) has been approved by the ERB.

We assume that you have answered all questions correctly. We will perform regular spot-checks so you need to keep your documentation (ERB form, informed consent forms, surveys/interview questions, description of experiment/prototype etc.) available for at least 6 months.

Good luck with your research and have a nice day!

Dear regards,

Marjolein Severens
ERB student assistent

From: Gurp, Jules van <j.a.m.v.gurp@student.tue.nl>
Sent: dinsdag 10 december 2024 16:53
To: Ethics <Ethics@tue.nl>
Subject: ERB form User Test

Dear Ethics Board,

In the attachments you can find the signed ERB form with the informed consent form as an appendix. Everything should be minimal risk.

Kind regards,

Jules van Gurp