Graduation Thesis

Virtual Reality Immersion in Magical Environments

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Tim Aarntzen

Abstract

This goal of this paper was to find out: *How could an avatar using inverse kinematics in first person perspective in Virtual Reality influence core gameplay?*

The definition of immersion and possible inverse kinematics solutions have been researched to test ways to improve gesture-based and other types of interactions in VR. Usability test with the target audience were conducted and results show that during fast paced gameplay users were not noticing indifferences but during slow paced gameplay the imperfections were more noticeable.

I conclude that an 1PP avatar can positively influence gameplay by providing the player with a frame of reference while playing.

Due to lockdown during the COVID-19 pandemic, the sample size of the usability test are low and this may reduce credibility of this research.

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Abbreviations

1PP	First Person Perspective.
AI	Artificial Intelligence.
HMD	Head Mounted Display.
IK	Inverse Kinematics.
PCVR	Personal Computer Virtual Reality.
UBIK	Upper Body Inverse Kinematics.
UE4	Unreal Engine 4.
VE	Virtual Environment.
VFX	Visual Effects.
VR	Virtual Reality.

Glossary

Aesthetics	Emotional responses evoked by the player.
Asset	Game object which can be either visual or audio.
Dynamics	The run-time behaviour of the mechanics.
Immersion	Feeling of being absorbed into a Virtual Environment.
Mechanics	The base components of the game.
Sense of Embodiment	Ensemble of sensations that arise being inside, having, and controlling a virtual body in VR applications.
Simulation Sickness	Nausea from simulated experiences.
Standing VR	Standing play area for users that do not have enough play area.
Room-scale VR	Large play area where users can walk freely within set area.

1. Introduction

While in Virtual Reality, you will often wonder can I do this? If these expectations are met, then immersion will not be broken. Immersion can be defined as the state of being absorbed into the Virtual Environment (VE), just like reading a good book. With VR being a relatively new platform, that means new expectations from players arise.

The creative idea for this project was to develop a VR wizard duelling prototype with a high immersion factor and exploring ways to create the main mechanic, casting magic spells in VR. The game prototype will be developed for Personal Computer Virtual Reality (PCVR) as core gameplay requires interaction using motion controllers. The game engine used for development is Unreal Engine 4 (UE4), to be more specific version 4.25.4. Core gameplay is battling other players in 1 on 1 duels, all while an avatar is visible in first person perspective (1PP). During a duel, players use combat spells to hit each other. Players have the option to defend themselves with defend or parry spells or dodge them by physically moving around in their play space. There are 2 magic types that the player can use:

- Player Magic, for non-combat spells and is cast using hand gestures.
- Wand Magic, for duelling spells and is cast using wand gestures.

This thesis explores what immersion in VR means and how to enhance it when in a magical environment. Experiments comparing a 1PP avatar to no avatar have been done to see if a 1PP avatar could influence core gameplay in any way.

Due to lockdown during the Covid-19 pandemic user testing was limited.

2. Project Description

2.1 Assignment

The student will be working together with a fellow graduate student Joey van Merode on the project. For this assignment, the idea was to make an intuitive spell casting VR game and explore innovative interactions for VR. The theme of the project is a wizarding school where students learn magic spells. The goal was to create a magical world to be fully immersed into and make you feel like a wizard or witch while casting spells using gesture driven interactions.

The reason for this assignment is to find out what it takes to create feeling of presence while avoiding simulation sickness so everyone can enjoy VR games. During the project, the student has conducted research towards topics like the sense of presence, the sense of embodiment, the self-avatar follower effect, and accessibility options in VR. It was expected to learn what the do's and don'ts are when it comes to immersion in VR.

The product that will be created will be a VR prototype of the wizard duelling game with an immersive player avatar and gesture-based gameplay interactions.

2.2 Scope

The project has a 5-month research and development period. During this period, the focus will be on functionality of the VR avatar and gesture interactions and will not focus on the look of the game. All assets used in the product are placeholder and are subject to change.

In the table below shows a list of what the product will include.

Table 1: Project Scope

Alpha 1.0	**Vertical Slice**
VR Avatar	• Locomotion. (Teleport / Joystick Movement.) • Grip mechanics/dynamics. (Fluid grabbing animations and functionality.) • Avatar IK system. (Physically correct arm and torso IK, accessible for all player heights.)
Gesture Spell Casting	• Gesture based casting. (Simple and intuitive interaction.) • Basic Attack and Defend type spells. (Simple spells for testing the gesture interaction system.) • Animation Assist. (System to assist players during gesture interaction.)
Test Level	• All items are physical and can be grabbed. • Simple test dummy AI. (Can casts spells and defend.)

Due to 5 months not being that much time and a small development team this product:

- Will not be a complete product ready for market. Exploring base mechanics only, final dynamics, aesthetics, and narrative will be a future project.
- Will not include option for motion capture or more than 3-point tracking. Only a system for 3-point tracking will be made.
- Will not include multiplayer yet. This will be a future project.

2.3 Limitations

The original idea for the project was a multiplayer game but since there are no qualified engineers in the development team, a single player experience will be created.

Since the game focusses on duelling, an option for either room-scale VR or standing position VR should be available. In a hardware survey conducted by Oculus (figure 1) shows the average play area for Rift S users. Most users play in a play area of 1.5 – 2.0m by 2.0 – 2.5m or smaller. See Annex 2 for a more detailed image of the hardware survey.

	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	2.0 - 2.5m	2.5 - 3.0m
0.5 - 1.0m	1	2	1	0	0
1.0 - 1.5m	1	15	12	4	0
1.5 - 2.0m	0	7	13	19	2
2.0 - 2.5m	0	2	3	8	1
2.5 - 3.0m	0	0	1	2	1

Figure 1. Oculus Rift Hardware Survey avarage play area.

This means that the game levels should be traversable with locomotion but during a duel, players should still be able to dodge incoming spells using their physical body. Gestures should be simple so users with not a lot of space will not hit their surroundings when performing a spell in the heat of the moment.

2.4 Target Audience

The target audience are PCVR users using either HTC Vive (or newer), Oculus Rift (or newer) and Valve Index. Since VR is still relatively new (and expensive), the target audience is not aiming at specific users within VR but at all PCVR users. Because of such a diverse audience, the game should be accessible for all to increase interest in VR.

2.5 Indicators of Success

The project will be a success when the Spell Casting mechanic is fun and intuitive to learn. The users should be able to easily learn the Spell Casting mechanic, but it should be difficult to master this mechanic.

The following items can be used as indicators of success:

- Intuitive and easy to learn spell casting mechanic.
- Immersive Player Avatar.
- Reusable Blueprint code.

2.6 Preliminary Problem Definition

Staying immersed in a simulated environment is hard to achieve. During concept discussions a VR avatar in 1PP view was proposed to help stay immersed. One problem could be the implementation of an IK system in UE4. The problem is knowledge is lacking about IK solutions for player characters for VR. The head and hands can be tracked using the headset and the motion controllers' sensors, but the arm and torso twist still need to be calculated by inverse kinematics. The hips, legs and feet must be animated as there are no sensors unless your using expensive full body suits. Is such a system needed to complete the feeling of presence during gameplay? A system without the need for extra hardware that animates the self-avatar using only 3-point tracking would solve the need for full body tracking and bring more immersion to the masses.

Another problem could be current hardware. How far can the graphic fidelity go with hardware from 2020? How many particle FX can be used during gameplay before the game starts dropping frames? Assets and systems need to be optimized for high framerate, at least 90 frames a second and look high quality from up close.

3. Theory

3.1 What is immersion?

Video games are a great platform to experience immersion. VR takes this a step further by dropping the player right into the virtual world. When players put on the head mounted display (HMD) they block off the real world. Their vision and hearing are stimulated by the VE and because of this the player feels as if he/she is absorbed into the VE. This gives the player the sense of presence (Björk, Holopainen, 2004). The key component from the feeling of presence is embodiment. After reviewing literature, Kilteni et al. (2012) provide a working definition for embodiment in VR, they called it the sense of embodiment. The sense of embodiment is the ensemble of sensations that arise being inside, having, and controlling a virtual body in VR applications. They proposed an underlying structure for the sense of embodiment made up from 3 subcomponents:

- Sense of agency, which refers to having "global motor control, including the subjective experience of action, control, intention, motor selection and the conscious experience of will." (Blanke & Metziger, 2009, p. 7). Feeling as if one is controlling the body.
- Sense of body ownership: Body ownership refers to one's self-attribution of a body (Gallagher,2000; Tsakiris, Prabhu, & Haggard, 2006) and to induce ownership toward an external object, a basic morphological similarity with the real body part is needed.
- Sense of self-location refers to the spatial experience of being inside a body.

All 3 subcomponents are always experienced with respect to the biological body. In VR the visual feedback to the brain can be altered and so influence the levels of sense of embodiment. The most important subcomponent to test is the sense of agency because differences between actual movement and the visual feedback can negatively affect the feeling of agency and so reduce the sense of embodiment and therefor reducing immersion.

3.2 Inverse Kinematics.

In a systemic literature search by Caserman et al. (2019) analysis has confirmed that the sense of embodiment can be enhanced with a full body avatar using full body tracking and can improve immersion in VR. Most modern PCVR games use an HMD and 2 motion controllers to control the game. These 3 devices have sensors in them to track the location in the play space and translates that to the game engine. With these 3 tracking points, the positions of the elbows, the shoulders and torso can be estimated using inverse kinematics (IK), which "*is the process of calculating the joint rotations which connect the start anchor with the end anchor using multiple joints and bones*" (Parger, 2018). In other words, to animate the in-game avatar using math so it lines up with the player's physical body without using accurate body tracking suits.

In his master thesis, Mathia Parger (2018) compared 3-point VR tracking IK systems to an industrial motion capture system to find out if having arms in VR changes the user experience. Participants were asked to play 3 different VR games in 3 different ways. Once with a motion-capture suit tracking their body movement and rendering virtual arms and twice without the suit but with an IK solution rendering the virtual arms and hands or only hands. Virtual arms animated with IK achieved just as good if not better than only hands. Results showed that participants strongly preferred having arms over having only hands. Though, his experiment showed having arms does not necessarily improve the feeling of embodiment when players are busy during gameplay.

3.3 Enhancing the experience.

The player stays immersed by interacting with the VE. These interactions trigger the brain to create the sense of embodiment by using the physical movement to control the avatar. In 2020 Gonzalez-Franco et al. demonstrated the self-avatar follower effect. They showed how avatar motions could influence our own motor behaviour. In their experiment participants were put in VR and were asked to hold a controller near their chest and then extend their hand straight forward, the avatar inside VR followed their movement at first 1:1. Participants were asked to hold still. Then they were gradually introduced to a 30° visual offset from their own physical body to the avatar's body. When the avatar moved, participants tended to unconsciously follow the avatar and minimize the visual offset between their own and the avatar's body. When introduced with a sudden visual offset, participants knew something was wrong and only partially corrected their positioning. They concluded that compensations in the motor control loop work under visual guidance. Having a virtual body significantly decreases cognitive load while in VR. Furthermore, the follower effect will reduce when the embodiment is reduced.

4. Problem Definition

4.1 Immersion vs Comfort

One of the key components of immersive VR is the sense of embodiment of the in-game avatar in 1PP view. Currently most released VR games only show hands in 1PP but with recent developments in IK solvers more improvements towards the sense of embodiment can be made. And according to Gonzalez-Franco et al. (2020) with the self avatar follower effect, players tend to follow their in-game avatar's movement subconsciously. So, in what way could a 1PP avatar influence gameplay? Being able to defend yourself is a key component during duelling gameplay. The player could cast a defend spell but since casting a spell costs time, being able to physically dodge a spell could give the player another option to defend themselves.

The balance between immersion and comfort needs to be found. Different types of locomotion could help with comfort. The shapes of the gestures for spell casting need to be simple and easy to remember so the player can cast spells consistenly during a duel. In what way can the 1PP avatar increase or decrease the consistency of casting spells during a duel.

5. Main Research Question

How could an avatar using inverse kinematics in first person perspective in Virtual Reality influence core gameplay?

5.1 Sub Questions

1. *In what ways could an avatar in first person perspective influence interactions in virtual reality?*
   Keywords: avatar animations, motor behaviour, interaction, virtual reality

2. *How to increase successful rate of gesture casting in virtual reality?*
   Keywords: gesture casting, recognition, virtual reality

3. *How to increase the successful rate of grabbing items in virtual reality?*
   Keywords: inverse kinematics, interaction, calibration, virtual reality

6. Methodology

6.1 Desk Research

First to gain a better understanding of the topic, desk research will be performed using online search engines like Google Scholar. Research topics are targeted towards presence, sense of embodiment, the self-avatar follower effect and accessibility options in VR.

6.2 Field Research

Next to desk research, field research using YouTube will done to gain more insight in the VR industry by looking at reviews of released VR titles and look at gameplay videos to see what and how users are playing similar and other VR titles.

6.3 Design Thinking

This project has been developed using the Desing Thinking method. This method uses the following 5 phases, empathize, define, ideate, prototype, and test (figure 1).

The first 2 phases are used to define the current situation and problem regarding Immersion in VR. In the 3rd phase ideas are created and then the best is chosen to create a prototypes of. These prototypes are tested and adjusted untill satisfactory. This process is an iterative process and can be repeated if necessary.

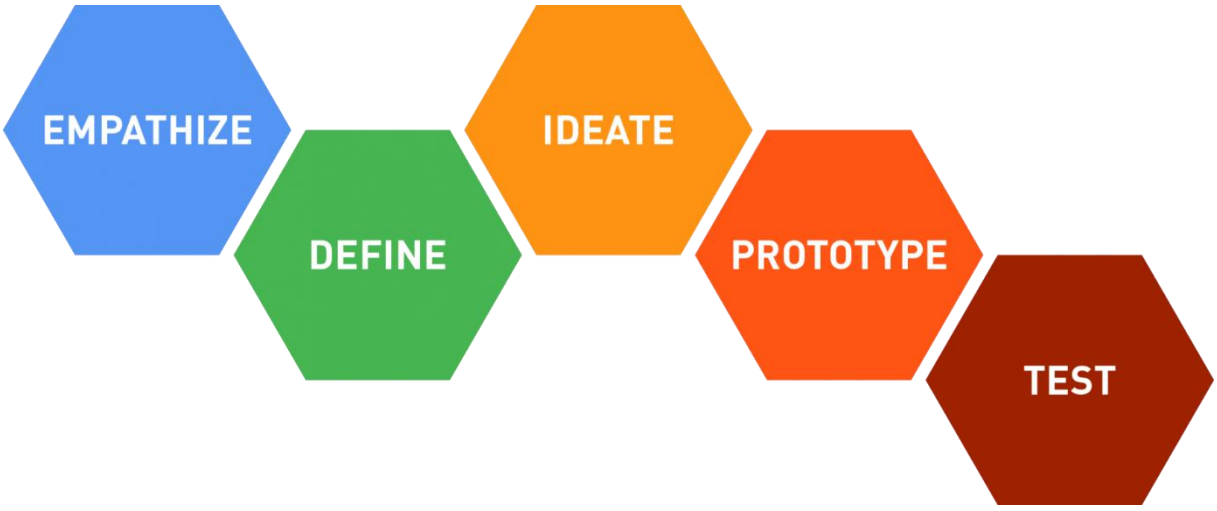


Figure 2. Design Thinking process. (2017, 6 maart).

6.4 Agile Development with Scrum

After research, agile development started with development sprints of 1 week to keep sprint goals small and containable. Every week a new sprint goal was set based upon the previous sprint results. Every day a daily stand up was held to keep each other up to date. At the end of each week an internal playtest was held to discuss the progress of the project and find the right direction for the game. For our scrum board we used Trello. For source control a GitHub repository was made and Sourcetree was used to share project files.

6.5 Prototyping

During development multiple iterations and prototype will be made. The very early prototypes will mostly be tested withing the development team and once the prototype is in good enough state, testing with play testers will be done to improve the experience.

7. Ideation

7.1 Concept and Design

After setting up all necessary documents and source control, Joey and I sat down to discuss the design of the project. We started with brainstorming and discussing possible ways to implement core gameplay elements. We made a design document and created simple mood boards to create some sort of shared vision for the game (see Annex 3).

Started on the design for VR Avatar and made a list of must have features:

- Locomotion with at least 3 different accessibility options
  (Teleport, Sliding Movement, Out of Body Teleport).
- IK solver for 1PP avatar animations.
- Runtime mesh changing so players can select different types of clothing/hats etc.
- Grabbing, holding, and equipping of items.
- Interactions with physics items.

The final look was not super important as long as all features were working. During brainstorming the idea for full body IK came up. Further research was necessary to see if full body IK was feasible.

Started on the design for Gesture based casting with making a must have features list:

- Recognition system so gestures can be easily repeated.
- Equip able wand for duelling with simple combat spells.
- Special spells for other interactions.

For the gesture recognition system more research was necessary on how to implement such feature. To make sure that the gestures are fun to perform, experiments and multiple iterations on gesture shapes was planned. For combat only basic spells were needed as the goal was to find the best gestures first before diving deeper into the duelling dynamics.

Some sort of debugging tool was needed as well for when you are inside VR because once you are in VR you do not want to have to take of the HMD to press a button on your keyboard. A simple item that can be picked up by the developer and contains buttons and pages with debugging options for a calibration tool, changing mesh in runtime, resetting the level and spawning items. This debugging tool had to be made in such a way that it was easy to expand later during development.

During this phase, a few milestones (table 2) for the project were set. I will be working together with Joey on each milestone to complete within the set timeframe.

Table 2. Milestones

Milestone	Date	Conditions of Satisfaction
VR Avatar	30 October 2020	1PP Avatar with IK, grabbing, locomotion, mesh changing, body interaction
Diegetic User Interface	30 October 2020	Seamless tutorial experience within the theme of the game.
Gesture Interaction UX	30 November 2020	Fun and intuitive gestures.
Gesture Interaction Assist	30 November 2020	Non-intrusive interaction assisting elements.
Game Level	31 December 2020	Vertical Slice of all planned features.

8. Implementation

Before the start of development, analyses had been done to determine what released software to use or if starting from scratch would be best. The main mechanic of the game is gesture casting and during desk research a few available plugins for UE4 were found. Some were free and others were paid. Table 3 shows an overview of released gesture recognition plugins for UE4 found on the internet.

Table 3. VR Gesture Recognition plugins for UE4.

Plugin	Creator	Release date	Price	Active in 2020
Custom Gesture Recognition	Deams	2016-04-21	Free	No
RunebergVR	Runeberg	2016-10-13	Free	No
Gesture Tracker VR	Hunter Delattre	2016-10-27	$14,99	No
VR Expansion	Joshua Statzer	2016-11-07	Free	Yes

They all have similar ways of recognizing a gesture, as it seems that they are all based on work published by HCI researchers Caramiaux et al (2014). After downloading all free plugins, each provided project was loaded up to see which one worked best out of the box. Custom Gesture Recognition was not updated in 4 years and would not work. RunebergVR did work out of the box as well as VR Expansion. I did not try Gesture Tracker VR because on video it looked very similar to VR Expansion and I did not want to spend money on something that probably functioned the same. Out of the box the VR Expansion plugin worked the best and because it still was being updated in 2020, the choice was made to use the VR Expansion framework to build upon as the plugin also included locomotion, grabbing, and other VR related features.

For the VR Avatar research towards available IK solutions was done. The original concept had full body IK in its design but since most gameplay does not include looking at your legs it was

decided that only an upper body IK solution was needed to save time. For this the Upper Body IK (UBIK) plugin was used. Table 4 shows an overview of found IK plugins for UE4.

Table 4. VR Inverse Kinematics plugins for UE4.

Plugin	Creator	Release date	Price	Active in 2020
BIK: Full Body IK Solver	Anomotion	2014-04-25	Quote	No
VR IK Body	Yuri N Kalinin	2017-10-02	$84,99	Yes
Full Body IK Plugin For VR	Anim IK	2018-03-05	$69,99	Yes
VRF VOL 1 Movement	H.E.L.P RnD	2020-02-03	$49,99	Yes
Upper Body IK	Jonas Mølgaard	2020-04-03	Free	Yes

The prices of the other plugins were also a reason for choosing UBIK.

9. Test Methods

To test sub-question 1, *In what ways could an avatar in first person perspective influence interactions in virtual reality?* in-person usability testing with the development team and with test participants was used to discover if a 1PP avatar could impact player behaviour during gameplay. Participants were observed while playing the prototype without any instructions. After each playtest feedback was gathered through the use a system usability questionnaire (Annex 4) and the feedback was used to iterate and improve the prototype.

For sub-question 2, *How to increase successful rate of gesture casting in virtual reality?* Usability testing was used to find a non-intrusive way to teach the player the gestures for the magic spells and to find out what is needed to make sure casting spells is consistent and fun. During testing users were observed to see how each gesture was being performed and which gestures were completed successfully the most. After the play test participants gave feedback via a questionnaire.

To test sub-question 3, *How to increase the successful rate of grabbing items in virtual reality?* A/B testing was used to discover if having a 1PP avatar helps with grabbing items in VR. Where in version A users did not receive a 1PP avatar and only saw their controllers in game and in version B users calibrated their height and then received a 1PP avatar fit to their heights. The avatar was animated by using the HMD and motion controller' sensors together with the UBIK solver. The sense of embodiment was measured with the following questions:

- I felt embodied in the avatar during grabbing of items,
- I felt like I had two bodies during grabbing of items,
- I felt satisfied with the interaction during grabbing of items,

Participants had to answer on a scale of 1 to 5, where 1 was strongly disagreeing and 5 was strongly agreeing with the statement. Based on these results the influence of a 1PP avatar can be tested.

All feedback was gathered anonymously, and no personal information was collected. This was verbally communicated with each participant.

10. Results

10.1 Iterations

Version 0.1

For the VR Avatar, each month a major version was planned to be developed, iterated on, and tested. The first iteration consisted of setting up the Unreal project and make sure inputs were working. Since the decision was made to use VR Expansion as a base it was necessary to go through the provided documentation to understand how the Player Controller and Pawn Blueprint logic were setup. In this iteration it was expected to learn how the VR Expansion and UBIK plugins operated and how to possibly be improved upon on.

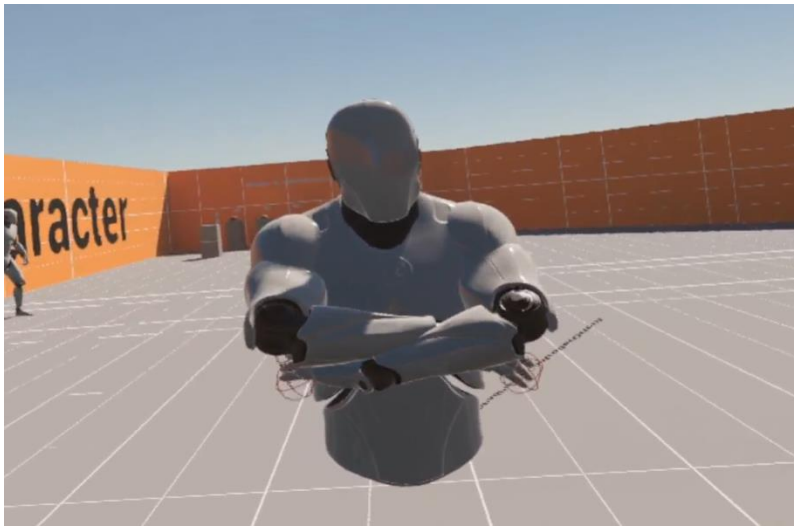


Figure 3. UBIK implemented into VR Expansion.

After understanding how each plugin worked, implementation of the IK system started (fig. 3). Once the Avatar prototype was setup correctly, development started on basic functionality for hand animations. The reason for this was to provide visual feedback for the player when grabbing items. The avatar was not yet lining up 100% with the biological body. During initial testing this was not a problem, but this needed to be addressed in the future.

For Gesture Casting we used the recognition system implemented in the VR Expansion plugin. The first experiments with creating custom gestures were done successfully. For testing I created a projectile which can be fired by performing a gesture. For the gestures we created very basic shapes like a horizontal line and circles but when more gestures were added to the database, the system would falsely recognize gestures as the horizontal line so more experiments with different shapes were needed. During testing we found out that aiming was also difficult when performing gestures. To solve this a short delay was added after performing of the gesture but the combination of the projectile movement settings and

gesture shape did not feel right during gameplay, as successfully completing the gesture was not consistent. In this version basic functionality for the visual effects (VFX) and sounds were added to help with player feedback.

A basic setup for the debugging book was made to test if pressing widget buttons would work with the laser beam functionality of VR Expansion while holding the book in your other hand. With minimal setup this did work and so the debug book could be developed further.

Version 0.2

After testing it became apparent that the avatar and real-life body dimensions were not the same for every play tester. The in-game hand was not overlapping with the real-life hand. This caused issues when trying to grab items. This was solved by creating a player height calibration tool. The goal for the height calibration tool was that the player would not know that he was calibrating. The idea was that the player would only see a dark area with 2 chains on either side of the player and the player would need to grab both chains and pull them towards the centre to complete. After completion, the world and avatar would spawn in with a cool effect. A prototype using VRLever components from the VR Expansion code base was made but during testing the height would not be consistently correct because both arms needed to be extended completely. However, most of the time 1 side would be grabbed and then the other but without extending both arms. To solve this, a push version was created where the player pushes the levers away from them as far as possible. Calibration was more accurate during initial testing and the avatar was starting to look physically correct. Only problem now was that the avatar arms were too short when fully extending the real arm. This was solved by tweaking the IK solver's settings by trial and error.

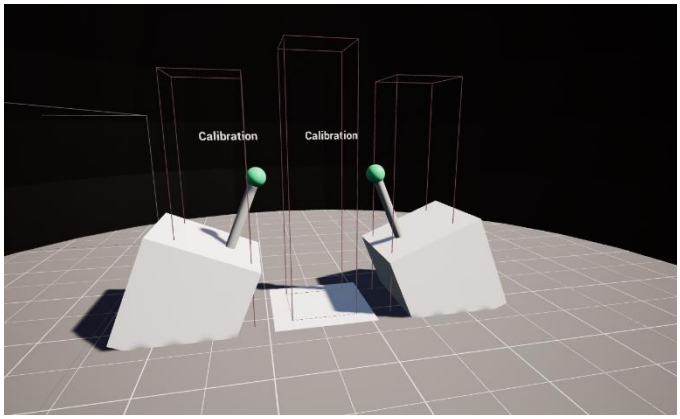


Figure 4. Height Calibration Tool V1.1 prototype

For testing of the duelling gameplay, a Base Spell blueprint class was created so multiple types of spells could be created without setting up base components like audio, niagara particles, and collisions every time. Created new attack and defend spell blueprints from this Base Spell class and new placeholder sounds and VFX were added to each spell. To improve casting spells, we made the choice to first cast a gesture to select a spell and then to invoke the spell with a V gesture. This way aiming was easier but when under pressure from incoming fire, having to perform 2 gestures to defend yourself was not ideal.

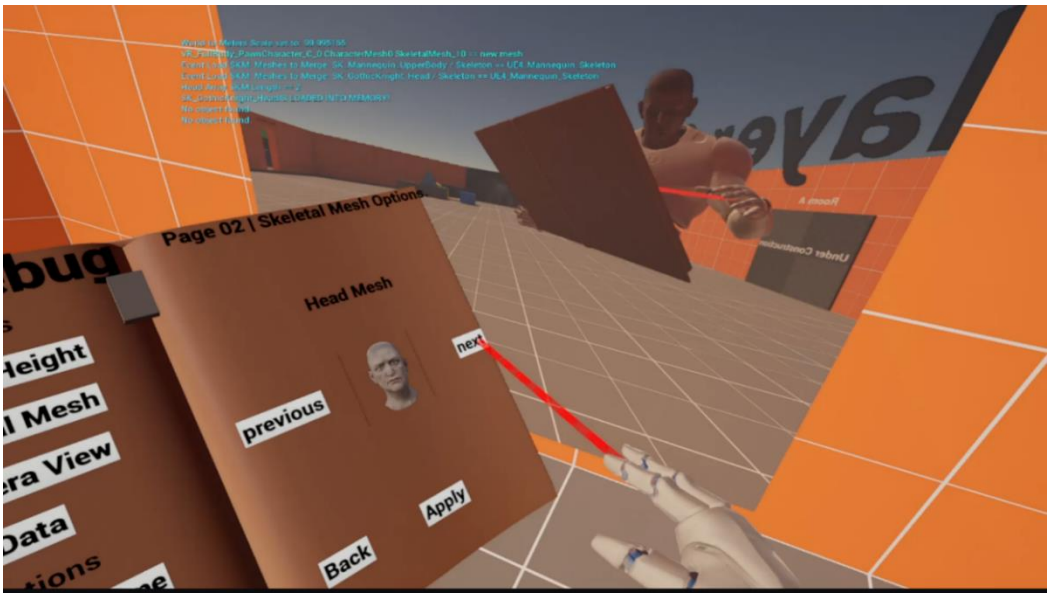


Figure 5. Mesh changing in the Book of Debug prototype.

In this version the debugging book was updated with a new 3D model and functionality for all pages was created and placeholder images and sounds (fig. 5) were added. For the new 3D model tests were done to find the right size when holding the book in your hands. The first buttons were way too small and hard to select so the buttons were made bigger and optimizations were needed as performance dropped when spawning the height calibration tool.

Version 0.3

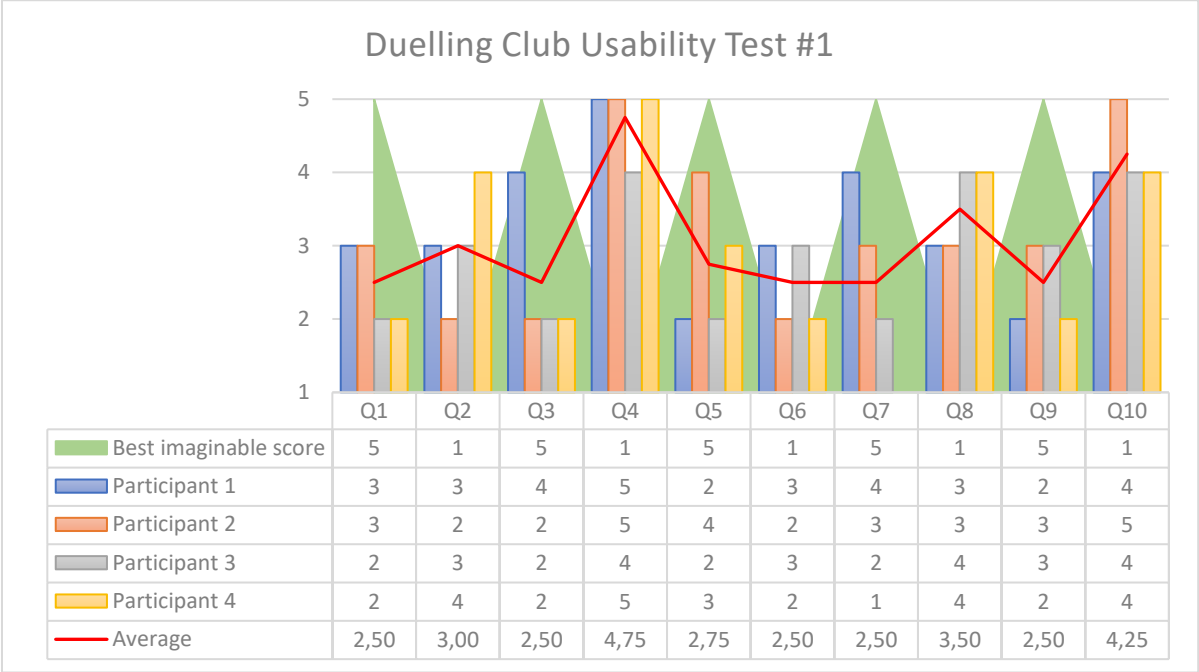
For the third version the focus was on the main mechanic, gesture-based spell casting. During this iteration, a lot of experiments with different gesture shapes was done. This iteration was also the first iteration tested with new VR players because the gestures were fairly consistent to perform and the VFX were updated. The project was in such state that the first impression should be impactful enough for players to feel like a wizard (fig 6).

Figure 6. Light Spell VFX prototype.

During testing of the gestures, I wanted to invoke the selected spell with my other hand, so I prototyped a quick hand casting mechanic and discussed with Joey about this new idea. He agreed that it would be a good addition to the game. This way you can aim with your wand and then fire with your other hand. Experiments were done with saving and loading the game

through a gesture. First iteration consisted of a S symbol for saving and L for loading. This caused issues with the other spells, so the symbols received an added circle around it, continuing in 1 motion. Now the saving and loading spells were not accidently being detected.

For testing of the defence spell a very simple enemy AI was created. The AI shoots back when hit by an attack spell. The AI was used to determine the time needed to perform a gesture, the speed of the projectile and distance between opponents during a duel. The way the controller was held during recording of the gesture was also important. During testing it became apparent that users were not holding the Vive controller horizontal as intended. Most users were using their arm with locked wrist movement to move the controller. This way the controller was pointing upwards instead of forwards. Testers had a harder time to successfully aim when performing the attack spell. This was solved by rotating the wand 10 degrees down when grabbed by the player. Now the controller could be held with a straighter wrist and so have less strain on the wrist as well.



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Best imaginable score	5	1	5	1	5	1	5	1	5	1
Participant 1	3	3	4	5	2	3	4	3	2	4
Participant 2	3	2	2	5	4	2	3	3	3	5
Participant 3	2	3	2	4	2	3	2	4	3	4
Participant 4	2	4	2	5	3	2	1	4	2	4
Average	2,50	3,00	2,50	4,75	2,75	2,50	2,50	3,50	2,50	4,25

Figure 7. Usability Test #1.

Above are the results from the first usability test that was conducted with 4 participants. After testing the prototype, participants were asked 10 statements regarding the VR prototype (see Annex 4 for detailed results) and had to respond on a scale of 1 to 5 whether they would disagree or agree with each statement. Each question has a best imaginable score as shown in green in the graph above. The results show that in every front the game needed to be better as participants needed a lot of help to get going. The gestures were hard to replicate and one of the problems was that the height calibration tool was too difficult to understand for new players. The tool required a specific pose but without any reference of the correct pose it was nearly impossible to complete without help. The tool became frustrating to use. My observation was that most users were not looking straight ahead but looking a bit down towards the ground, so their measured height was not correct. Also, most users did not extend their arms completely and so their wingspan measurement was not correct as well. Instructions

displayed in front of the player were added to help guide the player. This did seem to help with instructing what to do but the correct pose was still not being completed. The participants were told nothing before given the HMD to try the keep the experience as fresh as possible.

Level visuals were updated, and dynamic props were added that can be picked up by the player for added immersion. Based on feedback from play testers, an outline effect around interactable items was implemented to help with visual feedback when grabbing items.

Version 0.4

For the fourth version, improves towards the gestures and towards the flow of the game were made. Based on the feedback from the previous iteration gesture casting was improved. The flow of the game was also improved by teaching the player 1 mechanic at a time. This first mechanic the player learns is locomotion. After this the players learns how to use Hand Magic (fig 8.) and then grabbing of items. At last, the player learns how to use Wand Magic.

Figure 8. Attack Spell gesture (top) spell charge (middle) spell fired (bottom)

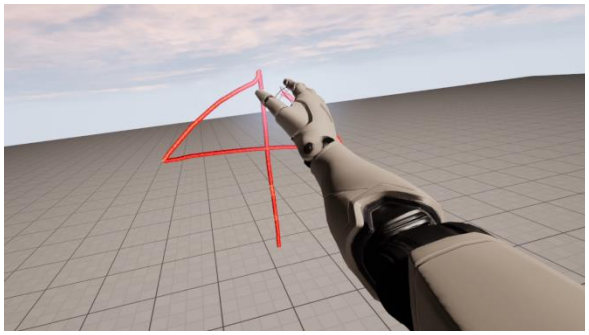


Figure 9. Hand Magic Teleport Spell.

To improve Wand Magic, only attack (fig. 9) and defend (fig. 10) spells are now available in the Wand Magic database. The open-door spell and light spell have been moved to Hand Magic. This was done to free up the database in Wand Magic so during a duel you can only cast combat spells and not accidently cast for example the light spell. Overall, this was a good decision for consistency during a duel but play testers were a bit confused about the different inputs for casting the different types of magic. This could have been because of how much information they were given when introduced with the Wand Magic mechanic as this was lacking at the time of testing.

Selecting a spell with a gesture and then firing with another gesture was also removed and was replaced with a short delay before firing. Now after casting a gesture, the spell builds up and then the player has the time to aim their wand before it fires the spell. This helped a lot with timing your spells during a duel as long as you were able to cast the attack and defend spell consistently. The new gestures and firing functionality improved gameplay and made duelling more fun.

Gesture recognition settings were adjusted to help with the accuracy of detecting the gestures. For the defence spell the direction the spell is cast from was changed. Before it came straight out of the end of the wand and sometimes would go under the grond because the wand was pointed downwards. So now the spell spawns in front the player, still based on the transform of the wand end location but on a fixed z (height) value so it does not spawn under the ground anymore. For hand casting the open door spell needed some more improvements as play testers had trouble with the gesture and where the spell was cast from. This was just a linetrace coming from the tip of the wand. The decision was made to use the linetrace coming from the player's HMD so now the open door spell ends where the player is looking at.

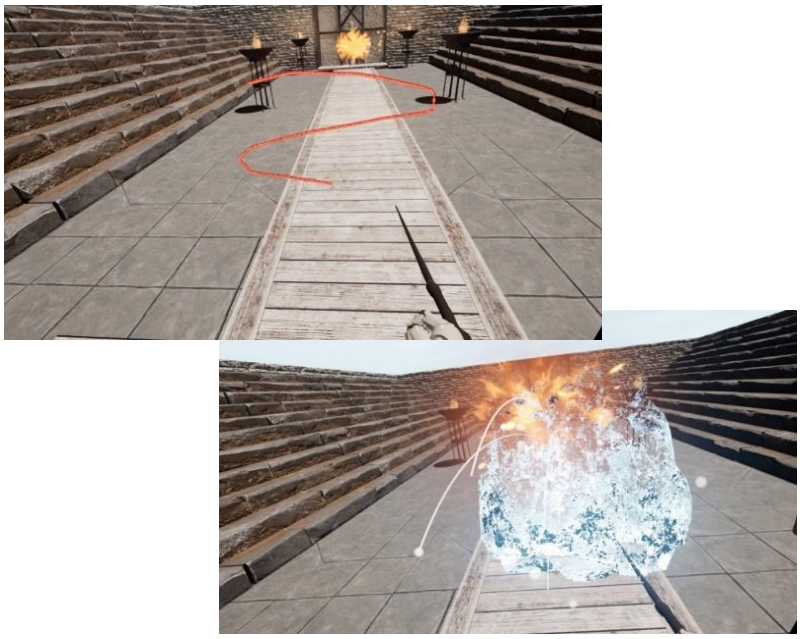
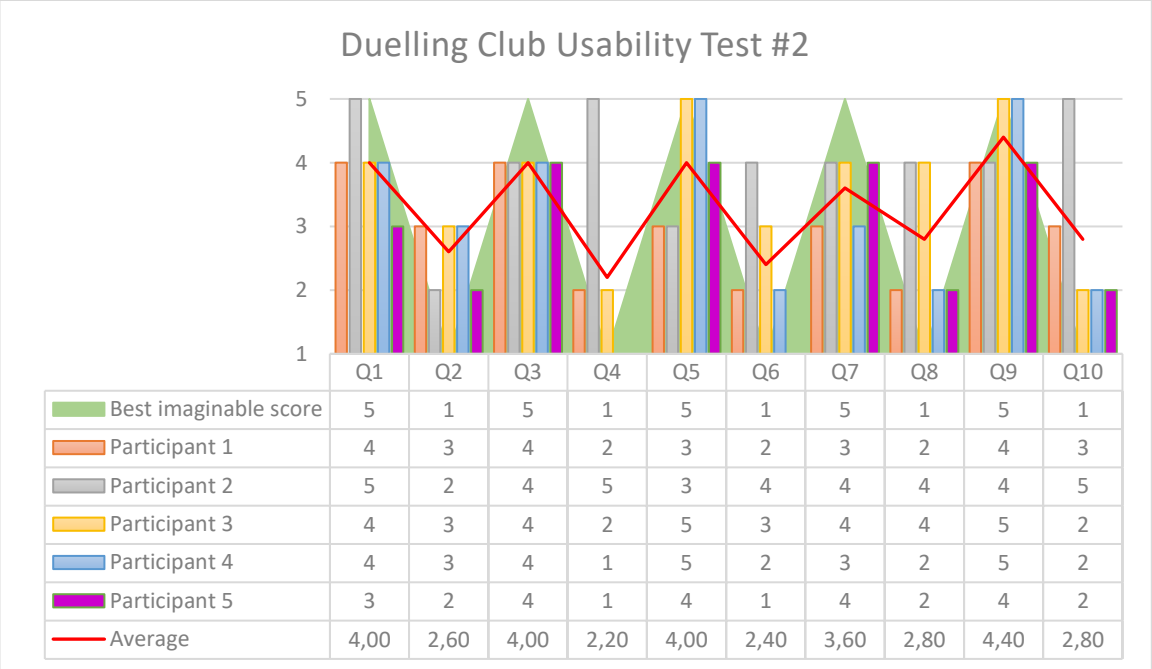


Figure 10. Defence spell gesture (top) and defence spell VFX when colliding with enemy attack spell (bottom).

For this version a more forgiving version of the height calibration tool was created where the wingspan needed be within ±2% of the hmd height to calibrate. But the tool was still too difficult for new players. All test participants were not looking straight ahead as they were looking at their hands or looking a bit down so their hmd height was lower than their actual height. During testing this iteration still proved to be too difficult as the correct pose was still not being met. Therefor, the hands did not line up correctly after calibrating. This caused embodiment reduction during interactions like grabbing but during duelling the feeling was

not as much reduced as most participants were occupied with trying to dodge and cast spells. When users were in a more relaxed environment they would notice the imperfections more.

When comparing the results from the first usability test to the second test (fig 11), it is clearly visible that improvements have been made over the overall experience. The flow of the game was way better, and the gestures were easier to learn because of the new shapes and visual and audio feedback within the game. To improve further the time between learning new gestures could still be longer. See Annex 4 for more detailed explanation.



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Best imaginable score	5	1	5	1	5	1	5	1	5	1
Participant 1	4	3	4	2	3	2	3	2	4	3
Participant 2	5	2	4	5	3	4	4	4	4	5
Participant 3	4	3	4	2	5	3	4	4	5	2
Participant 4	4	3	4	1	5	2	3	2	5	2
Participant 5	3	2	4	1	4	1	4	2	4	2
Average	4,00	2,60	4,00	2,20	4,00	2,40	3,60	2,80	4,40	2,80

Figure 11. Usability test #2 Improvements all around..

Version 0.42 (Latest)

This version contains mostly bug fixes and has one more added feature. Added EasyShakeVR component by Pavel Ksenofontov so when the player shakes the controller hard, the item they are holding falls out their hand. This adds immersion and it is to prevent users from spamming gestures during a duel.

The Height Calibration Tool has been improved with even simpler calibration. The wingspan is not being measured anymore, just the HMD height to the floor and added 1 final step before completing. The user can adjust their final height with a slider. The player now only must press a button in front of them and then has the option to confirm the calibrated height or to adjust it with a slider. Once satisfied with the adjusted height the player then presses the button again to confirm their final height.

10.2 Test Results

Sub-question 1: In what ways could an avatar in first person perspective influence interactions in virtual reality?

Results from observations and the questionnaire show that having an avatar helps with depth perception and gives the player a sense of embodiment. It can help locate the surroundings better by creating more awareness of the area being occupied in. During duelling where the user was actively moving more to cast attack and defend spells, the avatar would lag behind a bit even though this was not very noticeable during gameplay.

Observation during testing was that when roleplaying during sliding movement by pretending to walk, it can reduce motion sickness. I myself noticed this while testing and later one participant noticed it as well.

There were still some issues that need to be addressed that impacted the experience negatively. Since the hips are being estimated the body does not line up correctly all the time. Especially when crouching or leaning over objects in the VE. Core gameplay does not get impacted but for more immersion a better solution needs to be found when crouching down.

The hands had simple hand animations because of issues with the IK settings early in development. The hands would not line up with the controller when extended. Experiments with different settings later would fix this but then time was running out as the hand animations was a lot of work. The decision was made to scrap this feature and focus on improving the game else were.

On older hardware the performance of the prototype was not great and therefor the animations felt choppy. On new hardware, IK worked decent except the UBIK solver was not perfect when crouching or leaning over stuff. This reduced the sense of embodiment and immersion.

Sub-question 2: How to increase successful rate of gesture casting in virtual reality?

During quick action gameplay very simple gestures and differences between the start of each gesture, was very important. During slower interactions more elaborate shapes can be used. Ergonomics during gameplay were important when playing for longer sessions. Aiming improved when ergonomics improved.

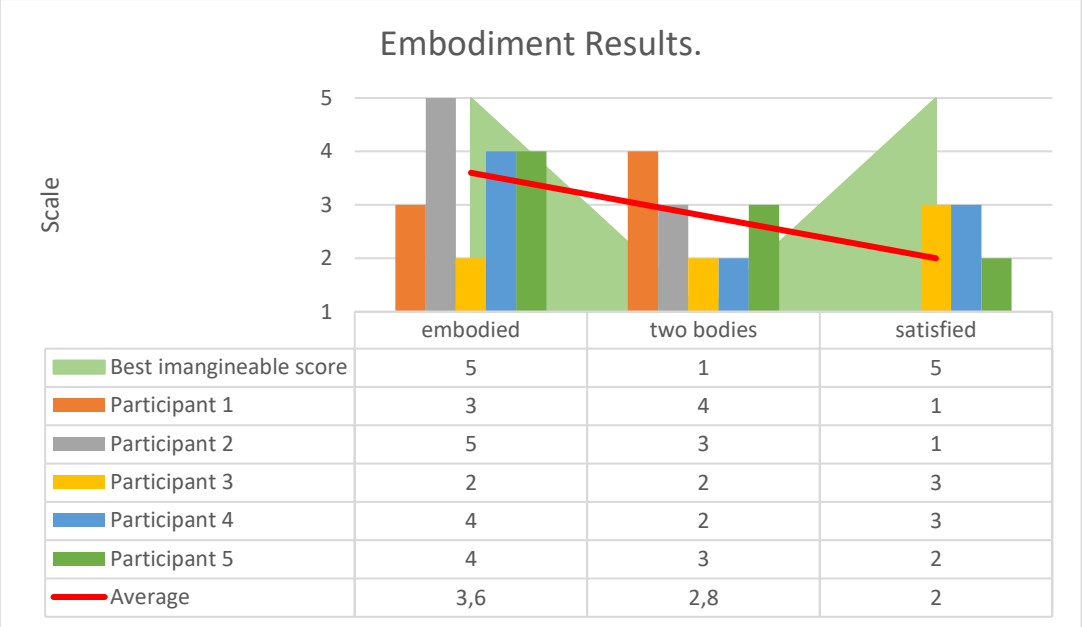
To increase the successful rate let users learn 1 spell at a time and give them time to create muscle memory for a gesture before introducing with another gesture. Also being able to see the gesture in front of you helped a lot with developing the right muscle memory.

The recognition software allowed for threshold settings to be tweaked. The thresholds could be raised to increase the recognition likelihood of a certain gesture. By splitting up the databases for combat and special spells, the system does not have to go through unnecessary gestures.

Sub-question 3: How to increase the successful rate of grabbing items in virtual reality?

The results from the A/B test showed that all participants preferred owning a 1PP avatar during gameplay. When owning a 1PP, one user felt more stable while moving around. Seeing an arm in VR helped a lot with depth. Grabbing items became easier because the grabbing motion was visual on screen now but when calibrated too short, users tended to miss the item when grabbing. The reason was that the avatar's arm could not reach where the controller was located. So, their in-game hand and biological hand were not in sync. When users were calibrated correctly, users felt more grounded and the virtual body lined up better with their biological body. To increase the successful rate of grabbing item, a good synchronization between the in-game hand and the biological hand is needed. Adding haptic feedback can help with notifying the player that he is in range of grabbing.
The following 3 statements were asked in the questionnaire:

- I felt embodied in the avatar during grabbing of items,
- I felt like I had two bodies during grabbing of items,
- I felt satisfied with the interaction during grabbing of items,



	embodied	two bodies	satisfied
Best imangineable score	5	1	5
Participant 1	3	4	1
Participant 2	5	3	1
Participant 3	2	2	3
Participant 4	4	2	3
Participant 5	4	3	2
Average	3,6	2,8	2

Figure 12. Embodiment Questionnaire Results.

The table above shows that satisfaction levels are under par and the participants did not feel as if they were complete owners of the avatar. While embodiment has mixed results (average 3,6) some users still felt the sense of embodiment when the 1PP avatar was calibrated correctly.

11. Discussion

The results indicate that 1PP avatars can influence gameplay when the pace is slower. During the faster paced duelling gameplay users were not paying much attention to the avatar. This means that there is a moment where the brain switches attention. Gesture-based interactions were not necessarily influenced by having an avatar as performing the gesture could be seen as an intensive task and so requiring more brain power. Meanwhile, during grabbing of items it is very important that the hand animations are done correctly or otherwise the sense of embodiment reduces.

Having an avatar can help with making the player feel more grounded in the VE. Even though hand animations were not up to par, all participants preferred having an avatar over no avatar during gameplay. Similar to the results of the experiments done by Mathias Parger (2018). This implies that having an avatar gives more sense of body ownership and sense of agency. The brain wants to be inside a body. By preferring an avatar over no avatar the results confirms the need for sense of self-location while inside VR. Furthermore, an avatar can help with depth perception while in the VE when the player has calibrated their height. If calibrated wrong then it can reduce the sense of embodiment.

The teleport spell and light spell currently have gold standard gestures. These gestures were easy to learn and memorable after a few tries. The spells for duelling are consistent but need improved dynamics to feel more satisfying. It is important to give the player enough time to let them develop muscle memory for gesture-based interactions. There are thresholds to adjust in the recognition software settings. The more satisfying the gesture is the more fun gameplay is as seen in the usability test results.

During more slower gameplay like grabbing items good calibration was required to maintain higher sense of embodiment levels. Other tactile ques such as haptic feedback when colliding with an item allowed for better grabbing. Visual feedback such as an outline around the item the player is looking at and trying to grab, provided another added layer of improvement for grabbing items.

Some corners have been cut due to my lack of advanced engineering knowledge and foresight. And so, some features like hand animations were very basic. The reason was that the system needed for this is in itself a big task and time was running out.

The results of the usability tests show that the prototype still needs improvement.

The generalizability of the results is limited by the COVID-19 pandemic as user testing was limited.

11.1 Conclusion

To answer the main research question, *How could an avatar using inverse kinematics in first person perspective in Virtual Reality influence core gameplay?* the following statements have been made:

- An avatar can positively influence interactions by helping creating a frame of reference to the world for the player.
- An avatar can negatively influence interactions by disrupting the sense of body ownership during moments where the IK solver can not handle the movement of the user.

11.2 Recommendations

When implementing IK make sure that the player correctly calibrates their height otherwise the immersion is drastically reduced.

For gestures it is important to make sure each gesture starts differently to another and each gesture should be repeated plenty of times before introducing with another gesture.

In the early days of VR most games used floating hands as the player avatar representation. The user that is experiencing the game does not pay too much attention to the hands as they are busy with playing the game, but a spectator only watches the user play the game. The spectator, who could be a potential buyer, sees a game on video whereas the player experiences the game. The difference in how one perceives the game is huge. For the spectator, the decision to potentially play the game is by the impression via the spectator screen. With immersive first person avatar, that potential buyer can be impressed just enough to buy the game.

Next step is creating more dynamics, building more gameplay flow by evolving the combat mechanics and better AI. Create levels with focus on gameplay and not to showcase features. Work on a system for better hand animations that follow the shape of the item being picked up and improve lighting as good lighting tricks the brain.

More tests with different gameplay paces and 1PP avatars could be done to determine where the line is where the brain goes from not accepting the disruption of the avatar to focussed on game tasks.

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Annexes

Annex 1: Content Creators

VR Expansion plugin - Joshua (MordenTral) Statzer - Engine PluginVR toolkit for Unreal Engine 4. An Open Source project using the MIT License. Includes the Advanced Session plugin for multiplayer support. As well as the OpenVRInput plugin for different VR headsets and controller support.
Official documentation:
https://vreue4.com/https://github.com/mordentral/VRExpansionPlugin

Upper Body IK plugin – Jonas Mølgaard - Engine Plugin
https://github.com/JonasMolgaard/UBIKSolver

Easy Multi Save plugin - Michael Hegemann - Engine Plugin
(*paid, was once part of the "Free For The Month" content)
https://www.unrealengine.com/marketplace/en-US/product/easy-multi-save

LE Extended Standard Library - Low Entry - Engine Plugin
https://www.unrealengine.com/marketplace/en-US/product/low-entry-extended-standard-library

EasyShakeVR component - Pavel Ksenofontov – Component

https://drive.google.com/file/d/1TbiIxL5SNVsPUlgkzitUrS2QdnRUyc1N/view

Gothic Knight - Talking Drums - 3D Assets
(*paid, was once part of the "Free For The Month" content)
https://www.unrealengine.com/marketplace/en-US/product/gothic-knight

Modular Fantasy House - Next Level 3D - 3D Assets
(*paid, was once part of the "Free For The Month" content)
https://www.unrealengine.com/marketplace/en-US/product/modular-fantasy-house

Fantasy and Medieval Architecture Kit - Denys Rutkovskyi - 3D Assets
(*paid, was once part of the "Free For The Month" content)
https://www.unrealengine.com/marketplace/en-US/product/fantasy-and-medieval-artchitecture-kit

Ancient Treasures - Dekogon Studios - 3D Assets
https://www.unrealengine.com/marketplace/en-US/product/9efde82ef29746fcbb2cb0e45e714f43

Soul: cave - Epic Games - 3D Assets
https://www.unrealengine.com/marketplace/en-US/product/soul-cave

Houseplant Pack - Ian Roach - 3D Assets
(*paid, was once part of the "Free For The Month" content)
https://www.unrealengine.com/marketplace/en-US/product/houseplant-pack

Temperate Vegetation: Optimized Grass Library - Project Nature - 3D Assets
https://www.unrealengine.com/marketplace/en-US/product/dynamic-optimized-grass-library

GOOD SKY - UNEASY - Skybox Blueprint

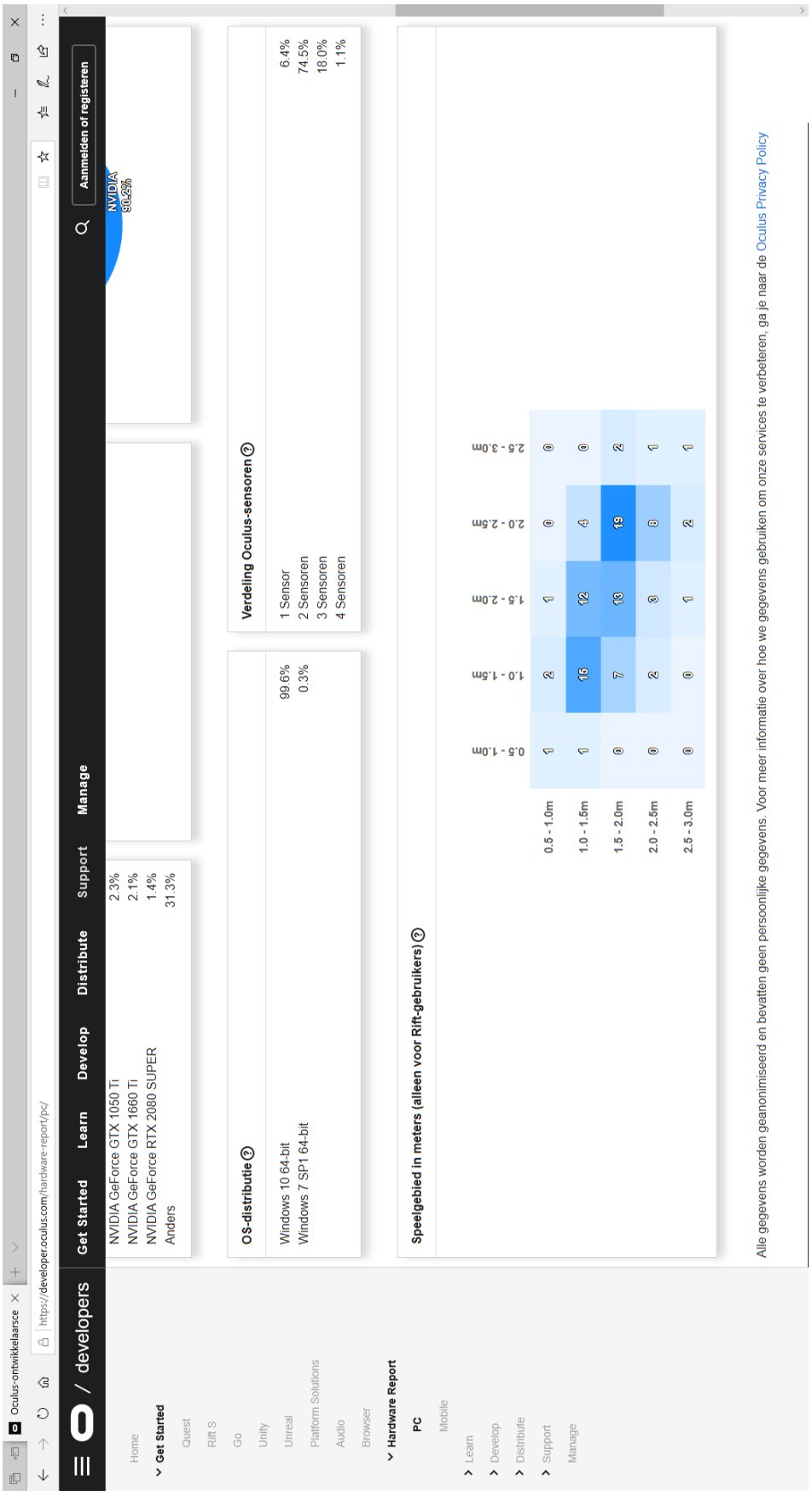
https://www.unrealengine.com/marketplace/en-US/product/good-sky

Ice Cool - Krystian Komisarek - Shader Materials
(*paid, was once part of the "Free For The Month" content)
https://www.unrealengine.com/marketplace/en-US/product/ice-cool

Chocolate Pastry - Quixel Megascans - 3D Assets
https://quixel.com/megascans/home?search=chocolate&search=pastry

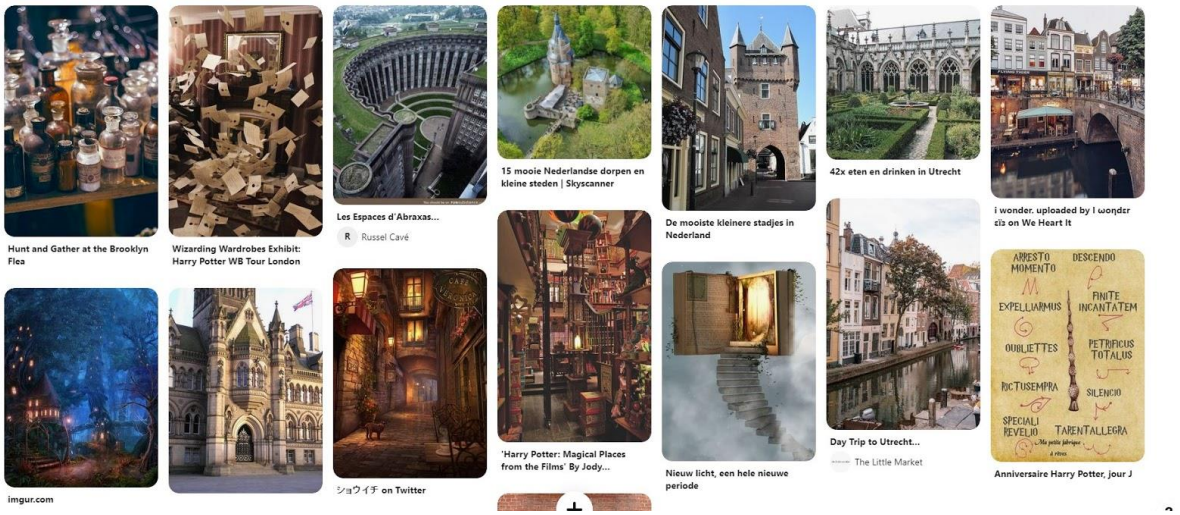
Local Outline material and Distance Fog - Tom Looman - Post Processing VFX
https://www.tomlooman.com/ue4-local-outlines/

Annex 2: Oculus Rift Hardware Survey



Annex 3: Mood boards

Environment



Character

Link to complete design document:

https://docs.google.com/document/d/1udbASLtMm35IRZpXTkrCDUS44S1cVfRqAIaoYzOl0_o/edit?usp=sharing

Annex 4: Usability Test

Below the Usability Test template used after each play test session with play testers.

PARTICPANT: _____ TEST: _____ DATE: _____

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

4.1 Usability Test Results

The combined results of the 1st Duelling Club prototype usability test. Green indicates best imaginable score and the red line is the average score.

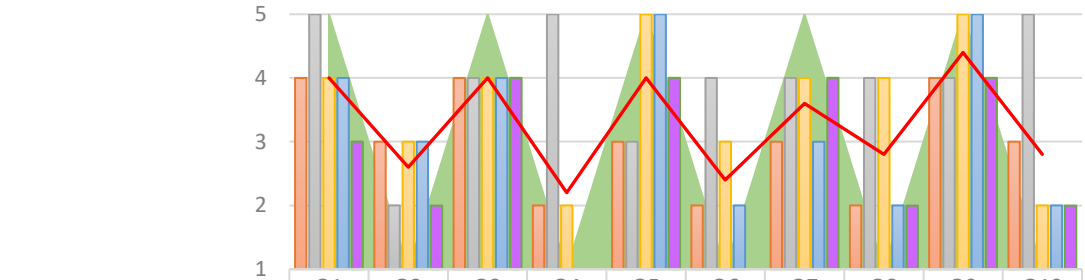
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Best imaginable score	5	1	5	1	5	1	5	1	5	1
Participant 1	3	3	4	5	2	3	4	3	2	4
Participant 2	3	2	2	5	4	2	3	3	3	5
Participant 3	2	3	2	4	2	3	2	4	3	4
Participant 4	2	4	2	5	3	2	1	4	2	4
Average	2,50	3,00	2,50	4,75	2,75	2,50	2,50	3,50	2,50	4,25

From the results it became obvious that users still needed a lot of help from someone when playing. Grabbing still was a bit janky. Players were too short when trying to grab something in front of them. This could be because of the avatar not lining up 100% and so the collision sphere used to grab items is not where the player thinks it is. The table on the next page shows what still can be improved upon.

Table 5. Usability Test 1 improvements.

Questions	What to improve
Q1: frequent use	Instructions were not clear enough for the player. Players had a hard time during gesture interactions. Improve gesture mechanic introduction.
Q2: complexity	Tutorial was to hectic as a lot of information was given. Reduce information load in the beginning of the game would improve this statement.
Q3: easy to use	If the tutorial for explaining gesture mechanic is improved this will be improved.
Q4: support	Improving onboarding would help with this statement.
Q5: intergrated	Gesture casting can still be improved by experimenting with new gesture shapes.
Q6: inconsistency	Still missing some assets and VFX were still placeholder in a few spells. Improving level design and VFX would help with this statement.
Q7: learn to use	After a few tries most users could sufficiently move around and perform the gestures but due to the tutorial being to hectic the process of onboarding took more effort from play testers. Making the onboarding process longer would improve this statement.
Q8: cumbersome	Because the gesture shapes were difficult to perform and selecting spells and then invoken them caused frustrations during duelling. Simpler shapes and quicker casting is needed.
Q9: confident	When the muscle memory kicked in users tended to feel more confident. The recognition system was not 100% accurate and therefor reducing confidence in players. Make sure the system is 100% during gameplay.
Q10: learn a lot	This is not really a bad things as long as the information given about new features is spread out better.

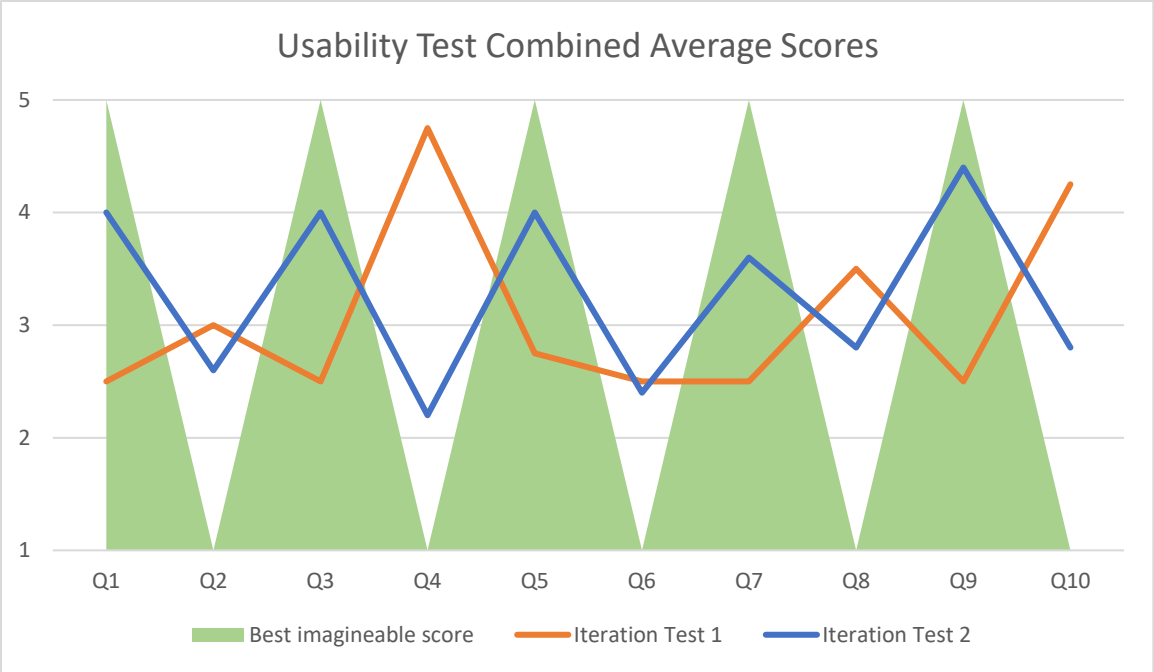
The combined results of the 2nd Duelling Club prototype usability test. Green indicates best imaginable score and the red line is the average score.



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Best imaginable score	5	1	5	1	5	1	5	1	5	1
Participant 1	4	3	4	2	3	2	3	2	4	3
Participant 2	5	2	4	5	3	4	4	4	4	5
Participant 3	4	3	4	2	5	3	4	4	5	2
Participant 4	4	3	4	1	5	2	3	2	5	2
Participant 5	3	2	4	1	4	1	4	2	4	2
Average	4,00	2,60	4,00	2,20	4,00	2,40	3,60	2,80	4,40	2,80

Every aspect has improved so the prototype is going in the right direction. But the complexity (Q2) is still too high. Gesture casting was still cumbersome (Q8) to use probably not all visuals were up to the same standard and some issues with the expectations during gesture casting. Players often wanted to cast gestures in mirrored directions.

By introducing the player with less information they can store more information as only the spread of information was improved since the last iteration. It was still the same amount of information given only over a longer period. This should still be improved by allowing players more time with each mechanic.



Combining the average of each iteration test shows the difference and improvements clearly. The blue line is closer to the best imaginable score but is still not good enough. Improvements need to be made before labelling this finished. This can be done as shown in the table below:

Questions	What to improve
Q1: frequent use	More content like advanced spells would help with keeping players returning to the game.
Q2: complexity	Time in between learning new gestures should be longer to help with reducing complexity. More gesture decals in the game to help with visual feedback.
Q3: easy to use	If tutorial would be improved more than the game will be easier to understand.
Q4: support	The amount of repetitions the player needs to do the learn a gesture during tutorial should be higher even.
Q5: intergrated	Hand animations need to improve to help with this.
Q6: inconsistency	Same as above and some lighting issues might solve this.
Q7: learn to use	More repetitions during tutorial.
Q8: cumbersome	Lighting spell should not activate as much as it did and grabbing was not feeling right yet.
Q9: confident	Some special spells still can be improved like the door spell and light spell gestures and functionality.
Q10: learn a lot	For non gamers it can still be a lot information given, by spreading the information load even more and letting them

Test #1 Participant #1

PARTICPANT: #1 TEST: #1 DATE: 20-12-2020

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #1 Participant #2

PARTICPANT: #2 TEST: #1 DATE: 20-12-2020

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #1 Participant #3

PARTICPANT: #3 TEST: #1 DATE: 20-12-2020

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #1 Participant #4

PARTICPANT: #4 TEST: #1 DATE: 20-12-2020

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #2 Participant #1

PARTICPANT: #1 TEST: #2 DATE: 02-01-2021

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #2 Participant #2

PARTICPANT: #2 TEST: #2 DATE: 02-01-2021

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #2 Participant #3

PARTICPANT: #3 TEST: #2 DATE: 02-01-2021

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #2 Participant #4

PARTICPANT: #4 TEST: #2 DATE: 02-01-2021

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Test #2 Participant #5

PARTICPANT: #5 TEST: #2 DATE: 13-01-2021

System Usability Scale

For each of the following statements, please mark one box that best describes your reactions to the VR Wizard Duelling Prototype today.

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

Comments (optional):

Annex 5: Questionnaire

The Duelling Club prototype

Thank you for playing The Dueling Club prototype. To improve our game, we would like to hear your feedback.
Please fill out the following questions below.

Preliminary Questions

A couple questions about hardware and software setup.

1. What kind of VR headset were you using?

   Markeer slechts één ovaal.

   - ◯ HTC Vive (Pro)
   - ◯ HTC Cosmos Elite
   - ◯ Oculus Rift (S)
   - ◯ Oculus Quest (2)
   - ◯ Valve Index
   - ◯ Anders: _____

2. What kind of VR controllers were you using?

   Markeer slechts één ovaal.

   - ◯ Vive Wands
   - ◯ Oculus Touch
   - ◯ Valve Index Controllers
   - ◯ Anders: _____

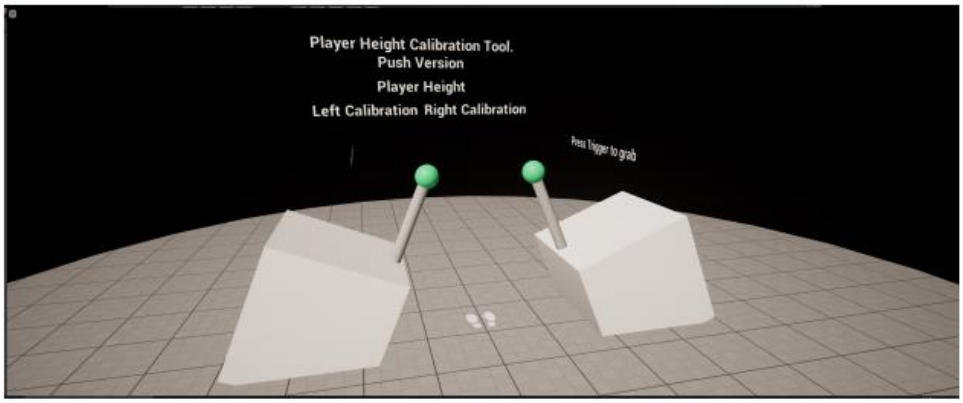
3. What kind of graphics card were you using? If you don't know, go to windows and search for dxdiag. Press yes and go to the Monitor tab and look for device name.

   _____

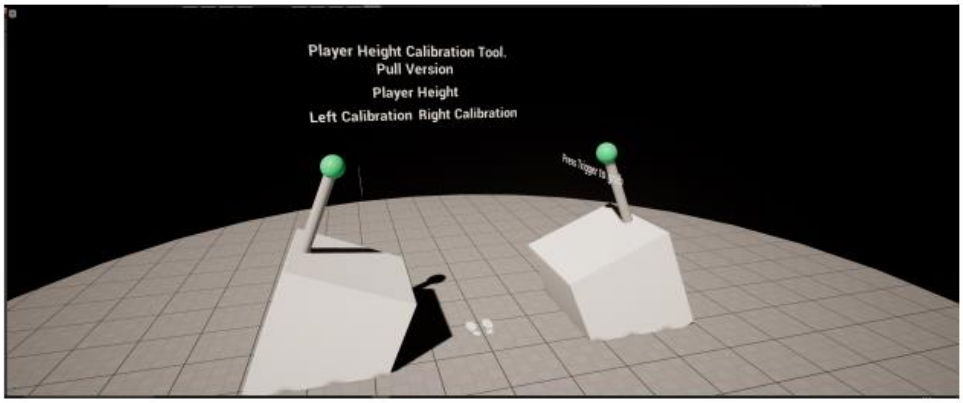
Questions regarding the Height Calibration Tool.

The following questions are about the functionality of the tool not the aesthetics.

Height Calibration Tool Push Version



Height Calibration Tool Pull Version



4. When testing the Height Calibration Tool, which action did you prefer?

Markeer slechts één ovaal.

- ◯ Pulling
- ◯ Pushing

5. Was your calibrated height the same as your real height?

Markeer slechts één ovaal.

	1	2	3	4	5	
Not even close	◯	◯	◯	◯	◯	Perfect

6. What did you like about the Height Calibration Tool?

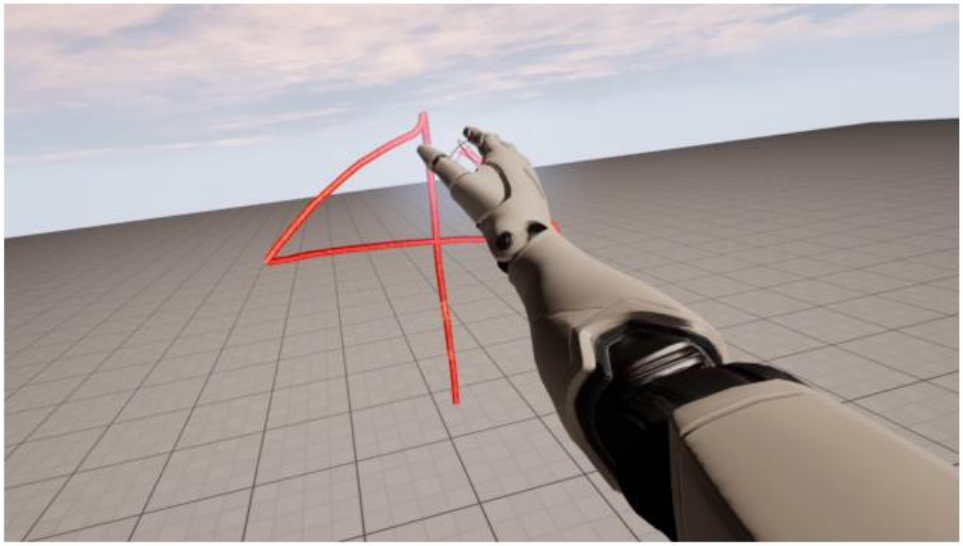
7. What did you wish was done differently regarding the Height Calibration Tool?

8. What if you could change anything of the Height Calibration Tool, what would that be?

Questions regarding Player Magic mechanic.

The following questions are about the functionality of the hand casting mechanic not the aesthetics.

Player Magic Gestures



9. Which avatar version did you prefer when casting player magic spells?

Markeer slechts één ovaal.

- ◯ Without a body
- ◯ With a body

10. What did you like about Hand Casting?

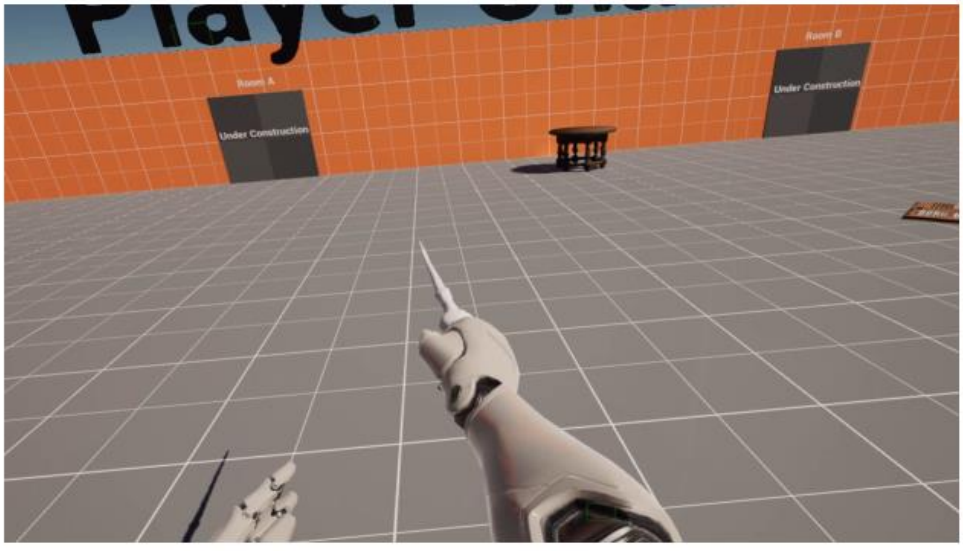
11. What did you wish was done differently?

12. What if you could change anything, what would that be?

Questions regarding Wand Magic.

The following questions are about the functionality of the wand casting mechanic not the aesthetics.

Wand Magic



13. Which avatar did you prefer when casting Wand Magic?

Markeer slechts één ovaal.

- ◯ Without a body
- ◯ With a body

14. What did you like about Wand Casting?

15. What did you wish was done differently regarding Wand Casting?

16. What if you could change anything regarding Wand Casting, what would that be?

Questions regarding Player Avatar.

The following questions are about the player avatar.

17. Did you feel more grounded when owning an in-game body?

Markeer slechts één ovaal.

- ◯ Yes
- ◯ No
- ◯ Anders: _____

18. When grabbing items which player avatar did you prefer?

Markeer slechts één ovaal.

- ◯ Without body
- ◯ With body

19. When dodging spells which player avatar did you prefer?

Markeer slechts één ovaal.

- ◯ Without body
- ◯ With body
- ◯ Anders: _____

20. I felt embodied in the avatar during grabbing of items

Markeer slechts één ovaal.

	1	2	3	4	5	
strongly disagree	◯	◯	◯	◯	◯	strongly agree

21. I felt like I had two bodies during grabbing of items,

Markeer slechts één ovaal.

	1	2	3	4	5	
strongly disagree	◯	◯	◯	◯	◯	strongly agree

22. I felt satisfied with the interaction during grabbing of items

Markeer slechts één ovaal.

	1	2	3	4	5	
strongly disagree	◯	◯	◯	◯	◯	strongly agree

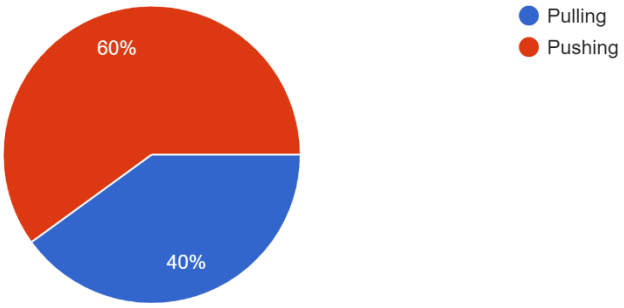
Thank you for answering these questions, your feedback will be used to improve the experience.

23. Optional, want to leave more feedback?

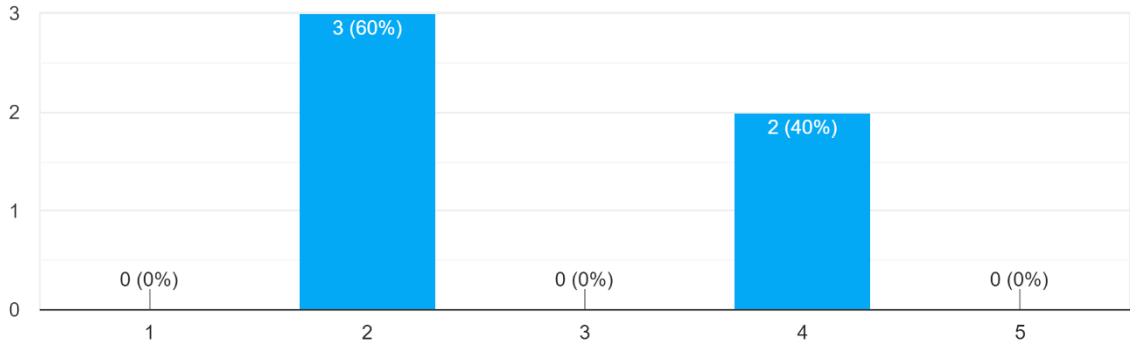
5.1 Questionnaire Results

Questions Regard Height Calibration Tool

When testing the Height Calibration Tool, which action did you prefer?
5 antwoorden



Was your calibrated height the same as your real height?
5 antwoorden



What did you like about the Height Calibration Tool?4 antwoorden

The push movement felt as if the calibration worked better, more precise. The position in which I was standing afterwards, t-pose standing straight, feels like it's a better indication for my height. Standing straight t-pose versus a bit hunched over arms crossed pulling the levers.
Het zag er mooi afgewerkt uit, alleen ik vond het nog wel lastig om te doen
dat je hendels moet vast pakken om ze daarna om te schakelen.
pass

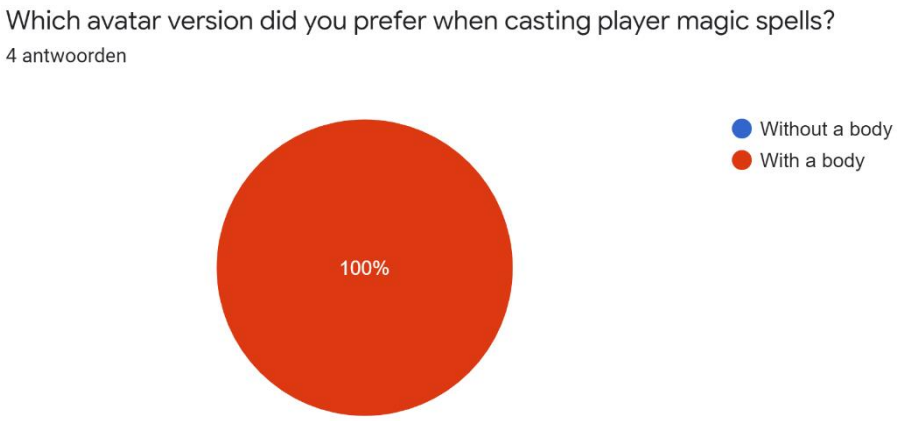
What did you wish was done differently regarding the Height Calibration Tool?4 antwoorden

Nothing, at first I thought the calibration tool came with the VR headset.
Als het kan zou ik het nog wat makkelijker maken om de hendels vast te pakken en te verschuiven
er had iets meer uitleg bij gemogen.
Have my right height

What if you could change anything of the Height Calibration Tool, what would that be?4 antwoorden

My height.
Wat ik hierboven heb genoemd
iets dat aangeeft of je het goed gedaan hebt.
add 10cm

Question Regarding Player Magic mechanic



What did you like about Hand Casting? 4 antwoorden

The muscle memory kicking in and being able to cast my spells really fast.
Het waren leuke tekens die je moest maken en het maakt het net alsof je echt bezig bent met de spreuken te maken
ik vond het cool dat je spreuken kunt uitvoeren. ik vond t wel lastig om ze dan goed te doen.
It was easy

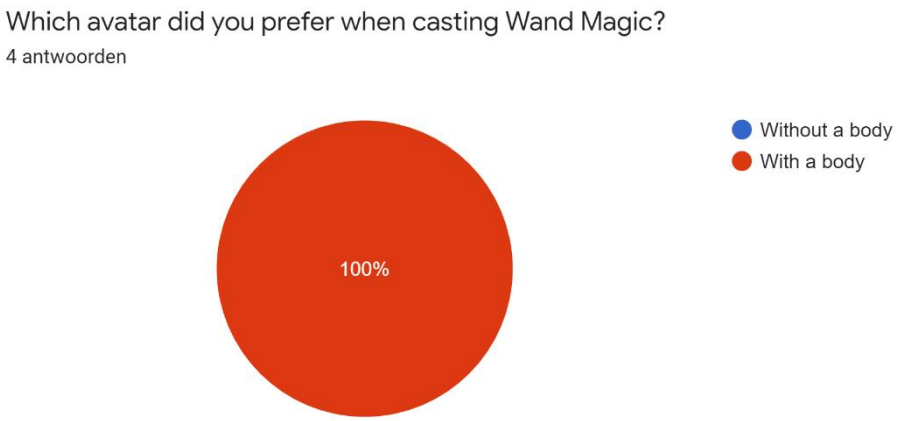
What did you wish was done differently? 4 antwoorden

To be able to cast spells using the mirror image of the handsigns. And it was a bit confusing that I could cast spells with my hands AND other spells with my wand.
Het was soms wat lastig om het tekentje te krijgen omdat het wel redelijk precies moest zijn dat er een breder spectrum is om het goed uit te voeren
Nothing

What if you could change anything, what would that be? 4 antwoorden

More spells! Multiplayer! And proper wand holding, I felt like single claw wolverine during the game.
Niet echt iets, alleen misschien de tekens wat versoepelen? Dus dat je niet precies het tekentje hoeft te doen maar als het maar in de buurt komt
niet echt iets. vind het een mooi systeem.
Nothing

Questions regarding Wand Magic.



What did you like about Wand Casting? 4 antwoorden

Casting a lot of spells simultaneously.
Was leuk om te doen, je hebt een toverstok vast wat het echt maakt.
super nice dat je een spreuk doet met een toverstok voor een aanval of verdediging.
It looked cool

What did you wish was done differently regarding Wand Casting? 4 antwoorden

The fireball spell uses a lightningbolt handsign, why not a lightningbolt spell then! Or a fireball handsign.
X
de spreuk iets makkelijker doen, of een training om de spreuk goed uit te kunnen voeren
Have the wand being held in the hand

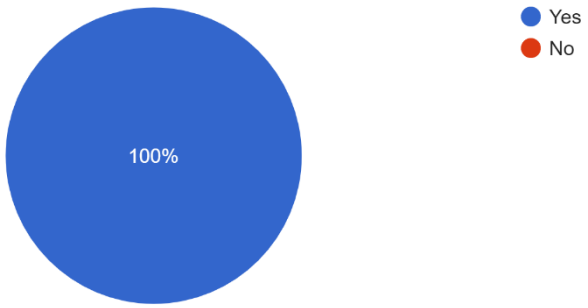
What if you could change anything regarding Wand Casting, what would that be? 4 antwoorden

My wand feels like a gun, make it more magical! I want sparks and see the weave of magic coursing through my wand.
X
makkelijkere spreuken, en eventueel verschillende type spreuken.
Hold the spell to aim untill you release the button

Questions regarding Player Avatar.

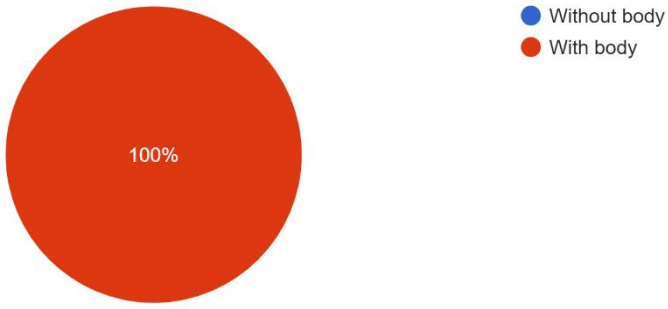
Did you feel more grounded when owning an in-game body?

4 antwoorden



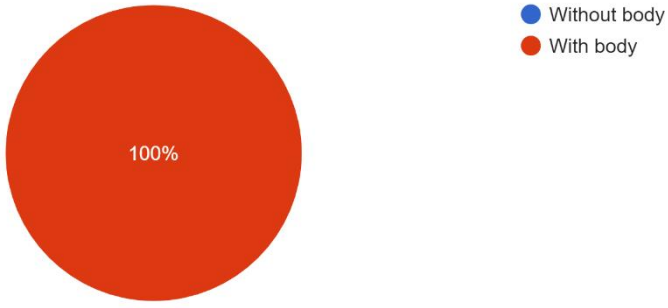
When grabbing items which player avatar did you prefer?

4 antwoorden



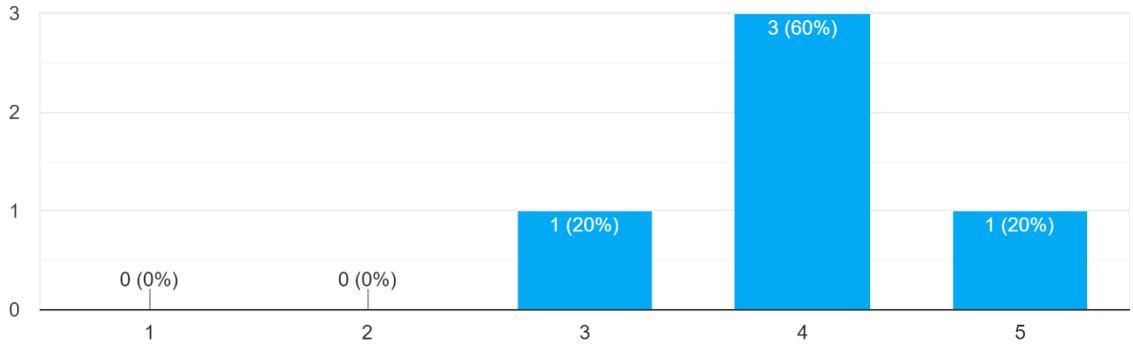
When dodging spells which player avatar did you prefer?

3 antwoorden



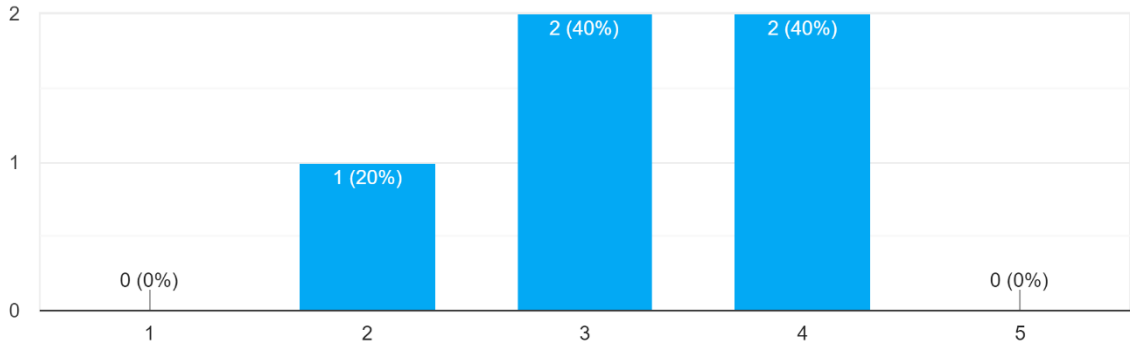
I felt embodied in the avatar during grabbing of items

5 antwoorden



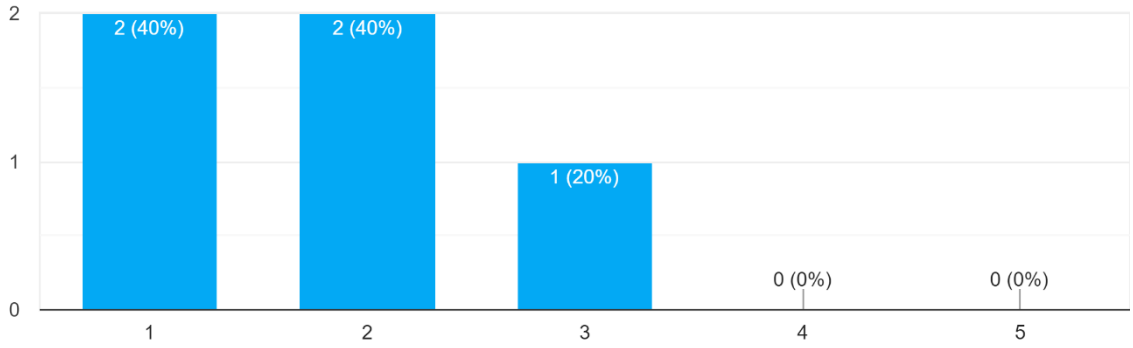
I felt like I had two bodies during grabbing of items,

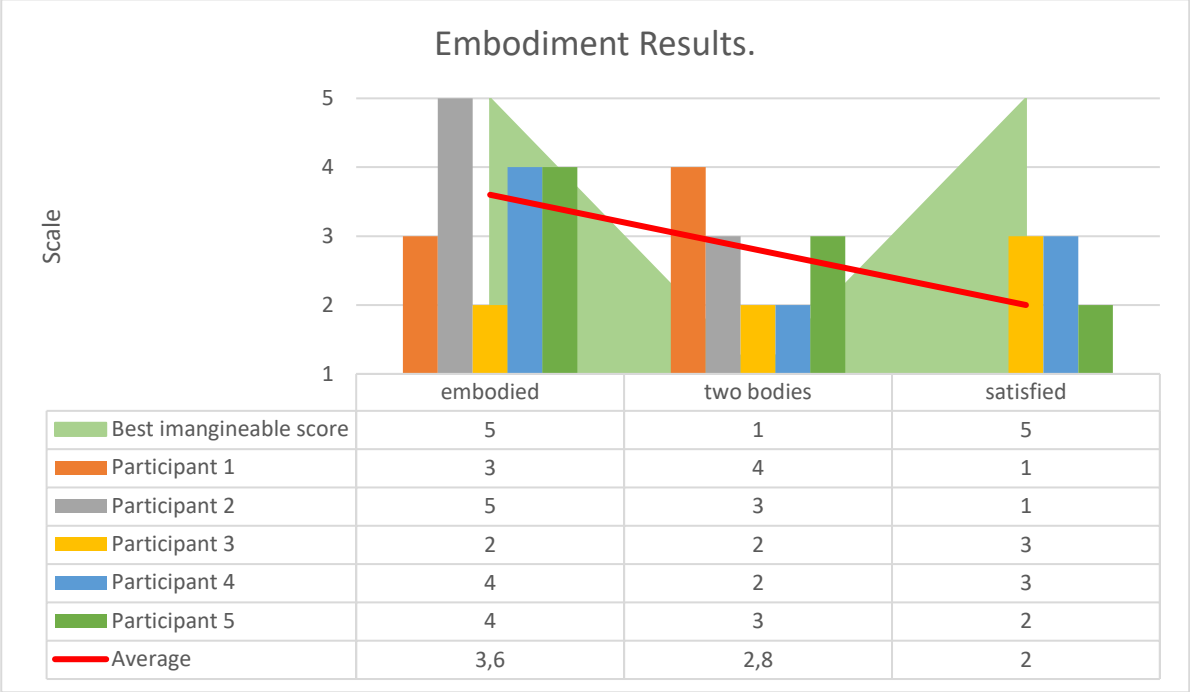
5 antwoorden



I felt satisfied with the interaction during grabbing of items

5 antwoorden





	embodied	two bodies	satisfied
Best imangineable score	5	1	5
Participant 1	3	4	1
Participant 2	5	3	1
Participant 3	2	2	3
Participant 4	4	2	3
Participant 5	4	3	2
Average	3,6	2,8	2

All users prefered having a body over not having one even though the hand animations were not following the shape of the items. Grabbing is not satisfactory.

Optional, want to leave more feedback?1 antwoord

Can't wait to see more content!

Annex 6: Game screenshots