De Weg naar Boven: Developing a Hearing Test Video Game

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Abstract

This thesis explores the development and evaluation of a video game designed to function as an engaging and more realistic clinical hearing test. My clients, the Amsterdam UMC, are looking for a hearing test that simulates the real world more, to give more realistic and effective hearing loss advice. Background research showed that this can be done by applying video game elements to non-game environments, such as hearing tests, to increase engagement. After multiple iterations, client interviews, and preliminary user testing with prototypes, a final idea was chosen and specified for the serious game.

“De Weg naar Boven” is an adventure story game where the player climbs a mountain by following a path. On their way, the player will encounter other travellers, who will act as a listening situation from the clinical hearing test. In this way, the player conducts a hearing test while being immersed and engaged in the video game. Realistic wind noise, visual cues, and video game affordances are added to increase realism.

The game was evaluated by 12 participants through observations, interviews, and a survey, and received many positive reactions. It was found that the art style and sounds in the game enhance each other to create one engaging and immersive whole. The movement and listening situations in the game had a small learning curve where but were clear after. In total, all participants completed the hearing test while being immersed and engaged in the video game, making the project a success for the clients, as well as for the future.

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My sincere thanks go to my family, friends, and girlfriend who always supported me during the project. Especially at the start of the project, they helped me through a difficult personal time that eventually led to this moment, of which I am very proud and thankful.

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Chapter 1 – Problem statement and research question

1.1 Research context

Traditional hearing tests, like those from the client Amsterdam UMC, are fully laboratory focused. This means the complex hearing situations experienced in the daily lives of people are left out of the test. Together with expert in video games and interactive media, Marcello A. Gómez-Maureira, and experts and providers of hearing tests from the Amsterdam UMC, the graduation project was opened.

The project seeks to develop a health-focused video game that serves as a hearing test using complex real-world auditory situations. While calibrated test tones can provide a focused measure for what a user can hear, everyday life brings unique auditory challenges through the layering of different sound sources as well as ambiguities when visual cues are introduced.

Video games can serve as engaging simulations of real-world scenarios, typically grouped under the label of “Games for Health”. By simulating real-world auditory challenges within a game environment, this project aims to provide a safe and encouraging platform for users to test and perhaps even practice their listening skills. The game should be structured to offer a progressive difficulty level and mimic the auditory complexities of the real world.

1.2 Problem statement

The challenge of the current situation is that the hearing tests at the Amsterdam UMC and the rest of the Netherlands are very laboratory specific. The problem is that the real world is not a laboratory, the current hearing tests do not simulate real life. According to the client, it is currently a trend in science to start moving away from laboratory-specific tests and move towards more ecologically valid tests; tests that simulate the real world more. The current hearing test gives as output a person-specific speech reception threshold (SRT). However, as the current test is very laboratory-specific, this number does not reveal much about a person’s everyday hearing issues. Two people who have the same speech reception threshold can have completely different hearing problems in the real world, meaning that with the current hearing test, real-life hearing problems can barely be predicted by the hospital. The clients from the Amsterdam UMC therefore want a hearing test that is more ecologically valid, it simulates the real world more. The problem now is that there is still a huge gap between the current laboratory-specific hearing test and the real world, as can be seen in Figure 1, where the client's current and wished hearing test is depicted.

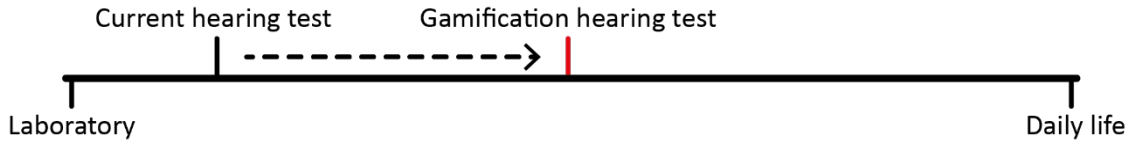


Figure 1: The problem of the current hearing test is that it is too laboratory focused, there is a big gap between daily life.

1.3 Research challenges

The challenge of this project is to make something, a health-focused video game, which acts as an ecologically valid hearing test, meaning that the new test should simulate the real world better than it does now.

Additionally, the game should be created as a form between a serious game and gamification. The non-game environment, the hearing test, must be modified with research-proven game elements that make the test more engaging for its users. The implementation of these elements is a challenge as there are no clear examples of engaging game elements for hearing tests from previous studies.

Finally, creating auditory sentences that can be used in a clinical hearing test is very difficult and out of the scope of this project according to the client. To accurately measure a person's speech reception threshold the same developed clinical sentence set must be used [1]. This set is provided by the client but limits the freedom of the serious game.

1.4 Research question

Finally, the project aims to answer the following research question:

How can a hearing test be developed into a serious game to facilitate ecologically valid testing?

Chapter 2 – Background and Related Work

This chapter describes the background and the related work to the project. The background consists of a literature review and an expert interview of the clients. Finally, a state-of-the-art concludes the chapter.

2.1 Serious games and gamification

Serious games and gamification are important terms in this project. Both terms must be defined to use them. Then, the importance of serious games and gamification can be explained in terms of this project.

2.1.1 Definition of gamification

There is no clear agreed-upon definition for gamification, but two similar concepts make up the term. Firstly, Deterding et al. [2] state that gamification is the use of game design principles in non-game contexts. Libbi [3] adds to this definition that the use of game elements has the goal of increasing motivation and enjoyment. Bitrián et al. [4] state that this non-game context can also be a non-gaming product or service. However, Wang et al. [5] imply that gamification means improving service with game affordances for a gameful experience to support the user's overall value creation. Huotari and Hamari [6] and Walsh [7] add to this definition that gamification is done to additionally increase engagement and motivation to act in the service. In conclusion, the definition of gamification can be described as using game design principles to improve a non-game experience, product or service, to increase motivation and enjoyment, or to encourage value-creation and engagement.

One example of gamification is the My Reward feature from the Starbucks application. Here, customers are rewarded by so-called stars when making frequent purchases at Starbucks. Customers can beat different “levels” by staying loyal to the coffee giant, which will give them more and better rewards. These gamification elements like levels, stars, and rewards have proven to capture enormous value for Starbucks, while also providing an enjoyable experience for the customers [8].

2.1.2 Definition of serious games

The definition of serious games is found to be difficult to define, however, there are three similar concepts. On the one hand, Kniestedt [9], Kuipers et al. [10] and Sardi et al. [11] define serious games as an umbrella term for all games with another purpose than pure entertainment. On the other hand, Libbi [3] and Kuipers et al. [10] state that serious games are games that have the goal of educating, training, or changing the player's behaviour. Kuipers et al. [10] differ from Libbi [3] in a way that they state serious games are games that additionally sacrifice a level of entertainment and aesthetics to reach this goal. Finally, Kniestedt [9] and Whyte et al. [12] imply in their definition that serious games have the primary objective of enabling players to apply what they learn by playing the game, in their real lives. To conclude, serious games can be defined as an umbrella term for games that have a goal other than entertainment but rather the goal to educate, train, or change behaviour that can be applied in the user's real life. For this project it should be noted that the game should not educate or train the hearing test user, changing behaviour that can be applied in real life is however a more desired outcome

Microsoft Flight Simulator is one of the first serious games ever released and its newer versions are still popular to this day [13]. In this game, the player can experience and learn about the world and

aviation through hyperrealistic flight controls and satellite images of the entire world. The goal of the serious game is not entertainment, rather it is focused on simulating the real world as close as possible to teach the player. Currently, many simulation serious games follow the same goal.

2.1.3 The importance of serious games and gamification in this project

Serious games and gamification show a great possibility to engage the user. This will help create an experience where the hearing test user gets fully immersed in the game environment. Just like in the real world, you are not focused on active listening. Listening goes just as breathing, you do not notice you are doing it and you cannot stop doing it. In this way, being fully immersed in the hearing test game will simulate real life more than the current test, where the user is constantly aware of participating in a hearing test. Serious games and gamification could be used to create a more engaging version of the hearing test that can immerse players and make them forget that they are doing a hearing test, which resembles real-life listening situations. Given this, the goal of this literature review is to give insight into how gamification/serious game methods can be implemented in a way to increase engagement in conducting a hearing test.

2.2 Designing for engagement

The next step is to find a definition for engagement. Then, based on literature research, gamification and serious games elements that have been shown to increase engagement can be found.

2.2.1 Definition of engagement

To find out how gamification and serious games increase engagement, a definition of the term is needed. Engagement with digital systems is described as an abstract construct with divergent meanings; authors do not agree about the concept being measurable. Bitrián et al. [4] describe engagement as a measurable concept that shows how deeply someone is involved with a digital system in terms of their time spent, emotions, actions, and thinking. Supporting this, O'Brien and Toms [14] also suggest engagement is measurable. They mention a scale of six factors, including focused attention, perceived usability, aesthetic appeal, endurability, novelty, and felt involvement, which can measure engagement for every digital system. Building on this, O'Brien et al. [15] improve the argument with more case studies and still believe engagement is a measurable construct consisting of aesthetic appeal, focused attention, perceived usability, and reward. On the other side, however, Kniestedt [9] states engagement is difficult to measure as it describes a state of flow, meaning the player is in full absorption (immersion) and enjoyment. Wang et al. [5], Whyte et al. [12], and Libbi [3] support this argument and define engagement as intrinsic motivation: the player acts for their own sake in a way that increases immersion and enjoyment. In conclusion, while it is debatable whether engagement is measurable or not, it seems the construct is closely linked to enjoyment, motivation and immersion.

2.2.2 Ways gamification and serious games increase engagement

Now that all terms are defined, it is possible to investigate how gamification and serious games increase engagement. There are multiple ways game elements increase engagement. The first way is that the game affordances evoke feelings of competence, relatedness, and autonomy, as stated by Bitrián et al. [4]. All three feelings have been shown to influence engagement in gamified systems.

Secondly, game elements seem to lead to more positive motivations and enjoyable user experiences, as suggested by Wang et al. [5], which is linked to engagement following the previous definition. Thirdly, feasible mid-term and long-term goals integrated into a story give the player more motivation and enjoyment. Additionally, the environments often found in serious games lead to a high level of immersion, as supported by Whyte et al. [12]. Both are linked to engagement following the earlier found definition. Finally, motivation and enjoyment, and therefore engagement, are increased by serious games as they provide only positive feedback and rewards for the player, as stated by Whyte et al. [12]. In conclusion, game elements found in gamification and serious games increase engagement as they provide feelings of competence, relatedness, and autonomy, as well as an increase in motivation and immersive experiences.

A great example of how game systems are used to foster engagement is the smartphone application "Zombies, Run!" [16]. This app gamifies running and exercising by providing an immersive and captivating narrative about a zombie apocalypse. The player starts the app before they go out on a run, and then while running the app will provide feasible mid-term and long-term running goals (like a time or distance) through audio, integrated into an immersive story about zombies. The app also allows for competition with other runners, which further increases engagement. The app has become very successful with more than 10 million users spanning different kinds of stories [16].

2.2.3 Game elements that provide increased engagement in case studies

Ultimately, now that the link between engagement and gamification and serious games has been made, it is important to find the specific game element that increases engagement, as they can then be linked to the problem of unappealing hearing tests. Three main types of affordances to increase engagement were discovered by the authors. Bitrián et al. [4] found three categories that define the game elements. First, achievement and progression-oriented affordances include the most popular game element in gamification and serious games; points, leaderboards, ranks, progress bars, progressive difficulty levels and medals/badges. Figure 2 gives an illustration of how some of these affordances are used in practice. Additionally, Whyte et al. [12] and Wang et al. [5] support this list and add "goals directed around specific skills" as well. Secondly, Bitrián et al. [4], Wang et al. [5], Whyte et al. [12], and Sardi et al. [11] mention the social-oriented affordances. These include cooperation, competition, social networking features, teammates and social interactions in general. The final category includes immersion-oriented affordances. Bitrián et al. [4] explain how these elements allow the player to personalise and change their vision of the world. This includes avatars, profiles, narratives, and customisation. Figure 3 gives an example of how these affordances are used in practice. Whyte et al. [12] additionally add "individualised training" and "the provision of choice" to this category. In conclusion, three categories of affordances can be used to make gamification and serious games more engaging: achievement and progression-oriented affordances, social-oriented affordances, and immersion-oriented affordances. However, while these categories are proven to be useful to increase engagement in serious games or gamification, it is not yet proven to be useful for a hearing test serious game. This will be included in the discussion part of this review.

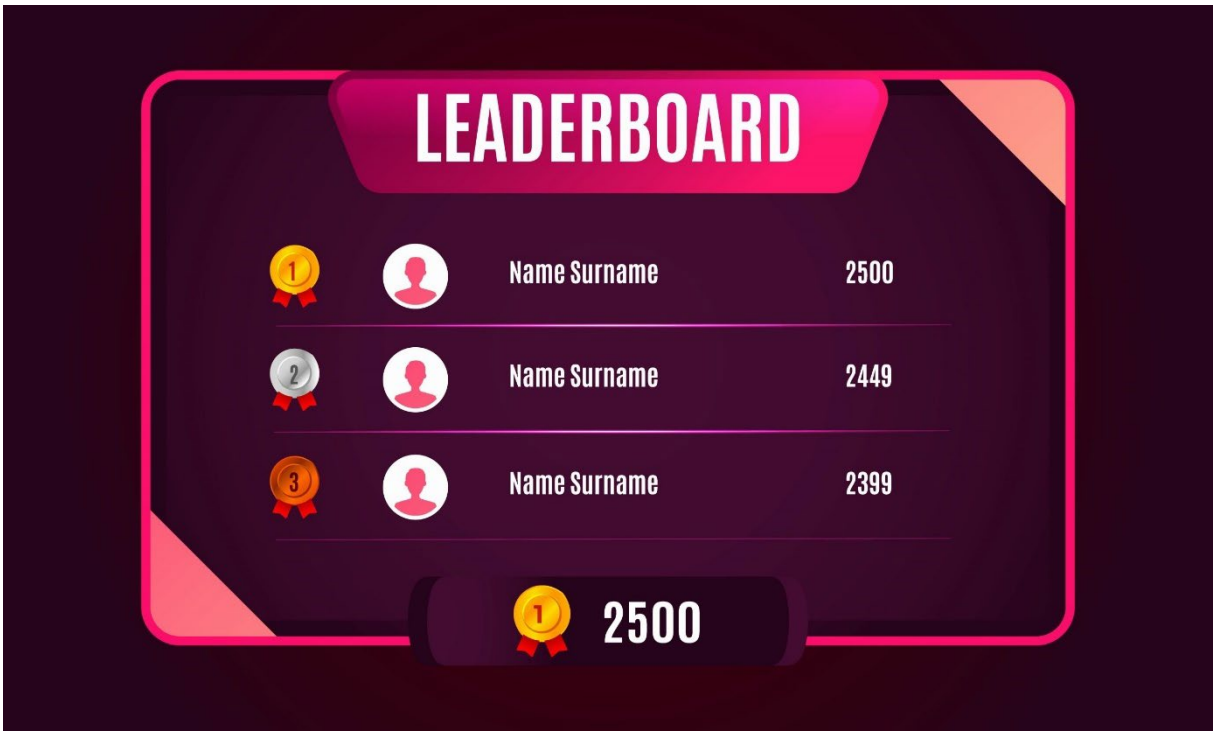


Figure 2: An example illustration of the achievement and progression-oriented affordances leaderboard, points, and ranking [17]

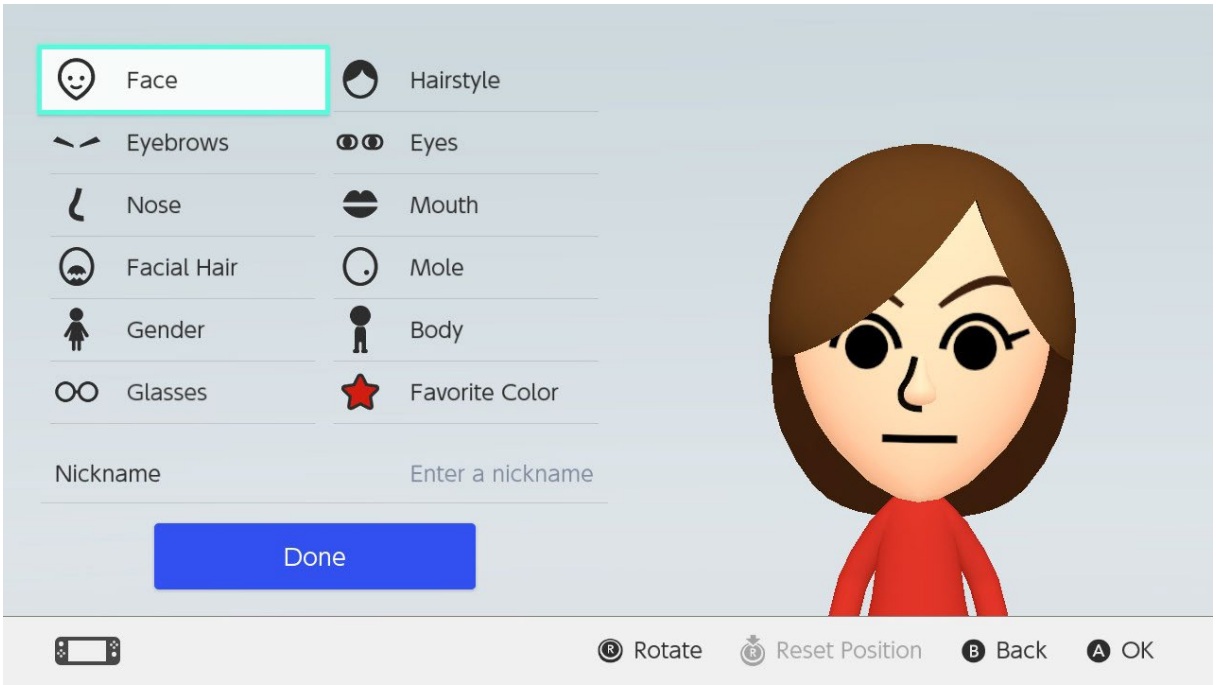


Figure 3: Example of the use of immersion-oriented affordances in practice. Nintendo Switch allows users to create a personalised avatar to express themselves [18]

2.3 Conclusion and discussion of the literature research

The main objective of this literature review was to give insight into how researched gamification and serious game methods can be implemented in a way to increase engagement in non-game-like

settings, like a hearing test. The first part of the study examines the definition of the important concepts of gamification, serious games, and engagement. Gamification seems to be the concept of applying game elements to a non-gaming experience or a product or service. This has four goals; increase motivation, enjoyment, value-creation, and engagement. Serious games are different from gamification in a way that the goal of these games is to educate, train, or change the users' behaviour that could be applied in the real world. Finally, engagement is an abstract concept that seems to be directly related to motivation, enjoyment, and immersion. One group of researchers argues that engagement cannot be measured, while the other group of researchers developed scales that measure the construct.

Ultimately, the study found researched gamification/serious game elements that can be implemented to increase engagement. These elements seem to increase engagement by providing the player with a feeling of competence, relatedness, and autonomy, as well as increasing the player's motivation and feeling of immersion. Case studies from the literature explain how three categories of affordances increase engagement in serious games and gamification, and therefore show a possibility of increasing engagement for hearing tests as well. First, the achievement and progression-oriented affordances include the points, leaderboards, ranks, progress bars, progressive difficulty, medals/badges, and skill-specific goals elements. Second, are the social-oriented affordances, with elements like cooperation, competition, social networking features, teammates, and social interaction. Finally, there are the elements that allow the player to personalise and give themselves a different look at the world. These immersion-oriented affordances include avatars, profiles, narratives, customization, individualised training, and the provision of choice. Implying these affordances could increase the engagement of hearing tests.

However, it is difficult to arrive at a definitive answer to the question by only following the literature. As hearing tests are a specific area, there was not any related study fully focused on increasing engagement through serious games or gamification for this test. As well as the fact that engagement is a subjective concept, there will never be a go-to approach to increase it in a new context, like the hearing test. This means that the above-mentioned elements could have a different effect on the hearing test and could prove to be not useful in increasing engagement. In terms of the question of whether engagement should be measured, for this project the answer will be yes, and the provided scale will be useful. This scale uses relevant questions that can be adapted to fit this project's needs, making it a useful tool to measure and compare engagement. Future research could investigate new theoretical areas about hearing tests in general and previous works, to find new ways of increasing engagement without the use of gamification or serious games. Additionally, future practical research should implement the mentioned affordances and test whether the engagement is in effect increased, or what other effects they bring with them.

2.4 Ecological validity in research

Before going more in-depth into the hearing test, the concept of ecological validity must be defined. Ecological validity determines how much research findings apply to real-world environments [19]. In terms of clinical studies, this implies that a test is ecologically valid if the results of the test reflect the real-world situation of the patient [20]. The client states that the current hearing test is not ecologically valid and wants the new hearing test game to be more ecologically valid.

As found from the literature research, multiple gamification and serious game elements could increase engagement in non-game environments like the hearing test. Furthermore, it has been shown that engagement is closely related to immersion, the feeling of being fully absorbed in the game. A problem

with the current hearing test is that there is no immersion or enjoyment, the user is constantly aware they are doing a hearing test. In the real world, this is never the case. When talking to someone you are listening to them, but it is not a hearing test. Therefore gamification and serious game elements that could increase engagement are useful for this project to create an ecologically valid hearing test, they can create a level of immersion that makes the user forget they are taking a hearing test.

2.5 Hearing test research and practice

Now, the current hearing test will be explained based on literature, as well as discussion and interviews with the experts from the field, which are in this case also the clients of the project. This section ends with a description of the Amsterdam UMC test setup.

2.5.1 Construction of the current hearing test model

The current hearing test model originates from Versfeld in 2000 [1]. This study deals with a method for the creation and evaluation of sentence materials that will be used in speech reception threshold (SRT) tests, the current hearing test model. The main goal of the study was to largely increase the sentence materials while yielding equal or better test efficiency as the already existing material sets, while additionally using the same testing procedure, i.e., the procedure described by Plomp and Mimpen (1979) [21]. Using specific selection criteria on data from newspapers the final number of sentences material came to 1272. The purpose of the selection criteria was to create a homogenous set, i.e., the sentences in the set are equally intelligible in a variety of listening conditions [1].

2.5.2 Description of the current hearing test model procedure.

Using the homogenous set, the speech reception threshold (SRT) test can be conducted. Before starting the listening experiment, the test ear is chosen based on the subject's pure-tone audiogram. This is a small test consisting of several beeps that find out how sensitive a person's hearing is. Then, the subject receives the sentences to the test ear over headphones while being in a sound-insulated room [1]. The sentences are played along with some sort of noise coming from the same headphones. The noise has a certain level of loudness, as well as the actual sentence. The ratio of these two is called the signal-to-noise ratio in clinical hearing tests. The subject's task is to repeat the sentence as accurately as possible [1]. Based on the adaptive procedure described by Plomp and Mimpen [21], the signal-to-noise ratio is varied in every list of sentences. The first sentence of each list has a signal-to-noise ratio of -8 dB, meaning the sentence is 8dB lower than the noise, and will increase in signal-to-noise ratio to 4 dB until the subjects can repeat the sentence accurately. The next sentences are only presented once. If the subject can correctly reproduce the sentence, the signal-to-noise ratio of the next sentence will decrease by 2 dB, oppositely, incorrect reproduction of the sentence leads to a 2 dB increase for the upcoming sentence [1]. If the noise is 2dB louder it will be more difficult to reproduce the sentence for the user. Based on this adaptive procedure the SRT test will eventually find an outcome that shows how many decibels of noise a person can tolerate to still have functioning hearing; this is the person-specific speech reception threshold (SRT).

An interview was conducted with the clients at the Amsterdam UMC to gather insight into the way they conduct a hearing test. The clinical hearing test at the UMC consists of at least 13 sentences that the user must repeat, to accurately output a personal SRT. During the test, there will be continuous noise that merges in with the sentence the user has to reproduce. The client states that there are two types of noises used by the UMC and a user always only has one type per test. The first and most

common one is a constant white noise. The other one is a male voice saying useless sentences through the actual sentence produced by a female. According to the client's test results, both types of noises show different results for the speech reception threshold of the users.

Additionally, the Amsterdam UMC measures the subject's pupil size to measure how much mental effort the subject uses. This is done by putting a camera in front of the user and using software to measure the size of the person's pupils. The general Amsterdam UMC clinical SRT test setup can be seen in Figure 4. The client notes that in normal circumstances the hearing test is conducted in a sound-insulated room with headphones, as described by Versfeld [1], but is currently conducted in a non-insulated but closed room with speakers instead of headphones due to a renovation at the UMC. The client states that there is not a significant difference found in results between the two testing environments. The screen that is included in the setup is currently not in use.

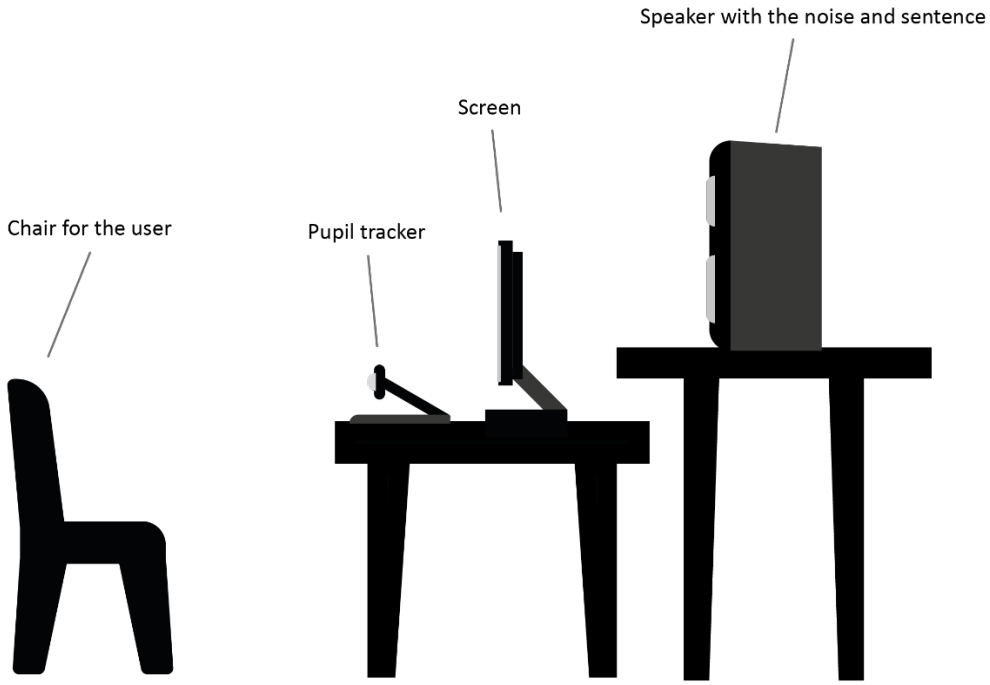


Figure 4: The Amsterdam UMC SRT test hearing setup includes a chair, pupil tracker, screen, and speaker

2.6 Previous attempts to increase ecological validity in hearing tests

There have been tests conducted to increase the ecological validity in hearing tests already that are worth looking into as they could provide valuable information about what elements are effective in increasing ecological validity and what are not.

One of the studies examines whether the presence of people could make the test feel more like daily life, as, typically, listening in real life takes place in copresence [22]. The study primarily focused on how copresence would influence hearing results and invested effort into the hearing. While the hearing results were measured using the normal SRT test procedure, invested hearing effort was measured through the pupil size eye tracker. A larger pupil was assumed to mean that more effort was invested by the user. The study was conducted using multiple blocks of hearing tests, based on the

earlier described adaptive procedure [21]. In some of the blocks, the test would resemble a traditional SRT test, while in another block the user would be confronted by two humans sitting oppositely of the user while taking the test. The humans would not make any sound and only got the instruction to look at the user. The result of the experiment followed that the speech-to-noise performance was not influenced by copresence, but the invested hearing effort was. It showed that with people looking at the user, there would be more invested effort into listening, as measured through pupil size [22]. Whether this meant the ecological validity was increased through copresence is unclear.

Another study in South Korea tried to make hearing tests more ecologically valid by providing visual cues to the users through virtual reality headsets [23]. The reason for this approach was that real life also shows visual cues when listening, and not only audio. The experiment was conducted by giving the user a VR headset while conducting the test. The VR environment consisted of a café, as this is one of the most common places people experience hearing problems [23]. While the test remained the same, this time the user could see the woman who is speaking the sentence the user must reproduce. Additionally, the user could now see where the background noise was coming from, instead of only looking at the speaker. Results show that these visual cues significantly increase the hearing test score for the users, as well as increase enjoyment. The research group states that a higher resemblance between daily life hearing was achieved and suggests the feasibility of VR hearing tests in other clinical practices [23].

Additionally, a more common thing often investigated when creating more ecologically valid hearing tests is altering the noise sounds to a more realistic sound. The daily life hearing situations are far more complex than the lab hearing test situation in terms of spatial, spectral, and temporal sound field distribution. There are noise sounds from multiple directions and these sounds tell more about the surroundings than the two noise sounds used by the current clinical hearing test, as described in Chapter 2.5.2. A research group has captured 13 different realistic typical environments (e.g., train station, dinner party, food court, office, café) that can be used to create more ecologically valid hearing tests [20]. These environments are stored in their Abisonic Recordings of Typical Environments (ARTE) database and include both 3D and 2D audio, as well as the fully researched known acoustic properties of the sounds. From the research it followed that the office, train station, and café were the most identifiable to the users, meaning these environment sounds could be a great replacement as noise sound for the Amsterdam UMC clinical hearing test. The ARTE database is openly accessible and shows that realistic noise sounds are a possible way to increase ecological validity in hearing tests.

Following from these case studies it becomes clear there are already known ways that could increase ecological validity in hearing tests. These case studies have not yet been linked to the concept of gamification or serious games and their immersion. However, properties learned from these case studies could be implemented into the game as well. For example, the game will also rely on visual clues and could implement realistic environment sounds, as found in the ARTE database, to make the game feel more immersive to the player.

2.7 State-of-the-art serious games related to hearing tests

In recent years, the amount of video games has grown a lot. This, together with the ever-growing technology made it possible for several hearing serious games to be created. These game examples will be investigated, to find out what they do great, and if this could be used for the creation of a hearing test serious game.

EarMonsters. In the serious game EarMonsters the user is trained about 3D audio [24]. The game is very simple, there will be a monster spawning from a specific direction. The player must guess which direction this is by listening closely to where the 3D sound originated from. EarMonsters has a very arcade feel and is also quite old already. In 2013 this game was available for download on Apple devices. A thing EarMonsters does great is its simplicity. There is no need for advanced movements of players or characters, the only input the player receives is a 3D sound and a very simple visual cue. It becomes clear that the focus of gameplay in this serious game is on the sound design part. Figure 5 shows a screenshot of the gameplay.

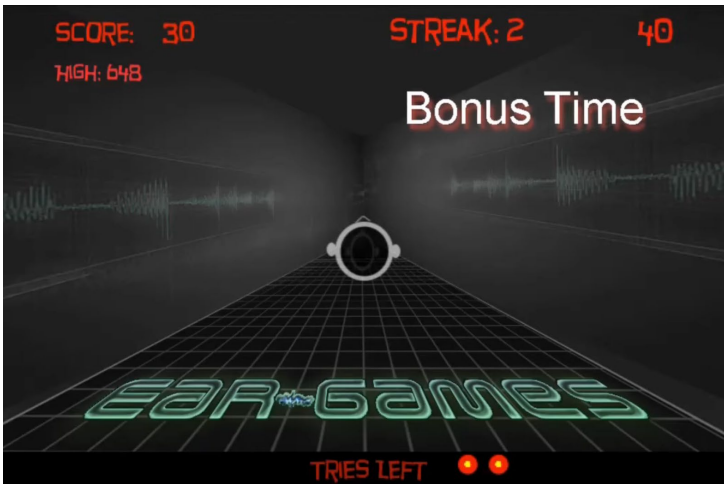


Figure 5: A screenshot from the serious game EarMonsters, the game is mainly focused on 3D audio so the visuals are kept simple as can be seen from this figure [24]

Ear Trainer. Ear Trainer is a very basic application for mobile devices that educates and trains people about sound design [25]. The focus of this app is mainly on teaching the user to recognise the notes and pitch of a sound. One thing that Ear Trainer does well is their difficulty progression, as can be seen in Figure 6. There are multiple levels the user can master, and they can additionally create their own. In this way, there is no difficulty maximum, which allows for personalised and engaged learning.

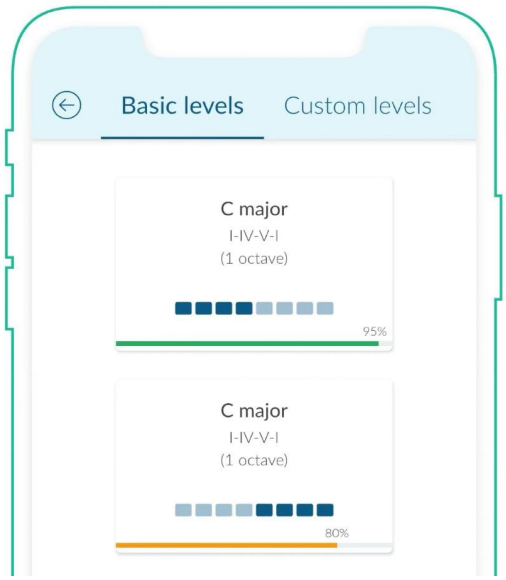


Figure 6: A promotional art of Ear Trainer that showcases its progressive difficulty [25]

Sound Scouts. Sound Scout is an award-winning hearing test game made for children [26]. The app is used in educational instances like schools, or at home. The selling point of the application is that it provides a hearing test without having to go to a clinical institution. This however also means that the provided test in Sound Scout is not a clinical test. In a series of small audio-based games a child's hearing capabilities are determined. Opposite to the previous two serious games, Sound Scout uses visual cues in the gameplay. The game follows a very cartoonish style to still make the game feel simple, as can be seen on the middle iPad in Figure 7. One great thing Sound Scout does is that the combination of visual cues and audio makes the player feel immersed in the game, only after they have completed their minigames they will see their test scores. Before this, it is unlikely that the children who play this game are aware they are taking a (non-clinical) hearing test.

Figure 7: Sound Scout promotional images showcasing the cartoonish visuals of the game, while also showing the hearing test part [26]

Sonification Sandbox. While this project resembles less of a serious game it has one great thing that could be useful for the construction of the serious hearing test game. This is the customisation and freedom available in Sonification Sandbox, as can be seen in Figure 8. In this project, the user can learn about auditory features such as timbre, pitch, volume, panning, and other useful sound design techniques [27]. The Sonification Sandbox cannot be called a serious game in fact, as there are not enough game elements to make this project playable. However, the project has the same goal of educating and training its users about sound design. This is less useful as the goal is not about hearing but about sound design, still, the customization and freedom in this tool show great opportunities for easy and versatile learning.

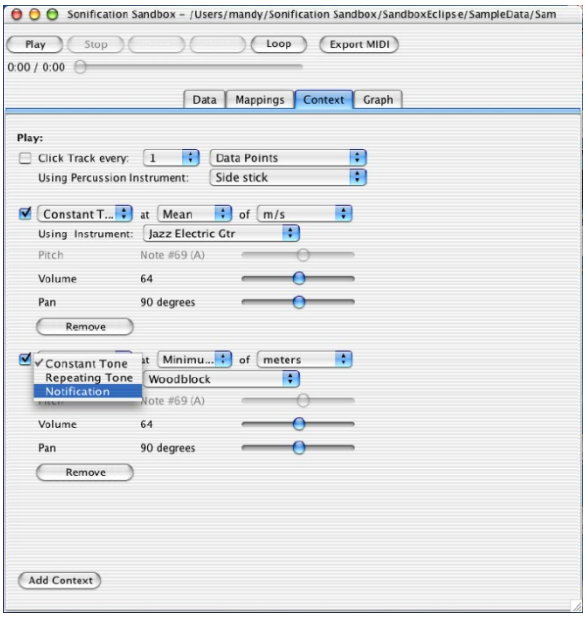


Figure 8: Screenshot from the Sonification Sandbox that shows the many options provided for customization for the users [27]

Chapter 3 – Methods and Techniques

In this graduation project, the Creative Technology design process will be used [28]. This process consists of four phases: Ideation, Specification, Realization and Evaluation. In this chapter, all these phases will be linked to the project.

3.1 Ideation

During this phase, a creative idea will be constructed. The starting point of the Creative Technology design process is in this case a request from a client. Their request is the motivating force in the ideation phase. In this phase, many different ideas will be generated by using brainstorming techniques. In the case of this project, the brainstorming technique used is a combination and elaboration brainstorming session with sticky notes. Before brainstorming can begin, the stakeholders have to be analysed, and the requirements should be clearly noted. These two, combined with the brainstorming sessions, will lead to one final well-worked-out idea.

3.2 Specification

During this phase, the functional and non-functional requirements will be formulated. The chosen idea that resulted from ideation will go through a feedback loop in the form of many prototypes to explore the design phase. In the case of a serious game, these prototypes will be paper-based as well as digital game mechanics or ideas that can be evaluated by the user. The evaluations will be done by the clients and the target group.

3.3 Realization

In this phase, the actual hearing test game will be created. This will be done based on the found functional and non-functional requirements from the specification phase, building on top of the tested prototypes. Finally, the finished game will be presented to the clients.

3.4 Evaluation

In the evaluation phase, the functional requirements set in the ideation phase and specification phase are tested by the users. Users will play the serious game, and after, they will answer a series of questions to test the product. Additionally, the non-functional requirements will be evaluated. This phase ends with a reflection and discussion of the results.

Chapter 4 – Ideation

This chapter will describe the ideation part of the project. First, the stakeholders and design requirements are analysed. After this, the brainstorm will be possible. The result of the ideation phase is a more elaborated project idea, which also includes ideas on interaction and experience, as stated in the Creative Technology Design Process [28].

4.1 Stakeholder analysis

It is important to analyse who are the stakeholders in this project, and what are their interests. There are multiple stakeholders.

4.1.1 The clients

The clients of this project are Adriana Zekveld and Sophia Kramer. Both are working at the Amsterdam UMC Hospital in the Netherlands. Both are not only clients of the projects, but they are also experts in the field of hearing tests and provide valuable information about this topic. The clients' interest lies in the development of a hearing test that is more ecologically valid, e.g., it simulates the world more realistically than the current test. This hearing test will be made as a serious game that has certain requirements which will be explained in dept in 4.2.

4.1.2 The developer

As the developer of the hearing test game, it is my goal to incorporate the interests of all stakeholders and find out what is doable in the given time frame. I will design the game based on the client's requirements.

4.1.3 The supervisors

Supervisor Marcello Gómez-Maureira and critical observer Kasia Zalewska will help me during this graduation project to ensure better results and progress of the project. Additionally, they are grading this thesis meaning they have requirements of what this thesis should include. Their guidance will help me create a better hearing test serious game.

4.1.4 The user

The users will be the persons playing the hearing test serious game. They will be adults who visit the UMC for their hearing test. The users want an engaging and accessible experience while playing the game, as well as a more reliable hearing test as it simulates the real world more. They should not get hurt or disengaged when playing the game.

4.2 Requirements

The clients and supervisors state multiple requirements that must be met in the final design. It is useful to note these requirements before ideation. The following requirements should be included in the first ideation design.

- The game has to function as a speech-reception-threshold hearing test.

- The game has to simulate the real world better than the current test.
- The game has to use the clinical sentences provided by the UMC (at least 13).
- The game has to include background noise during the sentences.
- The game has to include somewhat similar background noise during the different sentences.
- The game has to include context-related background noise during the sentences.

In addition to these requirements, the clients also have some wishes. These wishes do not have to be included in the final design but would be a great addition to the project, according to the client. The client states the following wishes.

- The game has an option to easily change background noise in between tests to provide easier testing for the UMC.
- The game has a single focus point on the screen while listening to the sentences, so the pupil tracker system can be used by the UMC.
- The game includes a realistic noise that has a frequency based on the sentences, so it is more effective.

4.3 Brainstorm

Now that the stakeholders are analysed and the requirements are known, the brainstorming process can begin. As described in the Creative Technology Design process, the goal of the ideation phase is to create a link between technology and user needs [28].

4.3.1 Initial categories brainstorm

The brainstorming is done on the online Lucidspark website [29]. This website allows for complete freedom of placing sticky notes. The colour option allows for quick categorisation of the sticky notes, which is useful for brainstorming. The brainstorming started with the thinking of all the categories needed in this project. Later, individual sticky notes could then be easily combined from different categories to create interesting ideas. The first category is about the possible camera styles for the game. While this category, and some other categories are small and less creative, writing it down helps the brainstorming get into flow. Additionally, the content from this category could be used in a combination brainstorm where different categories will be combined later. The second category is about possible game styles. Even though the game will function as a serious game, it will also still have a game style to ensure the game is engaging. While during the brainstorming there is no limitation of ideas, in reality, a serious game that has the game style of for example “Racing” will not be a casual game the client is searching for. However, it can still provide new insight into possible serious game ideas. The third category that can be used during the combination brainstorm is playstyles. While the current hearing test has no playstyle, the serious game hearing test needs to be playable. The game could be playable on a laptop using the keyboard, or for example by using a controller. These options could make the game more diverse and engaging. Finally, the creative category of this brainstorming is about the possible game themes. These ideas will be the centre of the second stage of brainstorming, where combinations will be made with a theme and possible listening situations.

Additionally, a last category was added that provided sticky notes on how to make the hearing test more ecologically valid based on the background research. This category consists of three sticky notes that will all be included in the creation of the serious game.

- Realistic noises. As described in Chapter 2.5.2 the SRT test consists of a spoken sentence and some type of noise. In the hearing test game, the noises will be more realistic which will improve the ecological validity of the test. Additionally, as stated in the requirements, the noise will be related to the context of the game to make the noises even more realistic and engaging.
- Visual cues. The background research showed that visual cues were successful in modifying the test to simulate the real world better. The current hearing test has no visual cues, it could be conducted without looking. The serious game, however, will have a screen where the game is played, this visual cue will make the test more immersive and engaging.
- Affordances to increase engagement and immersion. Finally, all affordances that could make the serious game more engaging are listed again in their own category. During the combination brainstorm these affordances could be combined with game ideas to create more ecologically valid ideas.

The category brainstorm can be seen in Figure 9.

Figure 9: Initial category brainstorm

4.3.2 Combination brainstorm

The next step of the ideation phase is to make interesting combinations of the sticky notes. The core of every combination will be a game theme, together with one or two interesting listening situations related to that theme, and a realistic noise. After some interesting combinations are made, they will be ranked on relevance. The most relevant ideas will get sticky notes from the other categories implemented as well, making the ideas more concrete. The outcome of the combination brainstorm can be found in Appendix A.

As can be seen in the figure, many listening situations are similar or the same. A challenge of this project is to find a listening situation in an interesting and engaging context. Additionally, since the sentences provided by the UMC have to be used, it might be difficult to get sentences that fit the context. There are essentially two ways this can be dealt with.

- The context fits specific sentences
- The context fits any sentences

For example, in the “cooking” and “getting order” combination, it only makes sense that the user hears sentences about food or the restaurant. However, in the combination “Open ocean” and “sentences from message in a Bottle” the sentences can be much broader. Based on this and other factors like feasibility, excitement, and innovation, the combinations can be ranked. The most prominent ones will be further developed with combinations with the other categories.

The combination brainstorm also includes one, two, or three initial game ideas. These ideas are very short and broadly written based on the theme and listening situations.

4.3.3 Ranking of combinations

Now that multiple combinations are made it is possible to rank them. The highest-ranked combinations will be further elaborated. The combinations were evaluated based on feasibility, innovation, interesting listening situations, interesting realistic noises, and connection to the requirements. After ranking there were five ideas with the highest rank. These ideas can be seen in Figure 10.

Figure 10: The combination ideas with the highest rank

4.4 Top 5 ideas

The five highest-ranked ideas resulting from the combination brainstorm will be worked out. The five ideas all showed promising implications for the project. After the five ideas are worked out a selection of three ideas will be made. These three ideas will be sketched out and further elaborated. Then, with consultation of the clients, a final idea for this project will be chosen.

4.4.1 Ghost train station game

In this game, the player can control a ghost that is flying around a train station. The ghost is listening to the stories of human travellers. The strong point of this game is that being a ghost allows the players to casually fly up to people and listen to their stories. The sentences provided by the Amsterdam UMC could be easily implemented as the player is not actively engaged in a conversation themselves. Also, the train station has an associated context, but people can talk about multiple different things at a train station. Travellers are not constantly talking about trains at a train station, so many different sentences would fit this context.

The game could be an adventure game where the player must explore parts of the station to find the people talking. Additionally, puzzle mechanics could be added, like the ghost being attacked by light. Overall, this game can become a casual game as the ghost will be able to fly around freely, where adventure or puzzle is the only obstacle.

The realistic noise in this game could be three different things. First, the noise could be many people talking, as big train stations in real life often have many travellers at the same time. This noise will be very realistic and will therefore increase the ecological validity the most. The second option could be an eerie ghost sound. The strong point of this noise is that it can be very monotone and simple, making it, therefore, easier for the UMC to adapt to perfect frequency based on the sentences, while still sounding realistic for the ghost. The same goes for the final and third option, the train whistle. This noise is more realistic than the ghost sound on a train station, however, the game has to be shaped in a way that only when listening to the sentences the whistle will blow. For the other two options, this is less important as they can be realistic and not annoying throughout the whole gameplay. For now, the first option, “people talking loudly”, is the most favourable one.

4.4.2 Spy game

The player will control a spy in this game. Initially, there were two ideas for creating a spy-based hearing test game. First, the player will intercept a spying device that outputs codeword sentences. These codeword sentences will be the sentences provided by the clients. The strong point about this idea is that every sentence can be used, as they are treated as codeword sentences anyway. However, this idea might lack engagement if the user is only listening and repeating sentences. This is why it could be combined with the initial second idea. This idea would be that the player actively eavesdrops on certain people to gather information, this idea is more engaging than the first idea. Combining the two ideas would lead to an engaging game where many sentences would fit the context.

In this game, the player will control a spy that infiltrated the enemy's mansion. By exploring the environment and by eavesdropping the enemies in the mansion the player will gather valuable information. The player will use an advanced sci-fi AI scanner-like tool that will convert the enemy text directly to codeword sentences and will speak this sentence. The player just has to repeat that

sentence through his walkie-talkie to report it to HQ. In this engaging way, the player is conducting an SRT test without noticing.

The theme of this game will be stealth and adventure. The realistic noise will be a buzz or literal noise coming out of the sci-fi AI scanner-like tool. A strong point of this noise is that it can be matched with the sentence's frequency without losing meaning, the buzz will still sound like a buzz but the test results for the Amsterdam UMC will be more meaningful. Another strong point of this realistic noise is that it makes sense to only hear this when listening, the noise will fit in the game and will not stand out much.

4.4.3 Future city time travel game

The player will get control of a time travel mechanic in this game. This mechanic can be used to change time in a certain city. This means that the player can experience the city when it was just, for example, grasslands, all the way to a futuristic megapolis. The player can use time travel to find people to talk to. For example, in the past, a bridge to cross the river was broken, but in the future, the player could use it to explore new areas of the city. The problem with this game idea is however that it is difficult to link to speaking situations other than people talking.

One option would be to make it more sci-fi themed, by for example having the goal to find the 13 time-gods that are scattered through time and the city. Then the player has to use the time travel mechanic to find a time-God. When the player finds one of these gods, the god will speak a sentence. The player has to repeat this sentence as if it is part of a time-cult. This would make the game engaging and allow for many sentences in this context, but it might be a too far-fetched or complicated game idea for this project.

This game will be a puzzle and adventure game, which could additionally include casual platforming. The realistic noise in this game would be a sci-fi time travel sound that the player will hear when the god is speaking. In this way, the frequency can easily be matched with that of the sentence. Additionally, it will fit in the game context, as time-gods can make sci-fi time travel sounds when speaking.

4.4.4 Planets and space game

In this game idea, the player will be able to control a spaceship and fly through space. This will be a futuristic game where humans have civilised multiple planets. However, due to some tragic circumstances, these civilisations are wiped out. The player will use their spaceship to explore the remains of these civilisations and explore their secrets. On the planets, the player will follow a tracking beacon to collect a hologram display. When flying into outer space again, the player can “play” the hologram. The hologram will consist of some character speaking one sentence. The player must listen and then repeat the sentence to their command centre through the intercom, before flying to the next planet. In this way, the player conducts a hearing test in an engaging and ecologically valid way. A great thing about using the sentences provided by the clients as ancient human stories is that every sentence can make sense, as every story could potentially have been told on a human-civilised planet.

The game will be an adventure game where the player has the freedom to get to the planets and explore on their own. The realistic noise could be the spaceship engine, which can easily be matched to the sentence's frequency without losing meaning. While listening to holograms in a spaceship sounds surreal, it is essentially the same as listening to someone on a train or plane in the real world.

The sci-fi elements of the game ideas are there to create an engaging experience for the user which will make them forget they are conducting a hearing test, making it more ecologically valid.

4.4.5 Mountain climbing game

The final highest-rated game idea is about climbing a mountain. In this game, the player will follow a trail leading to the top of the mountain. It will be a very relaxed-vibe game. While following the trail, the player will meet 13 other travellers on their way to the mountain peak. When the player approaches a traveller, they will say just one sentence about their life in a very dreamy way. The player will repeat this sentence and write it down in their notebook as if the player is capturing the stories of this dreamy mountain. The sentence will echo in the valley of the mountain. The travellers can say many kinds of sentences, as the mountain will feel like a place to seek refuge from the confronting busy life. So, for example, a traveller who is standing at a cliff overlooking the view and says: "the birds are chirping in the trees", will make sense in the context of the game.

The game will have a small adventurous game style as the player explores the trail from start to finish. The realistic sound while listening could be the wind playing with the trees, making the leaves rustle. This noise can be modified to match a frequency based on the sentences, while still sounding like wind.

4.4.6 Summary of elaboration brainstorm

The summary of the elaboration brainstorm for the top five ideas can be found in Figure 11. All five ideas now have one clear listening situation and realistic noise. The next step is to evaluate and select three ideas to further elaborate by adding the final sticky notes and providing illustration ideas.

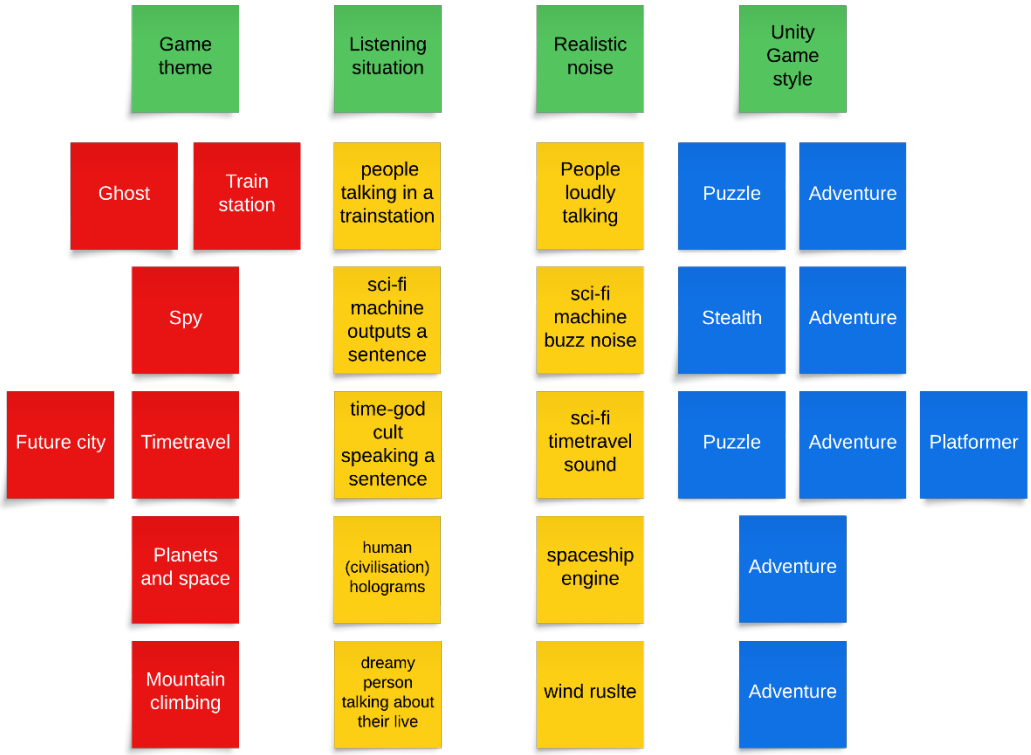


Figure 11: Outcome of the elaboration brainstorm for the top five ideas

4.5 Selection of top three ideas

To select the top three ideas, the most important questions were answered for each idea. The outcome can be seen in Table 1. After careful evaluation of this table, the following ideas were decided to elaborate further:

- Spy Game
- Planets and Space Game
- Mountain Climbing Game

Idea	Meet requirements?	How many sentences fit?	Realistic noise?	Casual?	Interesting?
Ghost Train Station Game	Yes	Many	Yes	Yes	Maybe
Spy Game	Yes	All	Maybe	Maybe	Yes
Future City Time Travel Game	Yes	Many	No	No	Yes
Planets and Space Game	Yes	All	Yes	Maybe	Yes
Mountain Climbing Game	Yes	Many	Yes	Yes	Maybe

Table 1: Evaluation of the elaborated top five ideas

4.6 Top 3 ideas

The final three ideas will be supported with more sticky notes from the initial brainstorm, as well as illustrations of how the game could look. The final elaborated brainstorming results of the top three ideas can be seen in Figure 12. While this brainstorm includes all pre-defined categories from Chapter 4.3, all categories are still open to change during the specification process.

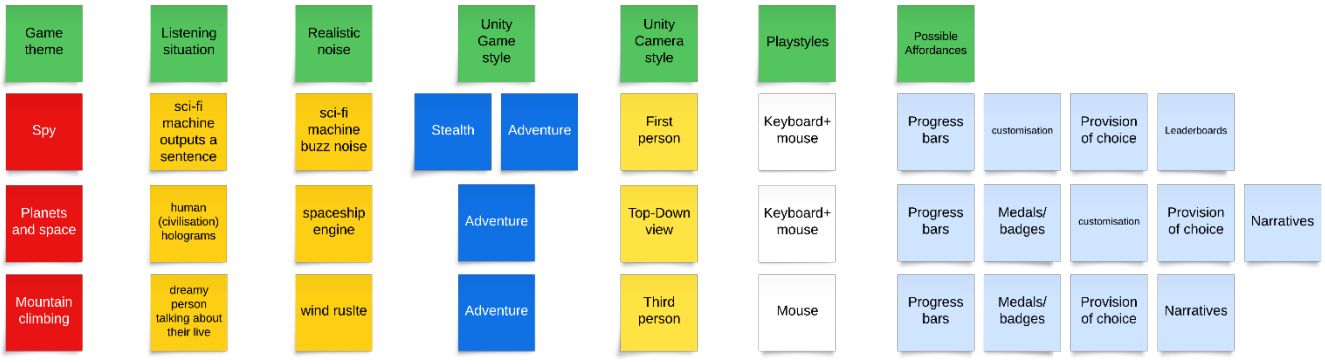


Figure 12: Final elaborated combination brainstorm of the top three ideas

4.6.1 Spy game

The Spy Game will be a first-person stealth/adventure game. The player will be spying on enemies in a big mansion on an island. The art style will likely be low poly to keep the game more casual, while

also preventing unnecessary time-consuming modelling. The suggested art style can be seen in Figure 13. Please note that this image is AI-generated by Adobe Photoshop with the prompt: “beach island with big mansion stealth spy game at night low poly”.

Figure 13: AI art of the possible art style for the Spy Game. This image was created with Adobe Photoshop Generative AI with the prompt: "beach island with big mansion stealth spy game at night low poly"

The player has to perform a series of actions to complete the game. First, the player must sneakily find valuable information by exploring the mansion or carefully listening to enemies talking. Second, the player must aim their sci-fi scanner-like tool at the information. Then the scanner-like tool will convert this information into a codewords sentence, and the scanner will speak this sentence out loud so the player can hear it. While the scanner is speaking the noise of the device will be heard. Then finally, the player simply has to repeat the sentence into a walkie-talkie to report the information to the Spy headquarters. This process had to be done 13 times, for all 13 sentences. The player will beat the game if they send all 13 sentences to HQ and escape the island. The sequence can also be found in Figure 14.

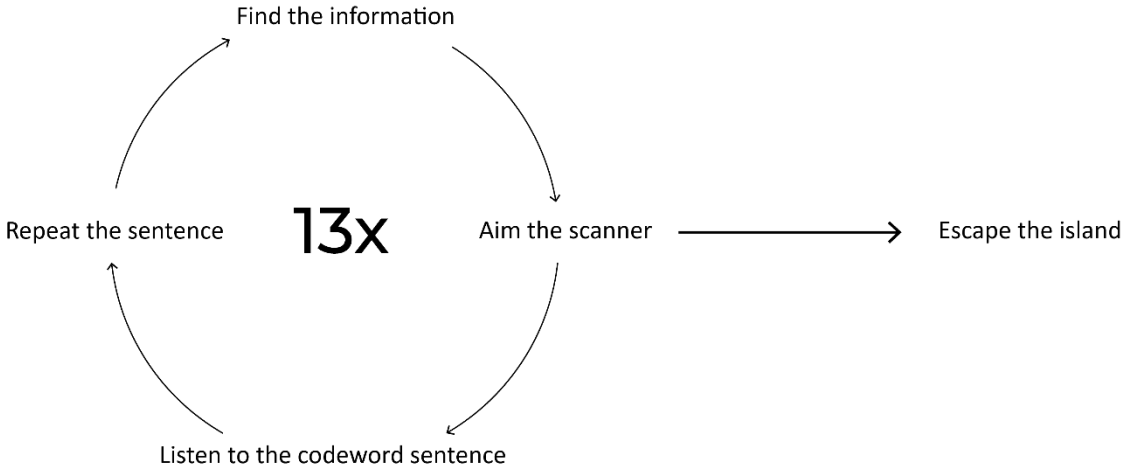


Figure 14: Sequence of the Spy Game

The game will include several video game affordances to increase engagement and ecological validity. First, there will be a progress bar at the top of the screen indicating the player their progress in sending the 13 sentences. Second, there will be customisation options like changing the colour of the scanner tool. While these customization options will have a small impact on the actual gameplay, they allow the user to express themselves more freely which, according to the literature, can help make the game more engaging. Third, the player will be able to make their own choices. The sentences can be found in any order and there will be a checkpoint every time a sentence is discovered and sent to HQ. In this way, the player can beat the game following their own choices of where to go next. Finally, the game could include a leaderboard based on how quickly a player can complete the game. This will make the game more engaging.

The game will be played in first person by using the keyboard and mouse. To ensure the game will not be too complicated only the basic movements in a first-person game will be used. The keyboard will be used for walking and jumping, the mouse will be used to look around and use the scanner.

An illustration of the possible gameplay can be seen in Figure 15. This figure shows in a first-person view how the player can 'scan' the information. The progress bar can also be seen at the top of the screen, which in this case indicates that the player has already scanned quite some information. In this example gameplay the information is in the form of two enemies talking, but it could also have the form of a confidential report or a laptop with information. There is a minimap in the bottom left corner that will help the player find the information and navigate their way in the mansion.

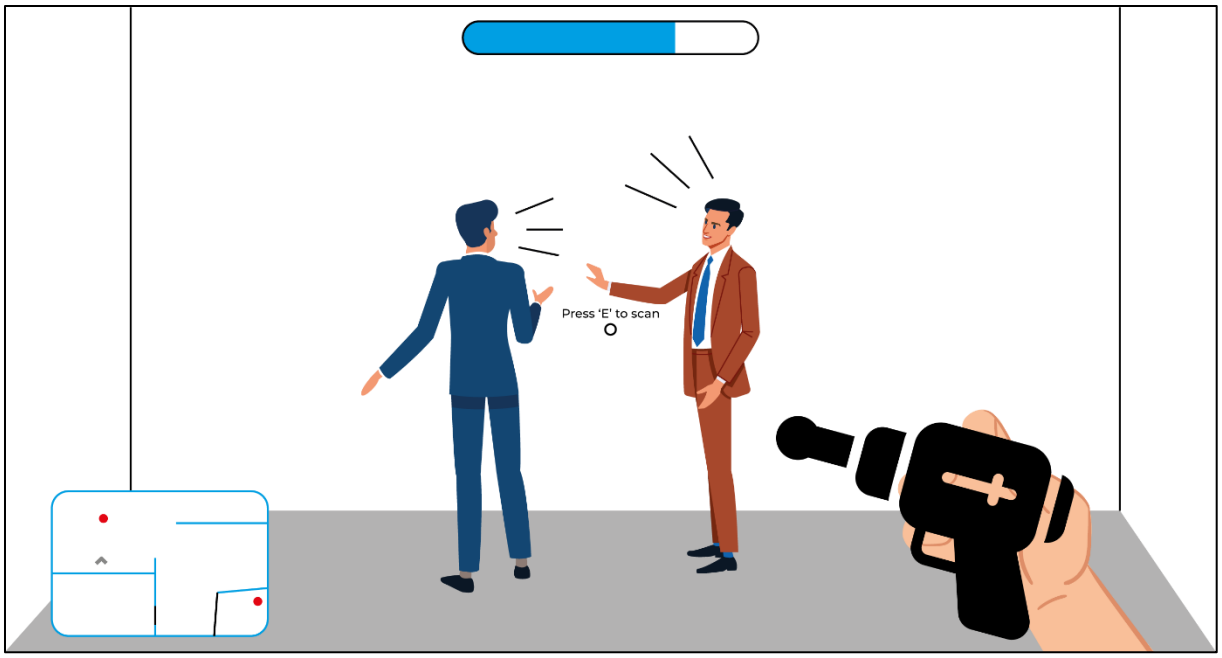


Figure 15: Basic illustration of the possible gameplay for the Spy Game, including the progress bar and minimap

Figure 16 shows the next step in the sequence. Here the scanner item has converted the information into a code sentence, which is one of the clinical hearing test sentences provided by the Amsterdam UMC. The scanner will make noise and tell the sentence, the player must listen and then repeat the sentence out loud as if they are talking in the walkie-talkie. The player has then conducted an SRT test without knowing, and the progress bar will fill up more.

Figure 16: Basic illustration of the possible gameplay for the Spy Game, indicating the listening situation in the game

4.6.2 Planets and space game

In this adventure game, the player will travel to multiple planets to find holograms about ancient human civilisations. The game will have a top-down view camera so the game will be easier to control, making it more casual. However, during the listening situation, the camera will switch to a first-person view, to make the listening situation clearer. The game will have a simple 2D art style, where every planet has a different colour. During the first-person view part, the game will still look simple to save time modelling and ensure a casual game style. The suggested art style can be found in Figure 17, which is an AI-generated image from Adobe Photoshop.

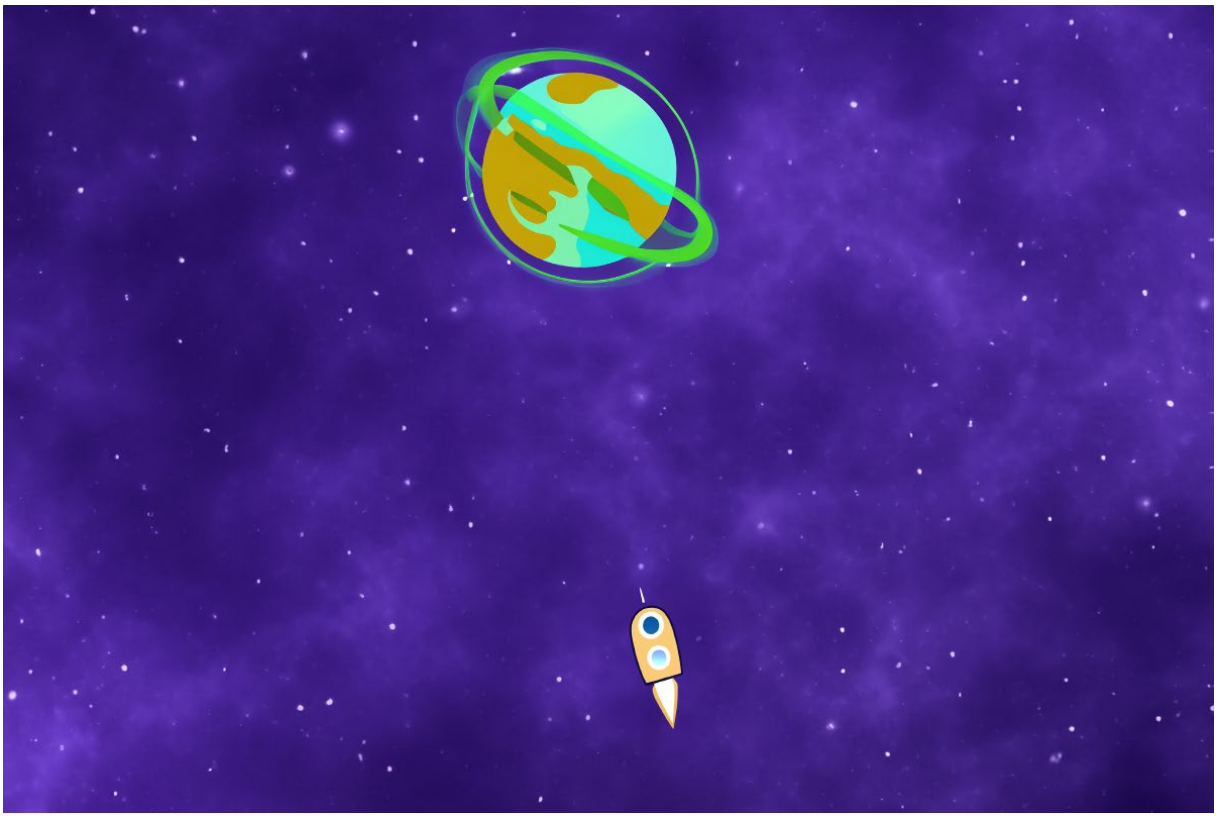


Figure 17: Possible art style for the Planets and Space Game

The player must complete several actions to complete the game. This sequence is shown in Figure 18. First, the player has to use their spaceship to fly to a planet. When the player approaches this planet, they will get out of their spaceship and explore the environment. The player must follow their tracking beacon to the hologram. When the player collects the hologram, it can be played in their spaceship. Similar to the Spy Game, the player first has to listen to the sentence with noise and then loudly repeat the sentence to send it to the main space station. In this way, the player conducts an ecologically valid hearing test without notice. Finally, when all holograms are collected and repeated the player can fly to the space station to complete the game.

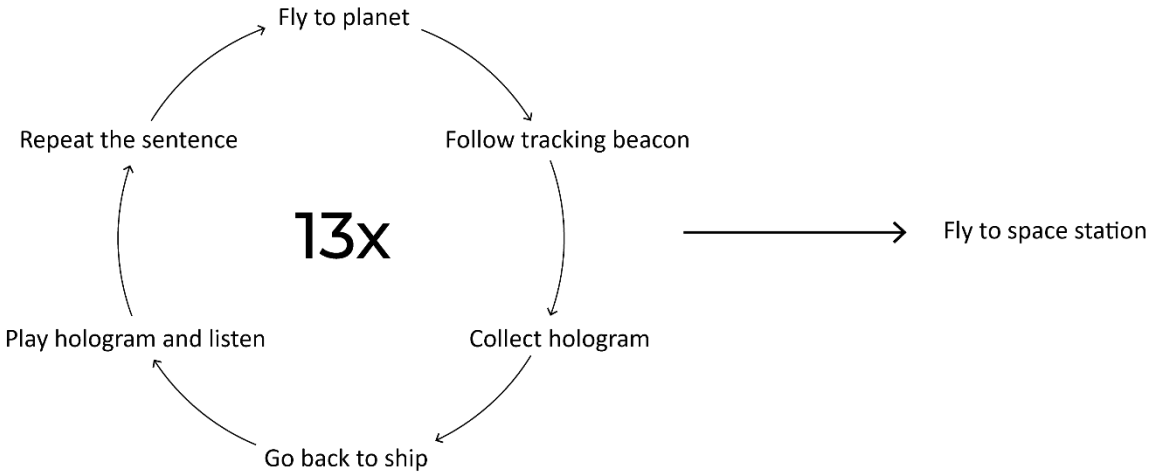


Figure 18: Sequence of the Space and Planet Game

To make the game more engaging several videogame affordances found in the literature will be added. First, there will be a progress bar similar to the Spy Game that shows the progress of the holograms collected and sent to the space station. Second, the player can earn badges every time they complete a planet. These badges will used to decorate the spaceship. These badges are hidden on the planets and are not required to finish the game. Their existence does however increase engagement and allow for more depth in the game. Third, there will be customization options for the player before they start the game. They can, for example, choose the spaceship and character they want to play with. This allows for more self-expression during the game, which will increase engagement. Fourth, the player can make their own choices when playing the game. They can choose what planet to go to next and what route they will take to collect the hologram. Finally, there could be a narrative about the ancient human civilisation on the planets to make the game more interesting.

The game will be played using a keyboard and mouse. The controls will be kept simple to ensure the game is easy to play. The keyboard will be used for moving, and the mouse will be used for interacting.

Figure 17 could be a good representation of the possible gameplay while controlling the ship in outer space. The only thing missing from this picture is the progress bar and some sort of navigation, like a minimap. Figure 19 shows the possible gameplay when the player is exploring a planet trying to find the hologram. The tracking device indicates which direction the player should go to find the hologram. Additionally, a round minimap in the bottom left corner will indicate the location of the hologram and the spaceship.

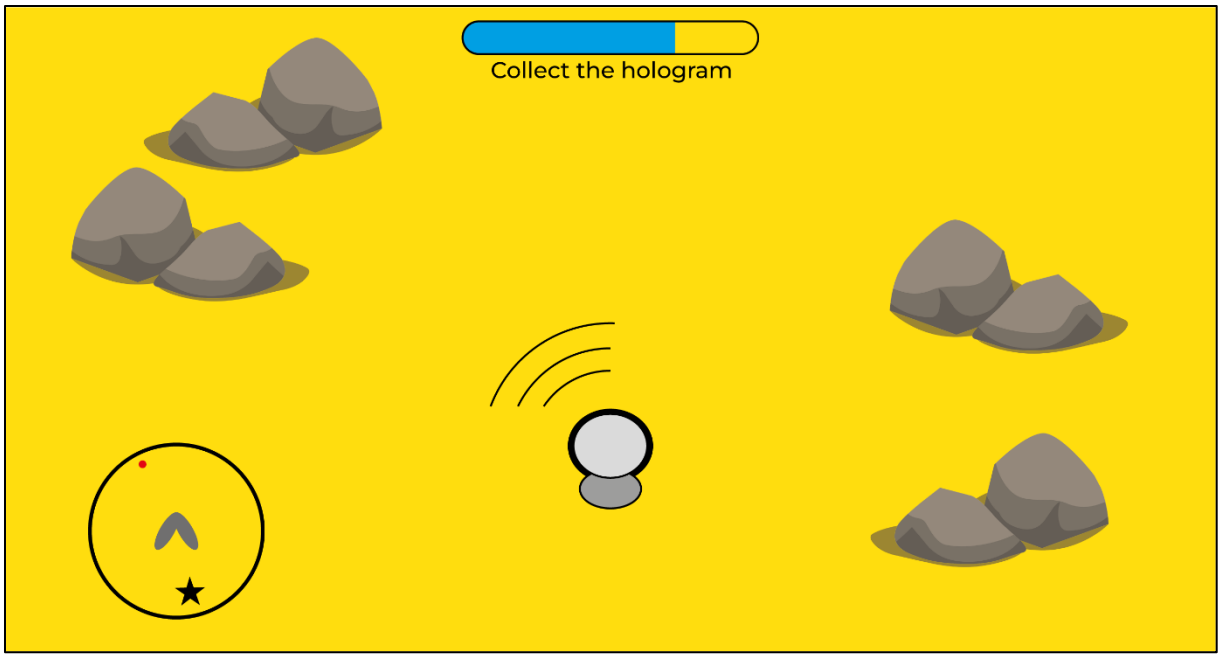


Figure 19: Basic illustration of the gameplay of the Space and Planets Game

Figure 20 shows a possible gameplay shot of the listening situation in the game. The collected hologram will be played in the cockpit of the spaceship. Like the Spy Game, the player will repeat the sentence into a walkie-talkie. The spaceship will make a realistic noise, similar to a plane or car in real life. Then the ancient sentence will be reported to the big space stations, which is in this case called “Orion”. In this way, the player engagingly conducts the hearing test.

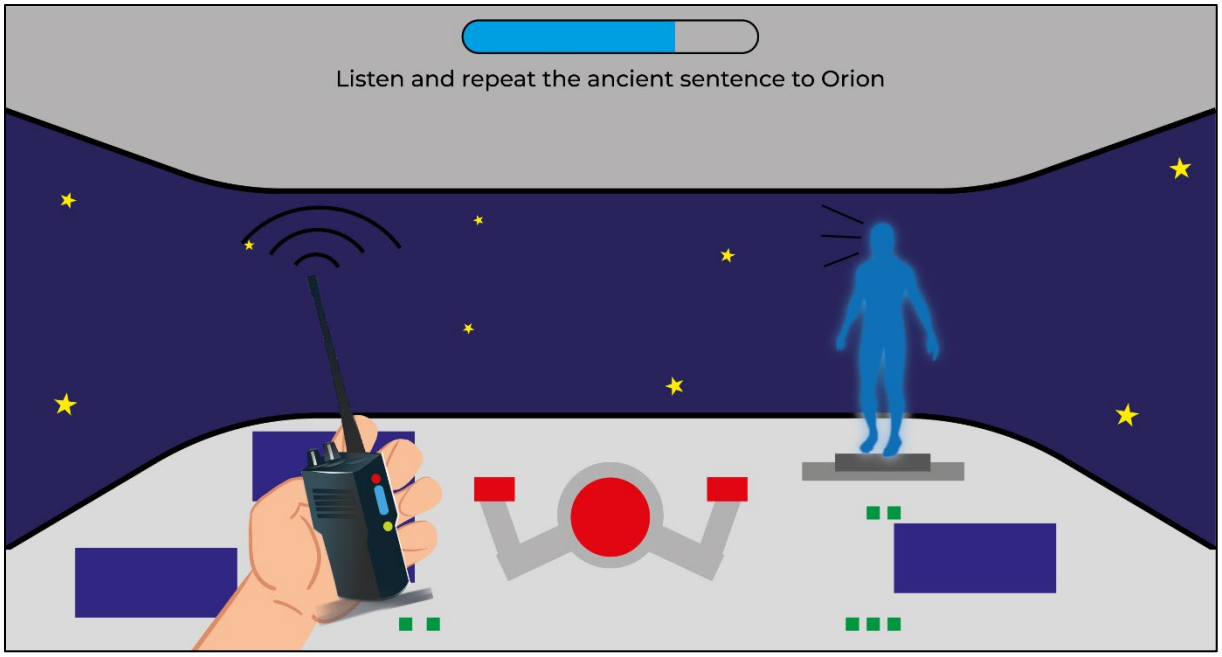


Figure 20: Example gameplay of the listening situation from a hologram in the Space and Planets Game

4.6.3 Mountain game

This game will be very dreamy and relaxed. The story will be about a traveller climbing a mountain all the way to the peak of the mountain. On their way to this summit, the player will encounter 13 other travellers. They will speak a dreamy sentence while looking in the distance from the mountain. Oppositely to the previous game ideas, this game will be very casual and can be played by only using a mouse. The game will be played from a 3rd person perspective. Similar to the Spy Game, the art style will be low poly to keep the game casual and prevent the making of unnecessary time-consuming high-quality 3D models. The art style can be seen in Figure 21, which is made using Adobe Photoshop Generative AI.

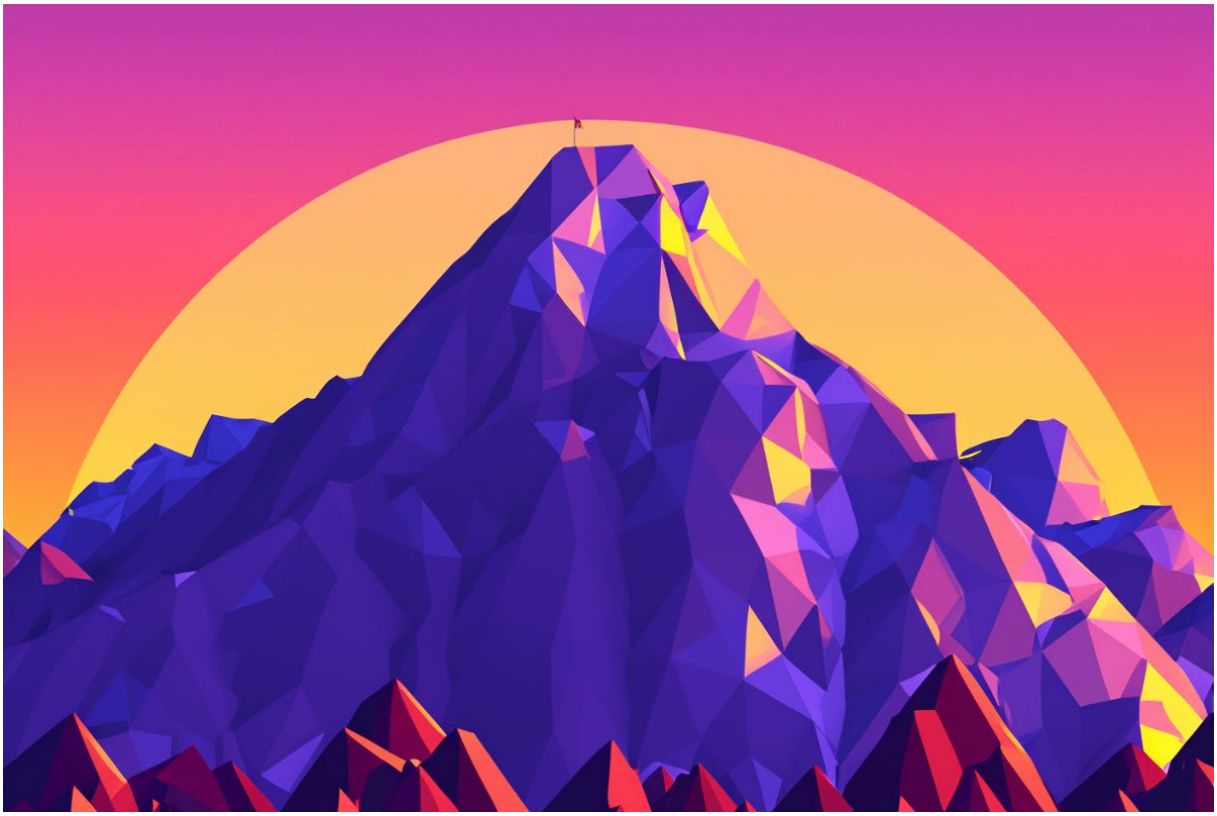


Figure 21: Possible art style of the Mountain Game, generated by Adobe Photoshop generative fill

The player has to perform a sequence of actions to reach the top of the mountain and finish the game. The sequence of the Mountain Game can be found in Figure 22. First, the player must simply follow the trail. This trail will lead to a traveller looking into the distance. When the player approaches this traveller, they will tell a story in text and finish with a dreamy sentence. This sentence is the sentence provided by the clients. While talking, the wind will provide a realistic noise. The player must repeat the sentence of the traveller. Additionally, the player will write something in their notebook in the game, this will have no meaning, but it adds more depth to the story. After talking the player will continue their way by following the trail again.

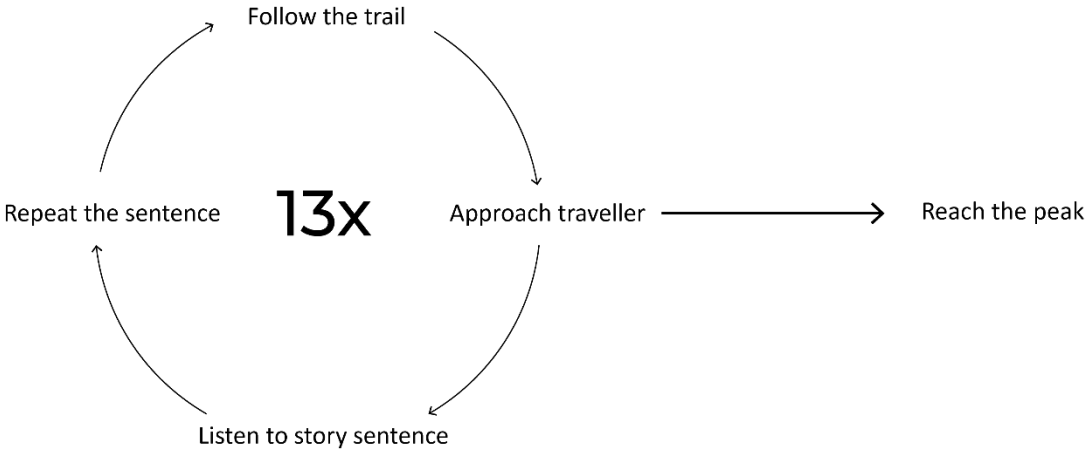


Figure 22: Sequence of the Mountain Game

Like the previous two game ideas, this game will include a progress bar. The progress bar will indicate how much height the player has climbed already. This starts at 0 and will increase by 100m every time they meet a traveller. Another affordance that will be added to the game is the collection of medals. The medals will be in the form of a stamp in the notebook of the player. Every time they talk with a traveller, they will get a stamp in the notebook. The collection of these stamps will make the game more engaging. Additionally, the player will get to often choose what direction they will take when the trail splits, which increases engagement. These choices can be completely fake leading to the same next scene in the game but for the player, this is impossible to know. The final affordance can be a narrative while the player is climbing up this dreamy mountain.

Figure 23 shows a possible gameplay illustration of the listening situation. The wind that rustles the trees will be a realistic noise.

Figure 23: Illustration of possible gameplay from the Mountain Game

4.7 Final choice

After careful evaluation with the clients and supervisors, I chose the Mountain Game as the final game idea. All three ideas were received very positively by the clients and supervisors. The main reason I chose the Mountain Game is because this game idea is the easiest to play for the highest amount of people while still allowing for engaging and ecologically valid content.

Chapter 5 – Specification

In this chapter, the final idea will be further developed. This will be done through an expert interview with the clients, preliminary user testing of a gameplay prototype storyboard, and the use of two personas to describe the interaction between the patient, the doctor, and the game. Finally, the chapter will close with the functional and non-function requirements that are important for the realisation phase.

5.1 Final game idea

After interviews with the client and testing multiple game idea sketches and prototypes, the final Mountain Game idea slightly changed. The player will follow the trail to reach the peak of the mountain. On their way, the player will encounter 13 travellers who are also seemingly making their way to the top. These travellers will either all be males, or all be females, due to the clinical sentences being spoken by only a male-voice or a female-voice. The game will have a very dreamy art style and atmosphere. The mountain will feel like some sort of mystical place the more the player climbs towards the summit. Elements that help convey this message are for example the calm and relaxing music, the low-poly 3D models, and the dreamy lighting and colours on the mountain. Additionally, the further the player walks on the trail the darker the sky will get. Eventually, this will lead to a sunset which emphasises the dreamy art style that the game intends to achieve.

Some changes have been made to the listening situation. The notebook idea has been scrapped after a discussion with the clients and after sketching game prototypes. It felt unrealistic to repeat a sentence the player had just written down. Additionally, a notebook might confuse the player's thoughts about the meaning of the sentences, and why they keep writing them down. Finally, this idea will not leave the player with an end to the story when they reach the top of the mountain. Instead, the story of the mountain has been altered.

The travellers approached by the player will start talking in a way visual novels do, meaning there will be a text area underneath the traveller in the game view. An example of this can be seen in Figure 24. In this way, the traveller can tell a dreamy story first, before saying the actual clinical hearing test sentence. The 13 travellers will all be the same person and will either be an older-looking man or woman, based on which sentence set is chosen. This is because older-looking people are less expected to be hiking on a mountain, which conveys the mysterious and dreamy message the game is trying to convey. Additionally, older-looking people are more likely to tell engaging life stories as they have more experience. However, as the actual hearing test sentence is spoken by a middle-aged man or woman, there might be some confusion for the player during the listening situation. This could decrease the immersion of the game and should therefore be tested by potential users.

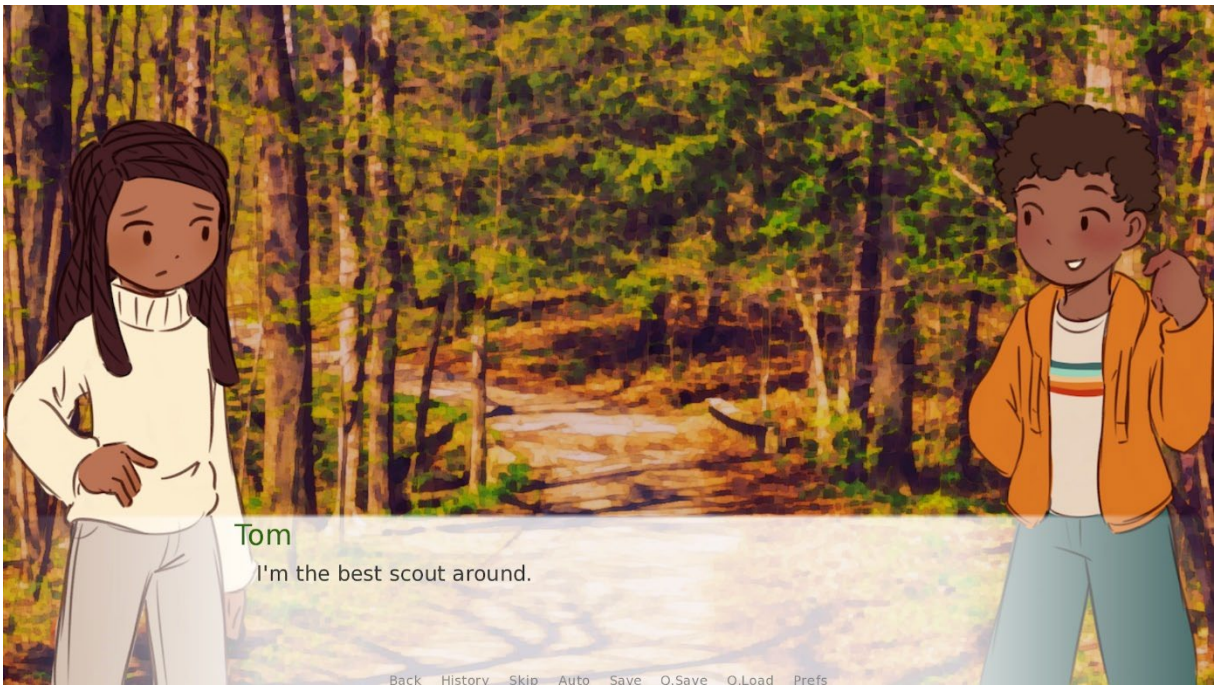


Figure 24: Example of a visual novel, where the text box is at the bottom of the screen [30].

Finally, to give the story more depth, there will be a grave at the peak of the mountain. This grave is where the player's grandma or grandpa lies. This grandma or grandpa is the thirteen travellers the player encounters on the trail. The grave will make the mountain more dreamy and more mysterious. It also explains why all travellers have the same voice and why the player is climbing the mountain.

5.2 Clinical sentences

The clinical hearing test includes clinical sentences that have to be repeated by the user to measure their hearing. These sentences are constructed and tested for a specific purpose and cannot be changed for this project, as discussed in Chapter 4.2 Requirements. In total, there are more than 1000 sentences provided by the client. Half of the sentences are spoken by a male voice, and the other half are spoken by a female voice. The sentences are grouped in blocks of 13 sentences. These blocks cannot be broken up as they are formulated using the clinal hearing test sentence structure, i.e., a certain number of vowels and sounds. Additionally, the sentences are spoken in Dutch as the clients use the sentences to measure the hearing of Dutch-speaking patients in the Amsterdam UMC.

For this project, one block of 13 sentences has been chosen to be used in the game. This is a block from the female-speaking voice. The content of the sentences is important for the immersion of the game. This is why the set of sentences is chosen first, and the environment around it afterwards. However, the virtual environment of the game cannot help the player guess the content of the sentence. For example, if the video game shows multiple insects and bugs on screen, and the traveller says one of the 13 sentences: “There are plenty of bugs”, it will be easier for the player to repeat the sentence. Something that is possible, is showing many bugs on screen after the player repeats the sentence, this will still increase the immersion, without falsifying the hearing test outcomes.

The chosen block of sentences goes as follows (translated into English).

The old man walks with a stick

We will call each other
They were unable to wake up
I know this from my own experience
Emotions are part of life
The gardens look beautiful
The dust takes your breath away
I already told this ten times
His students continue his work
She still lives in this street
He grabs his paper
She goes to school one day a week
The question is if this story is true

The set of sentences was chosen based on the content and the correlation of the separate sentences. This block of sentences is spoken by a female voice, meaning that the traveller on the mountain will be a grandma. To achieve a higher level of immersion this grandma 3D model must fit the sound of the female voice used by the UMC.

5.3 Paper prototype

To test the feeling of the game, multiple paper prototypes were created and evaluated. The prototypes consist of simple storyboard drawings of the possible gameplay of the video game, which can be seen in Figure 25. Drawing and thinking about the possible gameplay helped structure the sequence of actions the players needed to perform to complete the game. The paper prototype used for preliminary user testing can be found in more detail in Appendix B.

Figure 25: Simple paper prototypes of storyboards of the video game.

5.3.1 Preliminary user test

The prototype was tested by 7 different users with a mean age of 33. This user testing resulted in new insights that should be considered during the realisation phase. In general, the users found the idea of the game clear and engaging. They liked the idea that the player had to follow a trail to reach the top of the mountain, as it seemed easy to control while still allowing for engaging content. The testers liked the drawing of the surroundings and the idea of a setting sun during the game. However, for most users, the idea of the walkie-talkie was a bit unclear. They understood that this was how the hearing test would be conducted but the player's reason to repeat the sentence was unclear. Furthermore, some user testers didn't understand why the player was climbing the mountain in the first place. Finally, the grave on top of the mountain was seen as a little bit shocking but memorable ending. The testers were wondering who was buried there and what relation this person had to the player.

5.3.2 Preliminary user test conclusion

After testing, new important elements came to the surface that should be kept in mind during the realisation phase. A few things will change based on the prototype testing.

- A clean start scene will be added where the story and the reason for the sound recorder device will be explained.

- The player will no longer walk with the sound recording device, now it will only show up during the “Repeat the sentence” scene. This will make the game easier to understand.
- More game-like elements will be added, to make the game more engaging. This could be an element like blocked paths that only open after talking to the other traveller or more realistic sound cues.

5.4 Personas user scenario

To illustrate and give insight into how the hearing test game will be used in practice, two personas are made. First, there is a persona of an Amsterdam UMC hearing loss patient. This is Jens, a 52-year-old high school teacher who has difficulties with listening to his students due to his hearing loss. Second, there is a persona of the Amsterdam UMC doctor who assists the patient and conducts the hearing test game. This is Karlijn, a 41-year-old doctor at the UMC who gives patients like Jens hearing advice based on their hearing test scores. Both personas can be found in Appendix C.

5.4.1 User scenario

Jens has hearing loss problems and he visits the Amsterdam UMC. The Doctors at the UMC, like Karlijn, conduct hearing tests to measure Jens’ person-specific signal-to-noise ratio. Jens takes the train from Rotterdam to Amsterdam to visit the Amsterdam UMC. After some waiting in the lobby, he gets guided to the hearing test room by Karlijn. He notices something different compared to the other times he took a hearing test in this room. He sees a new setup with a screen and a mouse on the desk that is usually empty. The screen displays some happy colours, but Jens cannot clearly see yet what it is about. Karlijn asks Jens to sit down on the chair. She explains that the Amsterdam UMC is testing new ways to conduct hearing tests. This new version will be conducted by playing an engaging videogame. Jens is excited to see something new during the hearing test. He is wondering how this video game will test his hearing. Karlijn explains that this video game hearing test will simulate the real world better than the current laboratory-specific one. This will allow her to give better advice to Jens. He is glad to hear this, as his current hearing device still makes it sometimes difficult to hear his students ask questions in the classroom, and he wants to fix this problem. Karlijn asks Jens to put on the provided headphones and to follow the instructions in the game. She sits down on a desk in the same room as Jens and focuses on a screen herself too. She also has a keyboard in front of her and a printed paper with the sentences used in the clinical hearing test game.

Jens puts on the headphones and reads the text on the screen. It is a tutorial for the game. Jens is excited and already focused on this new experience. The game is simple to control, Jens is happy that he only needs to use the mouse and quickly figures out how to move the character on screen after following the tutorial. Jens is engaged in the game and is looking at the scenery of the mountain and the dreamy art style when he sees another avatar in the distance. This character seems to be an older woman happily waving at the player. Jens is surprised and walks towards this other traveller. When the player is close to the woman a dialog box appears on the screen. Jens reads the text and is interested in what the character is saying. Jens gets a mysterious feeling from the stories the older woman is telling. After reading all the text the scene changes in the game. Jens sees that there is more wind on the mountain suddenly and also hears this through his headphones. The sound he is currently hearing feels immersive and realistic for the visual scenarios he sees in the game. Jens reads the text that appears on the top of the screen in the game. It tells him to listen to the sentence. Jens is a bit confused about what sentence the game is talking about, but he starts to focus on listening. The older woman in the game performs a talking animation and speaks one of the thirteen sentences used in the clinical hearing tests. Jens listens closely and hears the sentence quite clearly. A new text appeared on

the top of the screen. It tells Jens to repeat the sentence out loud. Additionally, Jens sees a device appear on the screen that resembles some sort of voice recorder. It becomes clear to Jens that he has to repeat the question that he has just heard, so he repeats it loud and clear.

Karlijn is listening carefully to Jens. She looks at her printed paper of sentences and hears that Jens has correctly repeated the sentence. She presses a certain key on her keyboard which will increase the volume of the wind sounds in the game the next time Jens has to listen to a sentence again. Jens does not notice that Karlijn's actions influence his gameplay, as nothing seems to have changed yet. He now understands how this game will act as a hearing test, but he never was focused on this fact during the listening due to the engaging gameplay and the realistic sounds. He is a bit confused by the sentence that he has just heard but given the dreamy and mysterious feeling he got from the older traveller, he is not completely surprised. He is curious about where the trail on the mountain leads, so he continues playing. He notices that when he proceeds to climb the mountain a progress bar keeps increasing to fill, this makes Jens feel more engaged and motivated to reach the top of the mountain. Jens finds the older woman again next to the trail and a similar experience happens. However, this time the story of the woman feels a bit more as if this traveller knows the player already. This makes Jens more curious about this woman and her stories.

The scene changes again and the game tells Jens again to listen to the sentence. This time the volume of the wind feels a bit louder than before, but Jens does not directly notice this. This did, however, make him incorrectly repeat the sentence. Karlijn paid close attention and pressed a different key on her keyboard this time. This will make the volume of the wind sound lower again next time. In this way, Jens performs a clinical hearing test while being fully immersed in the game. The realistic sounds and the engagement make the test simulate the test more than the current one.

Jens keeps playing the game. The changing sceneries and the change in time of day add to the immersion and engagement. Additionally, there are parts where Jens can choose his own way when the trail splits. This makes him more engaged as well. After playing the game for some time he found the same older woman at multiple locations on his way to the top of the mountain. Jens understands the sequence and smoothly performs the hearing test without directly being focused on this. He sees on the progress bar that he is almost at the top of the mountain and gets excited. Karlijn actively followed along and changed the volume of the wind noise accordingly.

Jens sees a grave on the peak of the snowy mountain. He is surprised to see this here and wonders who is buried here. He quickly realises that the person buried here is the older woman who has been following him all the way to the top. This explains the mysterious sentences and stories she told him. It also explains how this other traveller could show up everywhere and disappear so easily. Jens is surprised by the story and is happy to find the answers to the questions he got while playing. The game has an ending screen and Jens is satisfied and surprised by the experience he just had. He completely forgot he was in the Amsterdam UMC conducting a hearing test. Karlijn wrote down his results and now knows his person-specific signal-to-noise ratio. She is happy because this ratio simulates the real world better than the ratio she would have gotten from the original hearing test. She can give Jens more effective advice. Jens puts off his headphones and listens to Karlijn. He is happy because her advice will help him with hearing loss, making it possible to continue teaching.

5.4.2 Persona user scenario conclusion

The personas helped to get a better understanding of the possible interactions between the doctor of the Amsterdam UMC and the patient. Certain points became clear for development after the persona user scenario. The easy controls of the game are needed to ensure many people can play the game.

Additionally, the story in the game needs to be engaging and immersive to ensure a more ecologically valid hearing test. Finally, the doctor needs to have access to the actual sentences as well as a keyboard to control the volume of the noise.

5.5 Functional and non-functional requirements

Functional and non-functional requirements are an important part of the project. They define clearly what the project aims to achieve. Additionally, they will help during the realisation phase as a blueprint. They specify what features are needed to be implemented. Finally, they will be used in the evaluation stage to assess if the project was successful or not.

5.5.1 Functional requirements

- The game must function as a hearing test.
- The game must have thirteen traveller encounters, each triggering a dialogue followed by a clinical hearing test sentence.
- The game must have a sentence in combination with a realistic noise sound.
- The game must provide an introductory tutorial to explain the story and game controls.
- The game must have simple controls (mouse-based) to ensure accessibility for a wide range of users.
- The game must present an ending screen upon reaching the mountain peak.
- The game must provide realistic sound effects that correlate with the visual cues.
- The game must be more immersive than the original hearing test.
- The game must be more engaging than the original hearing test.
- The game must allow the doctor to control the volume of background noise during the hearing test.
- The doctor must be able to monitor the patient's responses and adjust the game settings accordingly.
- The game must feature a consistent storyline involving the player's encounters with the thirteen travellers.

5.5.1 Non-functional requirements

- The game must run smoothly on the hardware available at Amsterdam UMC.
- The game must have minimal loading times to maintain immersion.
- The game must be easy to understand and navigate for users of all (adult) ages.
- The game must have a user-friendly interface with clear instructions and feedback.
- The game must consistently respond to the doctor's inputs for adjusting background noise volume levels.
- The game must be accessible to people with varying degrees of hearing loss.
- The game must be engaging and immersive to ensure ecological validity in the hearing test.
- The game must have an engaging storyline that motivates the player to complete the hearing test.
- The game must ensure the privacy of the patient's data and responses.
- The game must comply with relevant data protection regulations and hospital policies.

Chapter 6 – Realisation

This chapter will consist of two parts. First, the tools used to get to the outcome will be explained. Second, the final product will be showcased.

6.1 Tools used

In this subchapter, the tools that were used are listed and explained why they were chosen.

6.1.1 Unity

Unity is a popular game engine that was chosen for this project [31]. The video game was made using this engine as it is easy to use and freely accessible. Additionally, I had prior knowledge of this game engine and knew that my desired design of the hearing test video game was feasible within this environment. Since Unity is one of the most popular game engines, it has many available online support, which was useful for my project. Also, the Unity Asset Store allowed me to download assets from the internet and easily implement them into the hearing test video game. The skybox was downloaded from this online marketplace.

Unity has multiple different functions which allows for a diverse design experience of video games. One function that I used in particular for this video game is the Unity Timeline function. This function allows for the creation of cutscenes, which are small movie-like scenes where the player has no control over their character during the duration of the cutscene. Instead, all control will be given to the Timeline Manager, which is a GameObject that I created in the video game. The advantage of this is that I can specify the order of events during the listening sequence. This will make sure that the hearing part of the game is always the same throughout the game, which is required for a clinical hearing test.

A screenshot of a Timeline Manager can be seen in Figure 26. The function resembles the layout of popular video editor programmes such as Adobe Premiere Pro. The core of the hearing test part of the Timeline Manager is the orange audio blocks. A clinical hearing test consists of both noise and sentence, these can be found in the timeline. The “WindNoise” block is the noise from the hearing test, while the “Vrouw430” block is one of the thirteen sentences. In this way, the noise and sentence structure of the hearing test will be the same for every listening situation, just like in a real hearing test. The other blocks in the timeline manager ensure a smooth animation that will grab the attention of the player. A screenshot of this animation can be found in Picture 28. At this point in the timeline, the actual sentence will be told by the person on the screen.

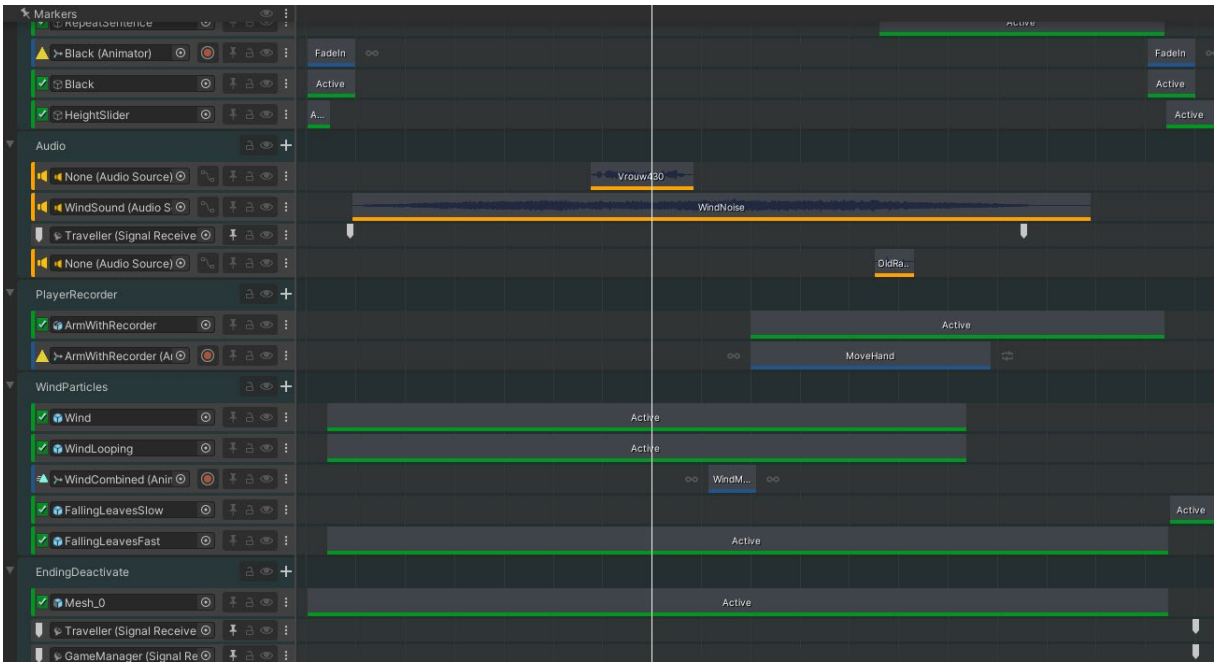


Figure 26: Unity Timeline function used to create the listening situation in the game

Figure 27: The output of the timeline manager where the person on the screen tells the listening sentence, along with realistic noise.

6.1.2 Meshy and Blender

Meshy is an upcoming website where you can generate artificial intelligence 3D models based on a prompt [32]. This website is useful for this project as the low poly art style is easy to generate for Meshy. The generative AI of the website is not perfect, so multiple models are adjusted in the 3D

modelling software Blender as well. These adjustments are very small and range from recolouring to filling gaps with missing vertices. An example is the player model, which is generated by Meshy and can be found in Figure 28. The prompt for this model was: “Traveler player model young man with backpack T-pose”. This model was later adjusted in Blender by recolouring and adding more vertices for the animation.

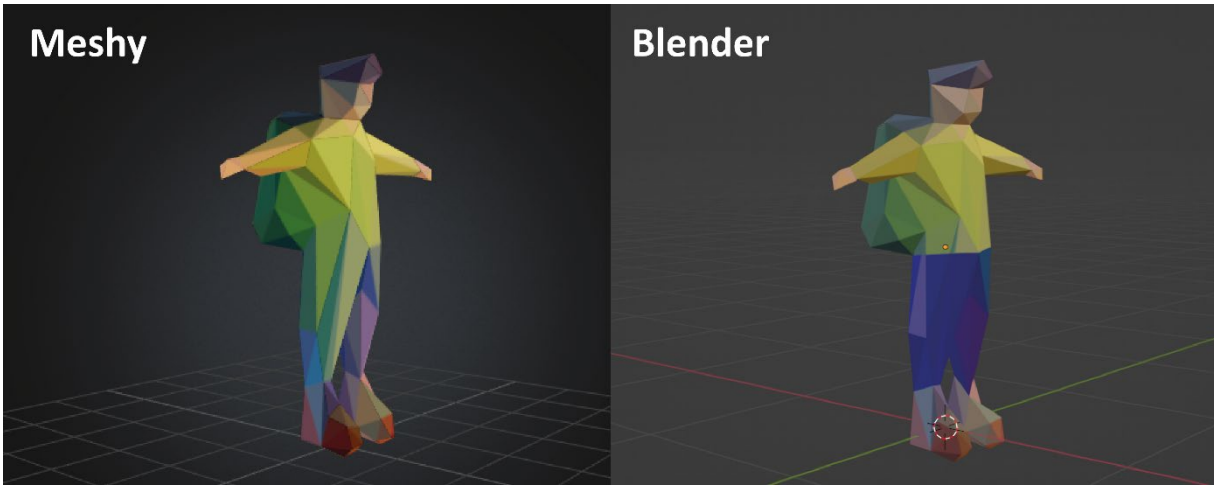


Figure 28: The player model, which is generated by AI (left) and adjusted in Blender (right).

Using Meshy saved lots of time while still allowing me to capture the imagined dreamy art style. Apart from the player model, Meshy was also used to generate multiple environment models. Examples of these can be seen in Figure 29. It is an excellent tool for this kind of model, as they are simple, quick, and efficient, while still allowing for visually appealing creative input.

Figure 29: Screenshots of multiple environmental 3D models used in the game, generated by Meshy.

6.1.3 Mixamo

Mixamo is a website from Adobe that allows for automatic rigging and animating of characters [33]. This website was useful for this project as it saved time while still providing realistic and smooth animations for the player model, as well as for the other traveller model. From this website, several

animations were downloaded, after the automatic rigging procedure. These are the animations "walking" and "idle" for the player, and for the other traveller this also includes talking animations and waving. Screenshots of the animations from Mixamo can be seen in Figure 30.

Figure 30: Screenshots of the animations in the game, downloaded from Mixamo.

6.1.4 REAPER

REAPER is a digital audio production application that was used for this project to create the noise sound [34]. The tool was chosen since I had prior knowledge and knew that the sound modification needed for this project was possible within this environment. First, multiple wind sound effects were downloaded from popular websites such as Pixabay and freesounds.org. Second, two of these sounds were combined to create a realistic wind noise sound in the REAPER application. Finally, the technical staff of the Amsterdam UMC ensured that the realistic wind noise met the clinical hearing test noise standards by changing the frequency of the wind noise sound. This was one of the wishes of the clients. The result of this process was a 15-second clip that sounds like a realistic wind noise while also meeting the requirements of a clinical hearing test noise.

6.1.5 Adobe Photoshop and Illustrator

Adobe Photoshop is a photo editing tool that was used to create the ground textures of the game. In total, the game has five different ground textures: grass, rock, snow, and two types of trails. The first three follow the same blocky low poly art style. This texture was created using the generative fill of Photoshop and recoloured to fit the desired layer. The two trail colours are single colours without texturing. Additionally, Photoshop was used to generate the normal maps of the three ground textures. All five ground textures can be seen next to each other in Figure 31.

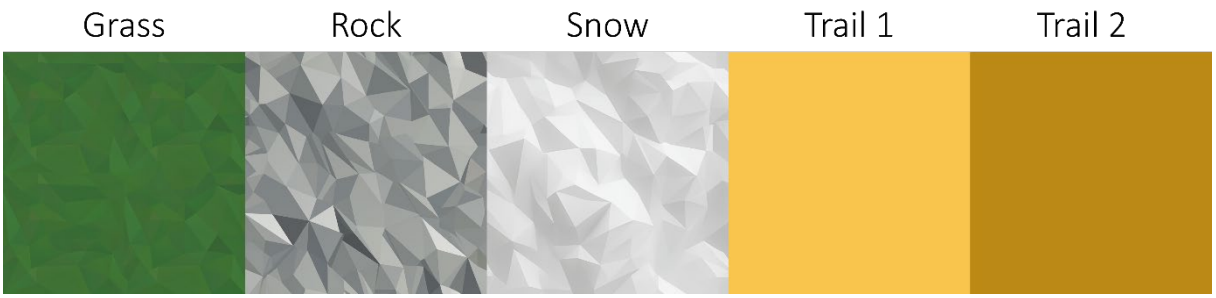


Figure 31: The five ground textures used in the game.

Furthermore, the Adobe Illustrator tool was used to draw all UI elements of the game. This consists of the dialogue box, progress bar, and tutorial screen. Both the Adobe Photoshop and Adobe Illustrator tools were chosen as I had prior knowledge of these tools and knew that they would be helpful in the creation of the game assets.

6.2 Final product

In this sub-chapter, the final product will be described. First, a general description will be given, after will follow a more in-depth showcase of specific parts.

6.2.1 General description

"Het Pad Naar Boven" (English: The Path to Beyond) is a Dutch adventure story video game. There is a clinical hearing test built into the game. In the game, you control a traveller who will walk up a mountain. On your way to the top of the mountain, you will encounter a certain other traveller. This traveller can somehow make the wind blow a lot faster than it normally would, while they are talking. This other traveller also teaches the player many engaging life stories and lessons. The further the player walks on the trail to the top of the mountain, the more personal the interactions with the other traveller become. The player will find out more about this other traveller's identity when they reach the top of the mountain.

The mountain follows a dreamy low poly art style. The change of scenery makes the walk a relaxing but engaging experience for the player. The player has to walk on bridges and cross different types of areas, like rocky canyons and snowy forests to make their way to the summit. In total, a full play-through of the game takes around 20 minutes.

The core of the game is the hearing test aspect. The hearing test happens when the player is interacting with the other traveller, who can often be found beside the trail. This traveller talks about their life stories and additionally plays a cutscene when they are done talking. During this cutscene, the wind mysteriously picks up and the traveller speaks one of the thirteen clinical hearing test sentences. The realistic wind noise acts as a hearing test noise throughout the listening situation. After listening to the sentence, the player is instructed to repeat the sentence out loud. This is symbolized by a red walkie-talkie that is showing on the screen, which indicates that the player needs to say something. This is to capture the magical feeling of the mountain and the inspiring life lessons of the other traveller.

While it seems this game is played by only one player, there is actually a 2nd person involved as well. This is the doctor of the Amsterdam UMC, who can control the volume of the realistic wind noise through the keyboard, similar to the original hearing test. So rather than playing the game, they have control of the conditions of the hearing test. In this way, the video game can clinically assess the player's hearing without putting the focus on the laboratory hearing test.

6.2.2 Art style

Since the game uses the easiest controls, a focus was necessary on the art style to keep the game engaging. The low poly art style is combined with the Unity Universal Render Pipeline and post-processing. Several, overrides are added to the global volume, such as tone mapping and bloom. Another part of the video game that helped enchant the art style where the particle effects in the game, with the wind and leaves particle effects in particular. These effects can be seen anywhere in the game while the player is walking. Up the mountain. Additionally, the game features different

environments to keep the game exciting and engaging, such as oak tree forests, pine tree forests, rocky mountains, water areas, and snowy forests. Also, the lighting changes to create new sights for the player, while additionally playing with the long shadows that appear when the sun sets. More screenshots of the game environments can be seen in Appendix D.

Finally, the audio helped create the mysterious but calm ambience of the game. The game features a relaxed song playing in the background while the player is walking. Additionally, after every encounter with the other traveller, a happy melody plays to reward the player. This sound effect later evolves into a full soundtrack that is played during the final cutscene to give the game a round ending.

6.2.3 Sequence of the game

The sequence of the game is given in Chapter 4.6.3. As a reminder, the figure that shows the five major steps the player has to follow to complete the game is repeated in Figure 32.

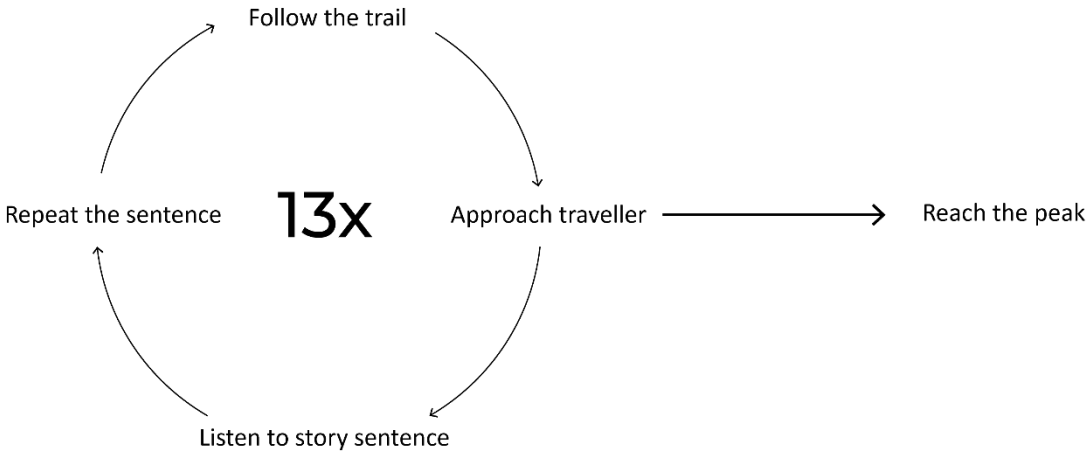


Figure 32: Sequence of the video game (repeated)

Now that the game is finished, the five major steps in the sequence can be explained in more detail.

6.2.4 Follow the trail

The first step the player has to take is to follow the trail. It is easily distinguishable by the bright yellow and brown colours. The player is dropped at the start of the trail, making it intuitively reasonable to follow the trail. The first thing the player will see on the screen is an introduction to the movement controls of their character. The game only has two simple instructions: walking with the right mouse button and talking with the left mouse button. These easy controls have been implemented to ensure the game is accessible to the highest amount of people. Additionally, arrow signs and wooden fences are placed next to the trail to guide the player in the right direction. A screenshot of gameplay where the player is following the trail can be found in Figure 33.

Figure 33: The player just started playing the game and is following the trail up the mountain.

6.2.5 Approach traveller

Besides the trail is will be another traveller, waving at the player, gesturing that the player should come closer. This other traveller is the other main character of the video game and will tell several life stories and lessons, while the two characters meet. When the player approaches the other traveller, they will start talking to the player in the form of text. The player controls the speed of the text themselves, making it easy to understand for every player. Throughout the journey, the player will grow a bond with the other traveller. In total, there are thirteen travellers next to the trail of the mountain. They are all highlighted by some sort of sign or camera movement to make sure the player will not miss the traveller and fail to complete the hearing test. After talking, the listening situation will start, as described in Chapter 6.1.1. Figure 34 showcases a screenshot of the gameplay where the player is close to the other traveller. They are talking about a life story to the player, while the camera focuses on their face.

Figure 34: Screenshot of the game where the player is close to the other traveller and they start talking about life lessons.

6.2.6 Listen to story sentence

When the other traveller finishes talking, a cutscene will start, as explained before. This cutscene always consists of two parts. First, there is the listening situation. Here the realistic wind noise is played as well as the clinical hearing test sentence. The wind noise is supported by visual cues such as wind particle effects and blowing leaves in the scene. Another thing that improves realism is the fact that the other traveller speaks the sentence while playing a speaking animation. One of the advantages of the cutscene is that everything goes automatically, and the player has no control of their character while listening. This means that the listening situation will always have priority in the game view, making it impossible to fail due to wrong user input.

Before the listening audio starts, the camera first zooms in on the other traveller model and a new UI text appears stating that the player should listen closely. Additionally, the background of the game becomes blurry, giving even more focus to the listening situation. A screenshot of the gameplay during the listening situation can be found in Figure 35.

Figure 35: A screenshot of the listening situation where the other traveller is saying the clinical hearing test sentence while there is a realistic wind noise playing in the background supported by a wind particle system and blowing leaves.

6.2.7 Repeating the sentence

The second part of the cutscene consists of a section where the player is asked to repeat the just-heard sentence. This part starts when the other traveller has spoken the clinical hearing test sentence and the wind cools down again. The UI on the screen changes and states that the user should now repeat the sentence loudly. Additionally, a red walkie-talkie appears on the screen to illustrate even further that the player has to say something. This walkie-talkie makes a start-up noise to indicate that the player can start repeating the sentence. Finally, after a few seconds, the walkie-talkie disappears again, and the camera will change to its original position. The player can continue walking on the trail to the top of the mountain. The other traveller mysteriously disappears and leaves a pink flower behind while a nice sound effect is playing. This increases the immersion and engagement of the player as they want to find out what is going on and what will happen next. Figure 36 shows a screenshot of the second part of the cutscene, where the red walkie-talkie and the UI text guide the player to repeat the just-heard sentence.

During this sequence, the doctor of the UMC will listen closely to the answers of the player. Depending on whether the player correctly repeats the sentence or not, the doctor will change the level of volume of the realistic wind noise for the next listening situation. In this way, a clinical hearing test is conducted without the player's notice.

Figure 36: Screenshot of the game where the player is instructed to repeat the sentence.

6.2.8 Reach the peak

The player continues this loop of walking on the trail and interacting with the other traveller twelve times. Throughout the player's journey, the environment of the mountain changes. This will increase the engagement of the player as the beautiful art style and the mysterious sentences will keep the player curious about their next encounter with the other traveller. Additionally, when the player climbs higher onto the mountain, the sun will set, leading into eventually a starry night. Finally, the player will reach the summit where they will encounter the other traveller one last time. However, this time the other traveller is covered in a mysterious blue aura, next to a grave, indicating that the other traveller has been dead for a long time. This also explains how this traveller could pop up at every spot on the mountain and why this traveller had so many life stories to tell. Figure 37 showcases the grave and the other traveller in the final encounter with the player. After interacting with the final other traveller, the listening cutscene will begin, and the final clinical hearing test sentence will be spoken by the other traveller. During the listening situations, it becomes clear that this other traveller is the player's grandma. The game comes full circle when the player puts pink flowers on their grandma's grave, and the camera zooms out into the credits while an emotional but happy song is played, this can be seen in Figure 38.

Figure 37: The final encounter of the player and the other traveller, at the top of the mountain.

Figure 38: Pink flowers appear on the grandma's grave while the camera zooms out into the credits. This is the end of the game.

6.2.9 Video game affordances

Following the literature, there were multiple ways in which video game affordances could potentially increase engagement. This game uses two of these affordances, a progress bar and the provision of choice. The progress bar in this video game features a simple design with only a red bar and a flagpole on top. It is shown on the left side of the screen when the player is not moving. When the player is

walking, however, the progress bar will smoothly move off-screen. This is done to not distract the player while they are walking and giving them the full opportunity to view the environment. When the player is following along the trail, the progress bar will slowly fill. Whether this increases engagement, as said in the literature [4], will be evaluated in the next chapter. The progress bar can be seen in Figure 39 on the left side of the screen.

The other game affordance used in this video game is the provision of choice. The literature states that allowing the player to choose for themselves will increase their engagement while playing [12]. In this game, this has been done by splitting the path at a certain section of the mountain, as can be seen in Figure 39. The player can choose whether they want to go left or right. Both paths will eventually lead to the same section again, but the provision of choice will hopefully increase engagement. This will be evaluated in the next chapter as well.

Figure 39: Screenshot of the game where the two affordances can be seen. The progress bar and the provision of choice.

Chapter 7 – Evaluation and Discussion

In this chapter, the final product will be evaluated. First, the evaluation preparation and procedure will be described. Second, the evaluation results will be discussed. Third, the client evaluation will be described. Finally, changes to the game will be made, and the requirements from the Specification Chapter will be evaluated. The second part of this chapter consists of a discussion.

7.1 Evaluation preparation

The video game was evaluated using multiple techniques. The first technique that was used, apart from observation by me, was a 1-on-1 interview, as this would give the most insight into the user's experiences and emotions they felt during the playtesting. Questions that were asked during this interview were based on Chapter 28 of the book "The Art of Game Design A Book of Lenses" [35]. These questions are useful in capturing the feelings of the users without leading them into any direction of answer. The six questions go as follows.

- *What was your favourite moment or aspect of what you just played?*
- *Was there anything you wanted to do that you couldn't?*
- *If you had a magic wand to wave, and you could change, add, or remove anything from the experience, what would it be?*
- *What were you doing in the experience?*
- *How would you describe this game to your friends and family?*

After these questions, more gameplay-related questions were asked to find design flaws. These questions ask about the game controls and sounds, as well as the game affordances used that hopefully increased engagement. Questions about the story of the game will be asked. Just like the previous questions, these questions will get follow-up questions to get a deeper understanding of the tester's emotions and feelings about the design of the game. These questions go as follows.

- *What did you think of the sound of the game?*
- *How realistic was the noise during listening?*
- *What was, according to you, the purpose of the bar on the left of the screen?*
- *How did you feel about this bar?*
- *What do you think of the part where you could choose your own path?*
- *What did you think of the controls of the game?*
- *What was, according to you, the story of the game?*
- *What emotions did you feel during playing?*

Finally, after this 1-on-1 interview, the users got a survey about the engagement of the game. The results of this survey will be used to determine the level of engagement of the video game hearing test. The tool used to determine engagement is the User Engagement Scale Short Form (UEL-SF) [15], which was found during the background research stage of this project. The scale consists of twelve statements categorised over four dimensions, which are, aesthetic appeal, focused attention, perceived usability, and reward. The twelve statements have been adapted to fit the description of this project and were evaluated through a 5-point Likert scale. They are presented to testers in random order through Google Forms.

Focused attention

- *I lost myself in this experience*

- *The time I spent in the game just slipped away*
- *I was absorbed in this experience*

Perceived usability
- *I felt frustrated while playing the game*
- *I found the game confusing to use*
- *Playing this game was physically demanding*

Aesthetic appeal
- *The art style of the game was attractive*
- *The game was aesthetically appealing*
- *The game appealed to my senses*

Reward
- *Playing the game was worthwhile*
- *My experience was rewarding*
- *I felt interested in this experience*

7.2 Evaluation procedure

The final product was evaluated through playtesting sessions with potential users. Adults of all ages were suitable for the playtesting session as the Amsterdam UMC uses the hearing test for all adult ages too. In total, 12 people participated in the playtesting sessions. These people were found in a random convenience sample. While the client will use the hearing test video game eventually with people suffering from hearing loss, for this evaluation it was not searched for in the testers. This is because the evaluation of the product solely focused on finding design flaws in the game design and not focusing on the user's hearing. The playtesters were informed that this game was a hearing test game developed for the Amsterdam UMC, and all gave consent to participate in the playtest session.

The playtest setup was quite simple and was based on the hearing test setup from the Amsterdam UMC. The users were asked to follow the instructions on the screen of a laptop. They only needed the mouse to complete the game. Additionally, the users wore headphones to listen to the game sounds. The setup of playtesting was the same for every player, making it possible to compare the results. I was sitting next to the playtester, acting as the doctor of the UMC. Just like in the real hearing test, if something were to go wrong, I could help the player. Additionally, I controlled the volume of the wind noise by pressing the keyboard occasionally.

7.3 Evaluation results

Playtesting went smoothly. The most important part was that every player made it to the end of the game. Every player listened to every hearing test sentence, making the game a working clinical hearing test. Of course, some things did not go as I imagined, which led to valuable insights.

7.3.1 Observation results

I closely watched the testers play the game. There were parts of the game where users had similar experiences and opinions, and there were parts of the game that evoked different experiences and opinions. The first thing I noticed was about the movement of the game. All testers carefully read the

instructions about movement on the screen. However, for two testers, the movement was still difficult in the beginning, as they were unsure which mouse button to use to walk. The majority of the testers did, however, figure it out immediately after reading the instructions. After around three minutes of playing, all testers were very confident in the movement, as I observed. All players made it to the top of the mountain and did not skip a single listening situation point, which shows that the movement of the game is easy to learn, which increases the accessibility.

The next aspect of the game was the first listening situation. All players immediately walked to the nearby traveller when they knew how to walk. They all looked curious about this other traveller and thought it was funny that they were waving at them. Some testers, however, had difficulties walking and standing still at the correct location next to the traveller. I noticed that most of the players were reading the story of the other traveller closely. Around four or five testers, however, didn't bother that much about the story of this first traveller and did not look to understand. After reading the text, the actual listening situation started. I noticed in all testers' faces that they were engaged by the sudden camera change and looked more focused immediately. When the UI stated that the user should listen closely, all players looked ready to listen and curious about what would come. Additionally, most players looked engaged by the wind and leaf particle effects in the background. After listening, it was not clear to all testers that they had to loudly repeat the sentence. If they didn't repeat the sentence, I asked them myself to repeat it for me. For the following 12 listening situations, these testers repeated the sentence out of themselves when the game told them to. It seems the listening situation has a small learning curve, but it is great that after this, it is easy to understand.

The players looked curious about the video game and noticed after this listening situation that this was the way the game would test their hearing. All players continued walking on the trail intuitively and were engaged by the nature they saw on the screen. Around four to five testers pointed out that they specifically liked the wind particle effect. After walking on the trail for a little bit, two testers walked into the forest as they were curious. When they noticed there was nothing in the forest, they made their way back to the trail. However, the players should not be able to walk in the forest deeply as they could have also gotten lost and failed the game.

When the playtesters saw the second other traveller, they immediately went to this person again. This time, the listening situation went smoothly for every tester, most likely because they knew what to expect this time. After this encounter, no tester showed difficulties with the movement of the game. again. It seemed like all playtesters knew what to do in this game and followed the trail and other travellers accordingly.

An interesting event happened when the testers reached the part of the game where they had to choose the left or right trail. Ten of the playtesters chose the right path, while only two chose to go left. This made it clear that the right path had a preference. For the gameplay, this is not important as both the left path and the right path will come together at the same point again. What is important, however, is that four testers got lost at this point. They chose to follow the right path, but when they came to the general path again, they instead followed the ending of the left part. They followed this path in the wrong direction, leading them again to the intersection point. All four testers realised that they walked the wrong way and eventually found the correct path by themselves. However, this problem should still be avoided, and the game will be changed accordingly by adding more arrow signs and changing the path a little bit.

The rest of the path seems clear for every tester as they make it to the end. Most testers looked curious and excited when they first saw the snowy forest. They additionally looked a little bit confused when they saw the grandma and their grave. All testers carefully read the story of the final encounter. Four

out of the twelve testers were deeply hit by the emotional message the game left, one of them even cried as they thought the story of the grandma was so motivational and personal. This shows that the players were engaged in the story and the game, which is great for the hearing test as it makes it more realistic. Finally, it was clear to all testers that this final encounter was the end of the game as they stopped playing. All testers looked satisfied when the ending screen popped up.

7.3.2 Interview results

After playing, the testers were asked to answer the questions described in Chapter 7.1. Following the first question, there were multiple things that the testers saw as their favourite moment or aspect. The most prominent aspects were the beautiful nature on the mountain and the round ending of the story. After follow-up questions, it became clear that most people especially liked the campfire, shadows, wind, and different biomes. Additionally, three testers mentioned that their favourite part was the calm music during the game and the sound effects. Also, the life lessons from the other traveller were mentioned often as a favourite aspect.

There were also things the testers wanted to do, but the game didn't allow them. Five testers mentioned that they were curious about what would happen if they moved away from the trail. They wanted to explore the forest for themselves instead of following a linear trail all the time. Another tester mentioned that they wanted to see a running option to traverse the path more quickly. Finally, some testers mentioned aspects that are unable to change, as they are inherent in the hearing test. These were aspects such as repeating the sentence or changing the noise in some listening situations. Five testers also mentioned that they were interested in even more diverse nature, such as animals, waterfalls, or even changing seasons.

When the testers were asked to explain the story of the game, several similar answers came to the surface. They mentioned that in this game you need to climb a mountain while listening to the life stories of a certain other traveller. Seven out of twelve testers figured out that this other traveller was the player's grandma who had already passed away. The testers all described the game as an easy interactive walk game. Five testers mentioned that it was a relaxing game to play. This was due to the nice calm music, pretty nature, and the life lessons.

From the convenience sample, one tester had known hearing loss. It was interesting when this person was asked to describe the game. They said that this version of the hearing test was much more innovative and realistic. They liked that there finally was a new concept in the hearing test world and thought it was more realistic since there were more distractions, just like in real life. They mentioned that in the original hearing test, they only sat focused listening to the next sentence, but in this video game version, they also felt enjoyment and curiosity, mostly due to the pretty art style and the interesting story of the other traveller and interactivity. While this is great to hear, it is only one person, and no conclusions can be drawn. Future studies could focus more on people with hearing loss to investigate the difference between the original hearing test and the video game hearing test.

Nine out of twelve testers mentioned that the controls of the game were very easy to understand and use. Three testers stated that they first needed to get used to the controls, but after that, it was easy. Most testers were positive about the music and sounds in the game. They all stated that the noise they heard was a wind sound that they could hear in the real world too, in a forest. Four testers also mentioned that the realistic noise was supported by the visuals on the screen. Two testers, however, stated that the background music was boring in the game. The other testers liked the background music as they thought it was a peaceful and relaxing melody. Based on these results, it sounds like the music helps the engagement of the game. Additionally, all testers liked the sound effects of the game,

especially the fire sounds were found to be nice and comforting. Finally, all testers thought that the sound of the speaking voice of the sentence fit the grandma character model, meaning that the character model does not have to change.

Eleven testers noticed the progress bar on the left side of the screen. One of the players however said they never noticed it, but also did not need it. The other testers thought it was a nice addition to the game, as it showed how far they still had to travel to the end of the game. Especially near the last segment of the game, multiple players were curious how long the trail would continue and were all relieved and excited when they saw the progress bar was almost filled up. Nine out of twelve testers stated that the progress bar increased their enjoyment, immersion, and engagement. The other game affordance added to the game was also interviewed. Ten out of twelve testers liked the idea of choosing their own path. They stated that it was interesting and exciting as they did not know what would happen if they chose the other path. The testers thought that the provision of choice increased their engagement in the game.

7.3.3 Survey results

After the interview, the players were asked to fill out a survey through Google Forms. The results per question can be found in Appendix E. Now the scores of the four different subscales can be determined using the literature [15]. After this, the full engagement score of the video game can be calculated. The scores are calculated where zero means fully disengaged, and one means fully engaged. This also means that scores closer to one have performed better in the game in terms of engagement. The scores can be seen in Figure 40.

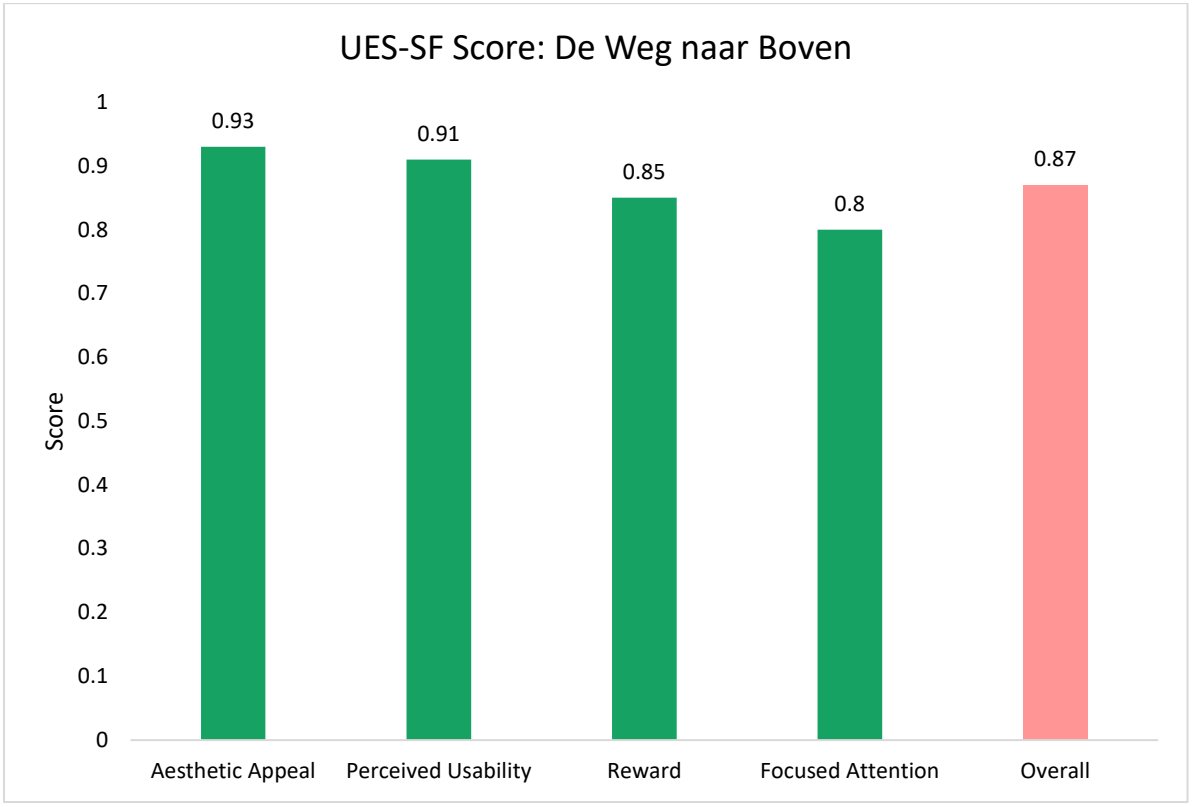


Figure 40: UEL-SF scores for the four subscales and the overall engagement score of the game

The game scored quite high on the scale. It is useful to look at the different subscales to see which part of the game is the least engaging to the players. First, aesthetic appeal is rated as the most engaging part of this game. This shows that the extra effort that was put into the aesthetics of the game paid off, which was also found in the interview section of the evaluation. Second, the perceived usability of the game is very high too. This means that the players had barely any difficulties understanding and playing the game, which shows that the wanted high accessibility level is reached so that many people can benefit from this hearing test game. Third, the score of the reward subskill is still quite high, showing that the players were interested in the experience and that playing was worth their time. They did, however, rate this as less engaging than the visual appearance of the game and the usability. Finally, the focused attention subscale is still rated high, but it is the lowest of the game. The players were immersed during the hearing test, making it more realistic. The scale shows that the users found a higher engagement level, from the other parts of the game. However, the score of this subscale is still high and no drastic changes need to be made to bring the game in balance, according to this scale.

7.4 Client evaluation

The hearing test video game was also tested with the clients of the Amsterdam UMC. This testing followed the same procedure and preparation as before but had more focus on showcasing than the actual design test. The clients are very happy with this video game. It completely fulfils their wishes, and they are excited to see where this new area of innovation in hearing test leads. The collaboration with the client went smoothly and the assignment was completed perfectly in their opinion. They had no suggestions for changes in the game.

7.5 Revision game

While the clients are already very satisfied with the current version of the game, the evaluation shows that there is room for improvement. However, it also showed that there is no need for drastic change as the evaluation led to many positive results. So, the changes made to the game are kept small, but useful.

The most significant change made to the environment of the game is at the section where the players can choose their own path. The layout of this section is changed slightly as multiple players got confused about where to go after they followed their chosen path. This problem has hopefully been fixed after placing an arrow sign and texturing a new path. The changes can be seen in Figure 41.

Figure 41: Two screenshots showing before and after the changes made based on the evaluation results.

In the before situation, the paths intersect again, leading to an option of three paths on the screen at the same time. One of these paths the player just took, and two of them look like new options to choose from. However, this is not the case, the player should go left, but the camera angle makes it difficult to see this path and going straight looks like a more prominent option. This is why this section has been changed by re-texturing the ground and adding a big arrow sign to guide the player, making it seem there is only one correct path. This arrow sign model has now additionally been placed at many more locations besides the trail.

Another change made to the game is blocking off the forest for the player. Invisible walls have now been placed to block the player from entering the forest deeply. This is done so players do not get lost and miss listening situations and fail to complete the hearing test. Initially, I didn't think about blocking this forest as I thought it was clear to follow the path only. However, the evaluation shows me that people are curious about the forest too. The invisible walls have been placed inside the forest, meaning that the players can still explore to a certain extent to their liking, but not deep enough to get lost. The change can be seen in Figure 42, where the blue part in the picture shows a walkable area.

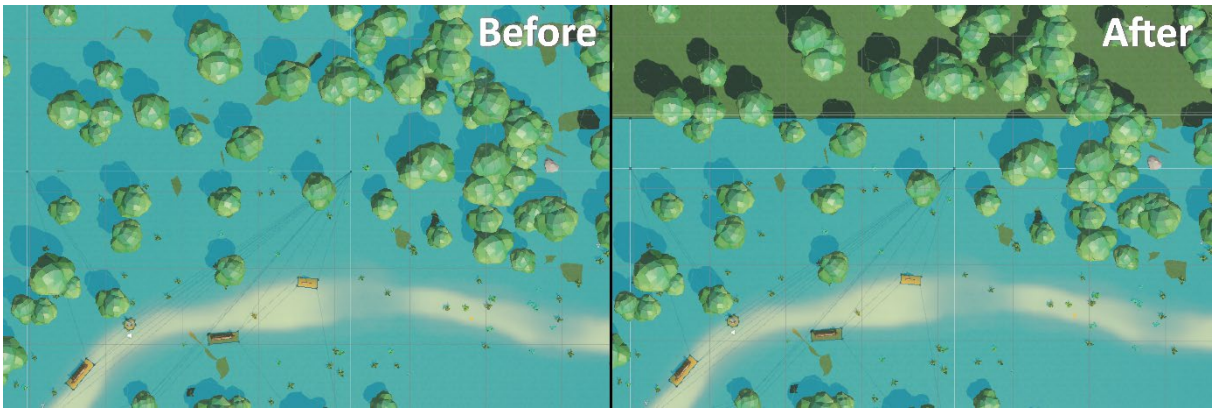


Figure 42: Top-down screenshots of the before and after situation about blocking the forest the blue part of the pictures shows the walkable area.

Finally, there were small changes to the game, such as fixing spelling mistakes and collision errors.

Some parts of the game did not change even though some testers thought it would be a great addition. First, we have one tester who mentioned that a running option would be more engaging. I decided to not add this option as it would make the game more difficult to understand and control. It additionally was only mentioned by one tester. Second, there were suggestions about improving nature even more with things like animals and changing seasons. While these are great suggestions, I decided to not add them as the survey shows that the visual appeal is already very high, and it will take a long time to add new models or mechanics.

7.6 Evaluation of non-functional requirements

The non-functional requirements can be evaluated after analysis of the results. The results can be found in Table 2.

Requirement	Achieved	Explanation
The game must run smoothly on the hardware available at Amsterdam UMC.	Yes	The game is a light programme and can run on the available hardware.
The game must have minimal loading times to maintain immersion.	Yes	The game has no loading time apart from the start-up scene.
The game must be easy to understand and navigate for users of all (adult) ages.	Yes	All players found the controls of the game easy to understand and use. Everyone made it to the end.
The game must have a user-friendly interface with clear instructions and feedback.	Yes	The constructions of the game were clear, according to the testers.
The game must consistently respond to the doctor's inputs for adjusting background noise volume levels.	Yes	The doctor can press two keys on the keyboard to change the volume of the background noise without any problems.
The game must be accessible to people with varying degrees of hearing loss.	Yes	The game includes a clinical hearing test making it accessible to people with varying degrees of hearing loss.
The game must be engaging and immersive to ensure ecological validity in the hearing test.	Yes	The players and the User Engagement Scale show that the game achieves a high level of immersion and engagement.
The game must have an engaging storyline that motivates the player to complete the hearing test.	Partially	All players completed the hearing test, but some liked the story more than others.
The game must ensure the privacy of the patient's data and responses.	Yes	The game does not store data from the user, it can be used as an extension tool for the current hearing test equipment.
The game must comply with relevant data protection regulations and hospital policies	Yes	The game complies with the relevant data protection regulations and policies.

Table 2: Evaluation of the non-functional requirements.

7.7 Discussion

The video game hearing test was received very positively by the user testers and the clients. The game is both effective and engaging. Most participants liked the audio in the game, which suggests that it does not need major changes. The realistic wind noise makes the hearing test simulate the real world more. Also, the visuals and the relaxing background music are well in harmony and enhance each other, which improves the engagement and immersion of the players.

In general, the players like the environment of the game very much, showing that no drastic change is needed in the game world. These visual cues make the hearing test more realistic as well. Both the listening situations and the movement of the game had a learning curve; however, they were easy to follow after. It shows that the instructions of the game are well enough, but they could be better by, for example, putting more focus on the instructions before playing. Additionally, a few testers walked into the forest where they had the chance to get lost. This has been fixed by placing invisible barriers next to the path, however, it should be tested to see if it actually fixes the problem. The same goes for

the other part where four testers got lost. Here they had to choose their own path, but it might be too confusing for some of the players.

However, it also showed that the provision of choice affordance increased the engagement of the player, as well as the progress bar on the left side of the screen. Given the success of these affordances, more could have been added to the game, such as customization or leaderboards. The reason that they are not added now is that they also increase the complexity of the game. The game is very casual, meaning that there was a focus on the art style to make the game more interesting and engaging. Following the scores of the UES-SF, this has been achieved as the visual appearance of the game is the most engaging. However, the focused attention subscale was rated lower than the others. While it is still high, more research and changes should be done to make the subskills more balanced. The UES-SF score of the original hearing test should be investigated too so a clearer comparison can be made between the game and the original hearing test. Additionally, more testers should be included in the evaluation as it could lead to more insights. Especially for the survey, more testers could improve the reliability of the scales.

Furthermore, there was only one person with hearing loss during the playtesting sessions. This person stated that this video game was a very innovative and engaging idea in the world of hearing tests, suggesting that there should be more projects like this. However, this is only one person, and there should be more tests with the actual hearing loss patients before conclusions can be drawn for this target group.

Finally, the game featured an emotional story that, for some people, was too difficult or confusing to understand. The story could be improved by, for example, hiring a voice actor to read the lines before the listening situation. This could improve the immersion of the players as well but was out of the scope of this project timewise. On the other end of the spectrum, some people liked the story so much they cried. This shows that the story can be very engaging to the players as well. The evaluation results showed that the story might not be the main factor that kept users engaged in this game, which is okay as other factors still make it an engaging whole.

Overall, the game is more engaging and realistic than the original hearing test. The strong points are mostly the story and the environment with sounds, but there are also points to improve in the future.

Chapter 8 – Conclusion and Future Work

In this chapter, the conclusion will be given, as well as future work.

8.1 Conclusion

The current hearing test is too laboratory-specific, it does not simulate the real world well. This means that the results from a hearing test will not reflect the daily life hearing problems of patients with hearing loss. This is why my client, the Amsterdam UMC, is looking for a way to make a more ecologically valid hearing test, meaning that the test simulates the real world more. This new hearing test version was aimed to be created as a serious video game as the literature shows that it would increase the engagement of the users. This bachelor thesis aimed to answer the following research question.

How can a hearing test be developed into a serious game to facilitate ecologically valid testing?

During the background research, it was found that serious game elements can be implemented to increase engagement, as they provide the player with a feeling of competence, relatedness, and autonomy, as well as increase the player's motivation and immersion. The use of some of these elements could increase the ecological validity of the hearing test game. Previous research in the hearing test area showed that visual cues and realistic noises could increase ecological validity as well.

The knowledge of the background research was taken into account in the ideation phase. Here several ideas were created by using a combination brainstorming technique where, a game theme, listening situation, and realistic noise were merged to create interesting initial combinations. These combinations were narrowed down and ranked as they grew broader and more interesting. Finally, this led to three deeply elaborated ideas, which were discussed with the clients and supervisors of this project until one final idea was chosen. This final idea was about climbing a mountain and encountering other travellers who would speak the clinical hearing test sentences to the player.

In the next phase, this idea was further developed through an expert interview with the clients, preliminary user testing of a paper prototype storyboard, and the use of personas. This elaborated and specified the mountain game idea even more. Finally, the functional and non-functional requirements were formulated, which would act as a blueprint during the realisation phase, as well as an assessor during the evaluation phase.

Now the game could be developed. "De Weg naar Boven" is a Dutch adventure story game. The Unity game engine was used to create the game, as well as several AI tools to create the textures and models to save time while still allowing to capture the imagined dreamy art style that is important to make the game engaging. In this game, you control a traveller who needs to follow a path to the top of a mountain. This mountain has several different areas to explore, such as oak forests, steep hills, lakes, and snowy forests. During this climb, the player will encounter a certain other traveller on the trail multiple times, who will talk about interesting life lessons and stories to the player. This other traveller will additionally speak the clinical hearing test sentences, making the game a hearing test video game. The further the player travels on the trail, the more personal the messages with the other traveller become. Finally, the story of the game will reach a climax when the other traveller can be seen next to

their grave on top of the mountain under a starry night. The game includes realistic wind noise, visual cues, as well as affordances from the literature to increase engagement and ecological validity.

During the evaluation phase, twelve participants from a convenience sample tested the video game to get insights about design flaws. The game was evaluated using observations, interviews, and a survey about engagement. The setup for playtesting followed the original hearing test setup, where the players simply sat in front of a screen with headphones and only used the mouse to play the game. The game was received very positively by the users. The visual appearance of the game was especially engaging as well as the realistic wind sounds and calming music that enhanced the art style. The story of the game was not clear to every tester, but in general was received as immersive and engaging. Finally, the movement and listening situations of the game were very easy to understand after a small learning curve. Every tester made it to the end, showing that the game has high accessibility and that many people can benefit from his ecologically valid hearing test. The game was revised based on the evaluation results, to ensure players will not get lost in the forest next to the trail, or walk in the wrong direction, as this would fail the hearing test. All non-functional requirements were met except the motivating storyline.

In general, the client was very happy with the final result. Not only is this version of the hearing test more engaging and enjoyable, but it also simulates the real world better than the current hearing test. This means that my video game can be used to give patients better advice at the Amsterdam UMC that will help solve their hearing loss problems more efficiently. This will help make the world a better place, and I hope my research stimulates other researchers to find more ecologically valid ways of conducting hearing tests.

8.2 Future work

While the video game is received positively by the convenience sample, it should be tested by the actual hearing loss patients in the future. They could have different opinions on the game than the people from my playtest sessions, and more people will also lead to more useful insights and opinions. Additionally, the game was revised and never tested again, this should be done in the future to ensure the revisions solved the problems.

In this thesis, the UEL-SF was used to measure the level of engagement of the video game. However, it has never been used to measure the engagement of the original hearing test. This should be done so the results can be compared. Also, background research showed that there were multiple opinions about whether engagement is measurable or not. In this thesis, I chose that it was measurable, but many arguments say it is not, meaning that the outcome of the scale used in this thesis could be less useful than I thought. In the future, multiple ways of measuring engagement should be examined and used.

The story of the game did not catch on to every player. For future work, this should be a focus point, as it could increase the engagement of the player significantly if they are attached to the player story, as was seen by some testers. This could be done by, for example, a voice actor or other more elaborate ways of telling a story.

Finally, the game affordances used in this video game were useful, but more could be added in the future. Future work should research the balance between casual gaming and complexity for engagement, to find the perfect point of video game affordances in a non-game environment like a hearing test.

While my project is likely the first video game that includes a clinical hearing test, it only scratches the surface of possibilities that can be done to make hearing tests more enjoyable and ecologically valid for patients. All future works will help improve the world for those with hearing loss.

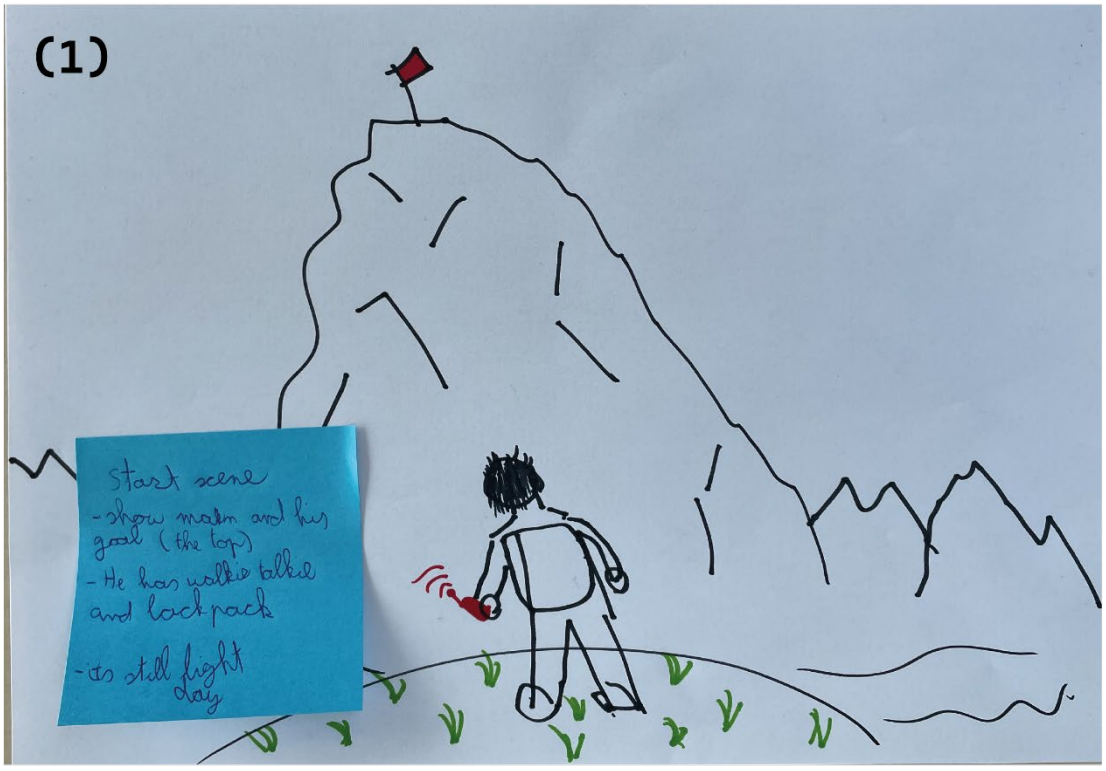
Appendix A: Initial brainstorm combinations

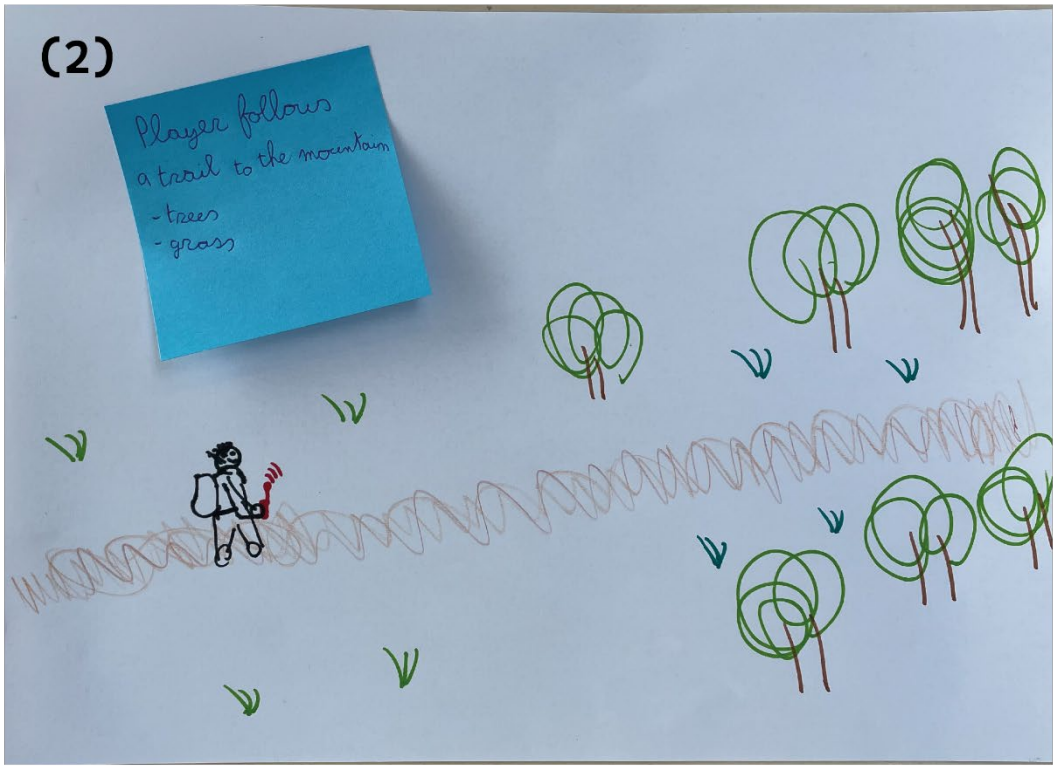
Game theme	Listening situation	Realistic noise	initial idea
Ghost, Train station	people talking in a trainstation; memories of ghost that were people	People loudly talking; Eerie ghost sound; Train whislte	player controls a ghost that flies around a trainstation listening to peoples stories
Beach	people talking at the beach; lifeguard hearing stories	People loudly talking; Sea waves	player is a lifeguard or tourist that is on a beach listening to peoples stories
Pirates	pirate crew stories on the ship; ancient hints to find a treasure	pirates loudly talking; Sea waves; cannon fight	player is a pirate and explores its ship to hear stories of the crew/ uses a ancient sentences to find a treasure.
Spy	intercept enemies code sentences; eavesdrop people to find real enemy	people talking loudly; Intercept machine buss noise	player is a spy and has to use a machine to intercept the enemies code sentences. player is a spy and has to eavesdrop people on some location to find clues about who is the real enemy
submarine, Underwater	submarine get instructions from above water; talking with co-pilot	people talking; submarine engine; eerie deep sea sound	player controls a submarine and talks with his copilot player controls a submarine and gets messages from control center above water player explores a sunken city and finds treasures (sentences)
fish, Underwater	fish talks to his friends about humans; fish is listening to human divers	people/fish talking; submarine engine; eerie deep sea sound	player controls a fish underwater that talks wiht his friends about humans player controls a fish underwater and is listening to what the human divers are saying player controls a fish underwater that explores the ocean for answers about humans
Prison escape	prisoners planning their escape; listening to guards while escaping	people talking loudly; police siren	player tries to escape a prison and listens to the guards talking in order to escape player tries to escape a prison and talks to the other prisones about their stories to escape
Cooking	getting order; listening to peoples story as cook in restaurant	people talking loudly; food cooking; Oven buzz	player is a cook and listenes to the customer to get the order player is a cook in a restaurant and hears people talking
footbal match	memories of conversations; listening to teamates or coach	people talking loudly; stadium cheering	player is a footbal player and while making its way to the goal to score he thinks back to conversations player is a footbal player and listen to teammates to play the game
Theme park	friends talking; speaker announcement at ride	people talking loudly; people cheering at attraction	player plays minigames at themepark with his friends
Future city, Timetravel	people talking stories; people walking on the street	sci-fi timetravel sound; people talking loudly; construction of buildings	player can timetravel in a city and see it transform from village to sci-fi futuristic city, listen to the inhabitants stories
River cruise	people talking stories; Tour guide at different stops	boat engine; people talking loudly	player is on a river cruise and explores the ship to listen to the stories of the other passengers player is on a river cruise and will go to different stops and listen to the tour guide
Planets and space	human civilisation holograms; other space ships intercom	spaceship engine; hyperspeed jump; aliens sounds like talking	player controls a spaceship and flies to different plantes to learn about the remains of old human civilisation by finding holograms player controls a spaceship and talks to other spaceships through intercom to defeat alien ships
New York Sightseeing	people talking stories; Tour guide at different stops	people talking loudly; cars and traffic	player can explore new york and its secrets with a group of friends player follows a tour in new york that goes to all famous spots
Open ocean	people talking stories; sentences from message in a Bottle	people talking loudly; boat engine; wind/storm	player is on a boat on full sea and finds messages in a bottle that lead them to a secret island player is on a boat on full sea and has to survive frequent storms by listening to the captain
Bomb defusing	intercom code sentences	thrilling action countdown music	player has to defuse a bomb by listening to the sentences provided by an intercom
Mountain climbing	people talking stories; person talking about the view	wind; campfire crisping	player will climb a mountain but finds many travellers on his way to the top, they all have their own story
Skydiving	instructor screaming	wind	player will do many skydiving but the instructor will talk during the dive

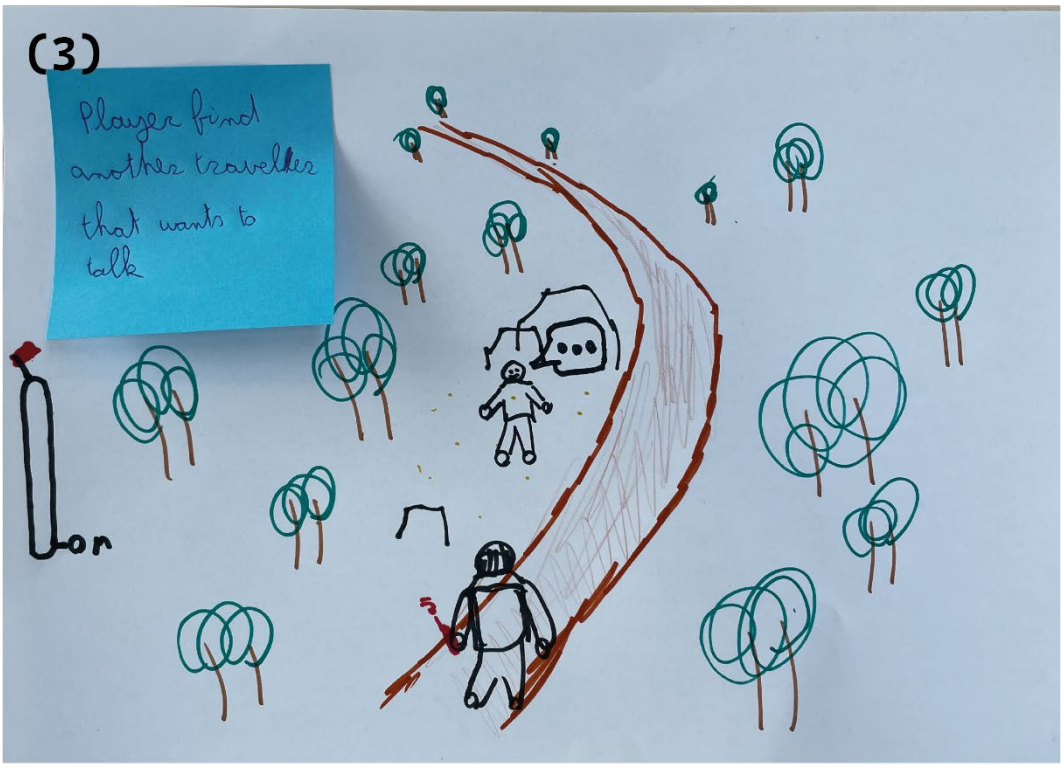
Appendix B: Paper prototype

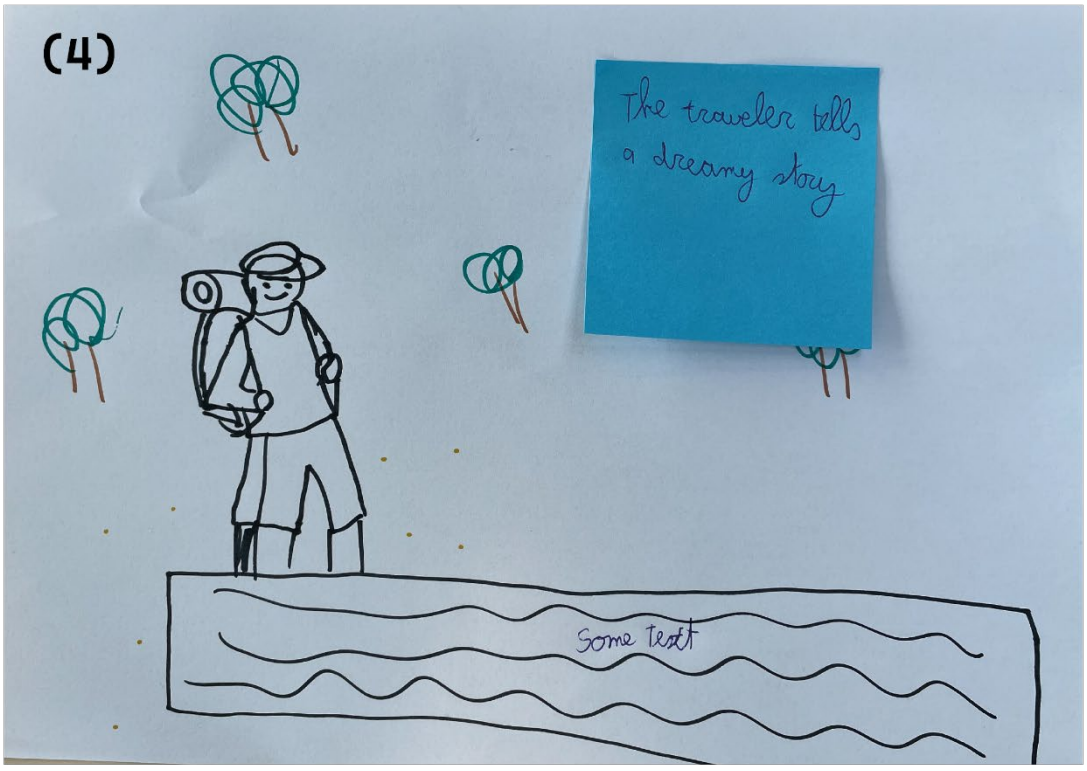
These are pictures of the paper prototype that was used for preliminary user testing. The pictures show the concept of possible gameplay for the hearing test game.

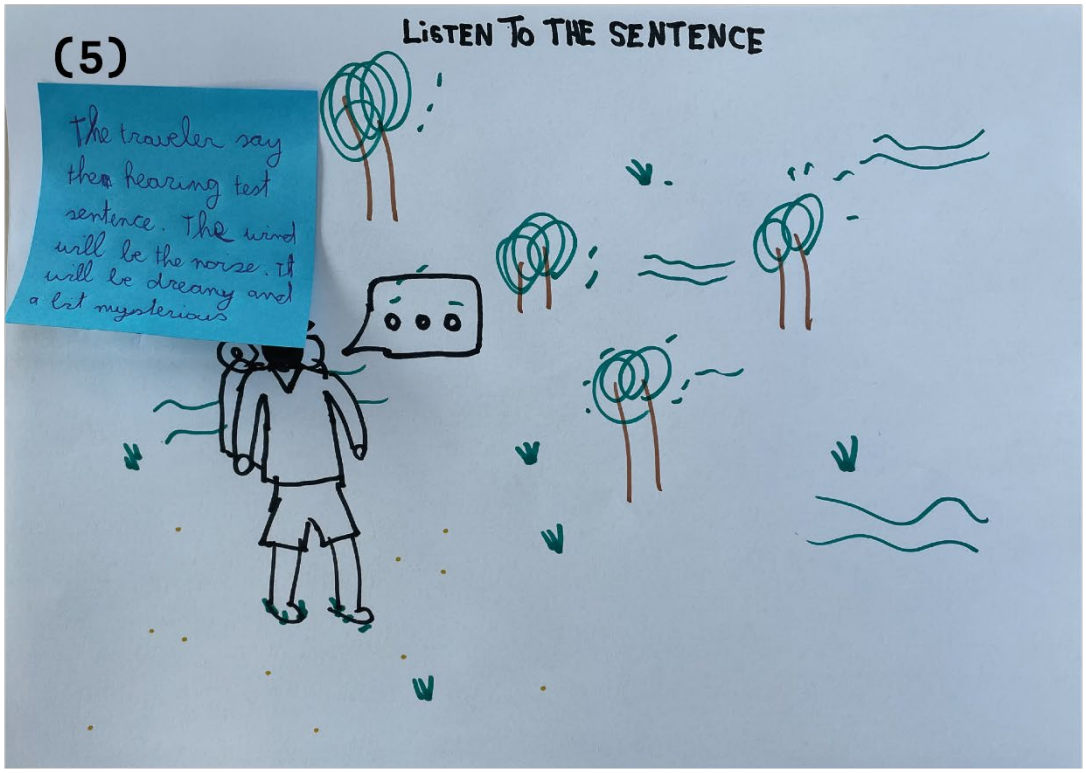
(1) Start scene of the game. The player sees the top of the mountain and it becomes clear that reaching this is the goal of the game. The player is wearing a backpack and is holding some sort of talking device that resembles a walkie-talkie.
(2) The player follows a trail to the top of the mountain. There are trees and grass.
(3) Next to the trail, the player finds another traveller. By the looks of it, this traveller wants to talk to the player. There is also some sort of progress bar on the left of the screen indicating the height the player has climbed.
(4) The traveller that the player just met is telling a dreamy story. This is done by a dialogue box with text at the bottom of the screen.
(5) Suddenly the wind starts blowing and leaves are all around the environment, this will be the noise of the hearing test. The traveller says one of the thirteen clinical hearing test sentences. It will be dreamy and a bit mysterious.
(6) Some voice recording device shows up on screen as if the player was holding it. The game tells the player to repeat the sentence. The background will be blurry during this scene to give all focus on the repeating of the sentence.
(7) The player continues on the trail to the top of the mountain. It is very windy in this area now.
(8) During the hike, the sun will slowly set the further the player proceeds to climb. There will be different kinds of rocks and trees. This will add to the theme of the game. The progress bar on the left of the screen increases when the player climbs higher.
(9) At certain points the player has to choose which direction to follow, this provision of choice will increase engagement according to the literature.
(10) Nature will look beautiful in the game to convey the artsy and dreamy feeling. This drawing shows another example of how the player could find another traveller who wants to talk.
(11) After talking to multiple travellers and climbing higher on the mountain the sun will slowly set, creating long shadows. This will add to the dreamy and artsy style of the game.
(12) Finally, the player reaches the top of the mountain. At this time, it will be already dark with a sky showing the northern lights and starts. This will add to the style. It will be the end of the game.

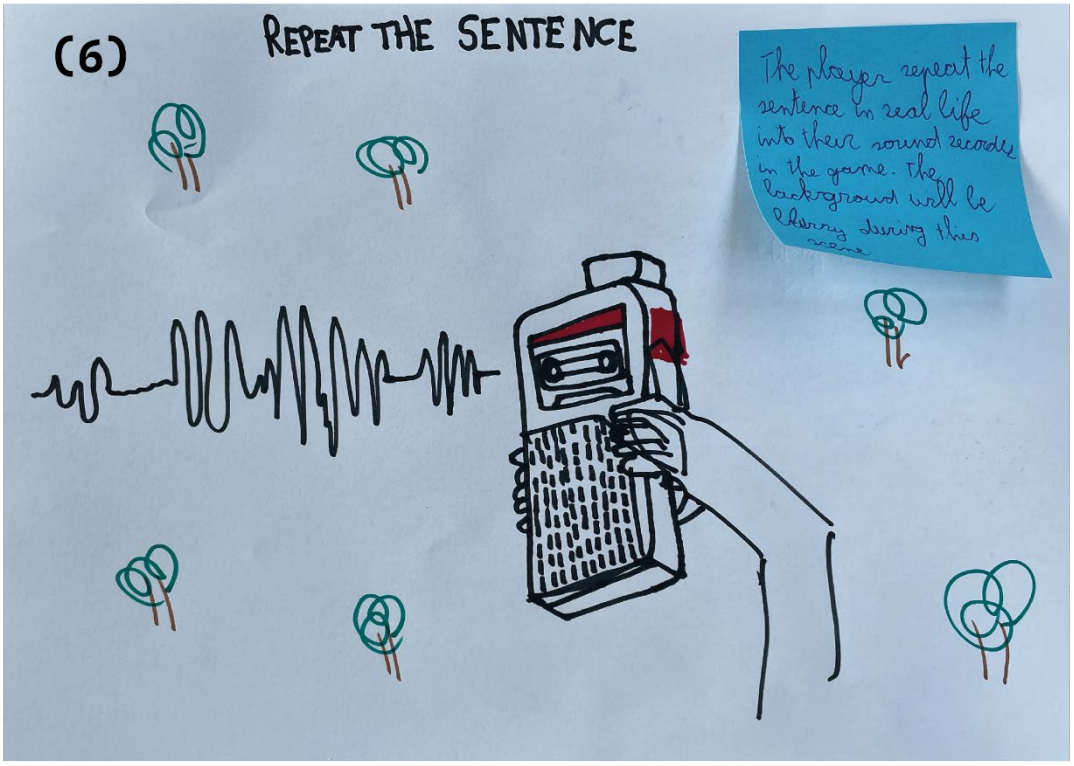

(1)
Start scene
- show main and his goal (the top)
- He has walkie talkie and backpack
- its still light day

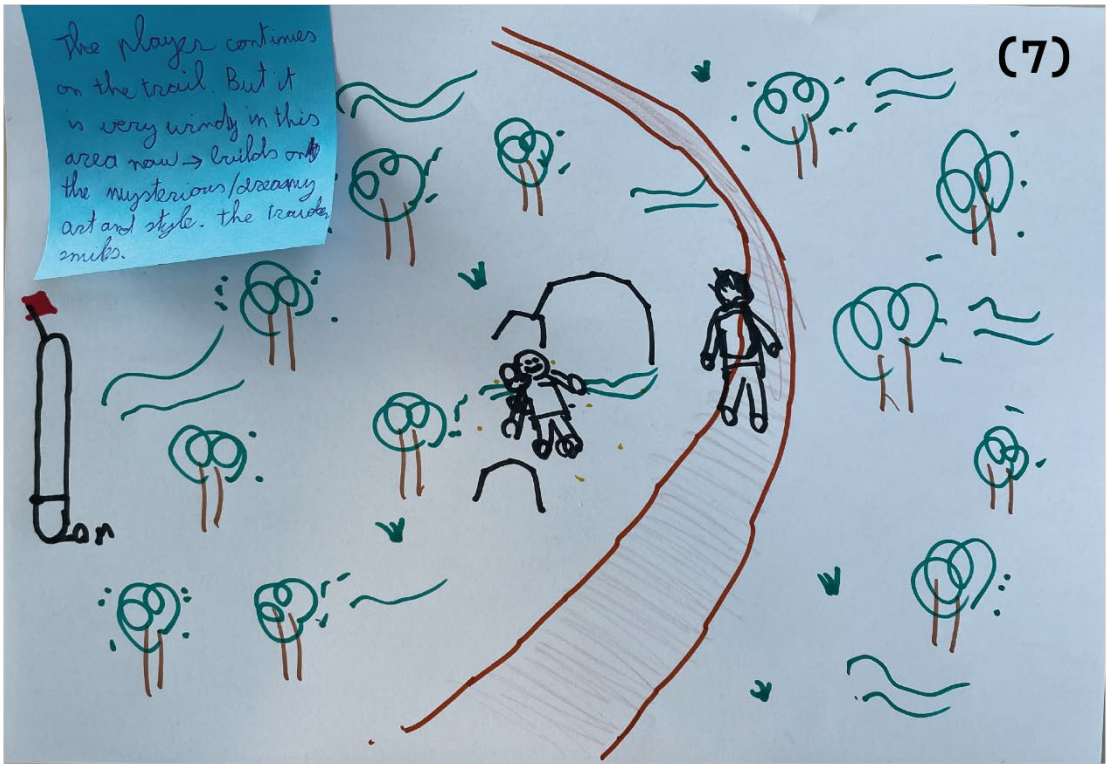

(2)
Player follows a trail to the mountain
- trees
- grass

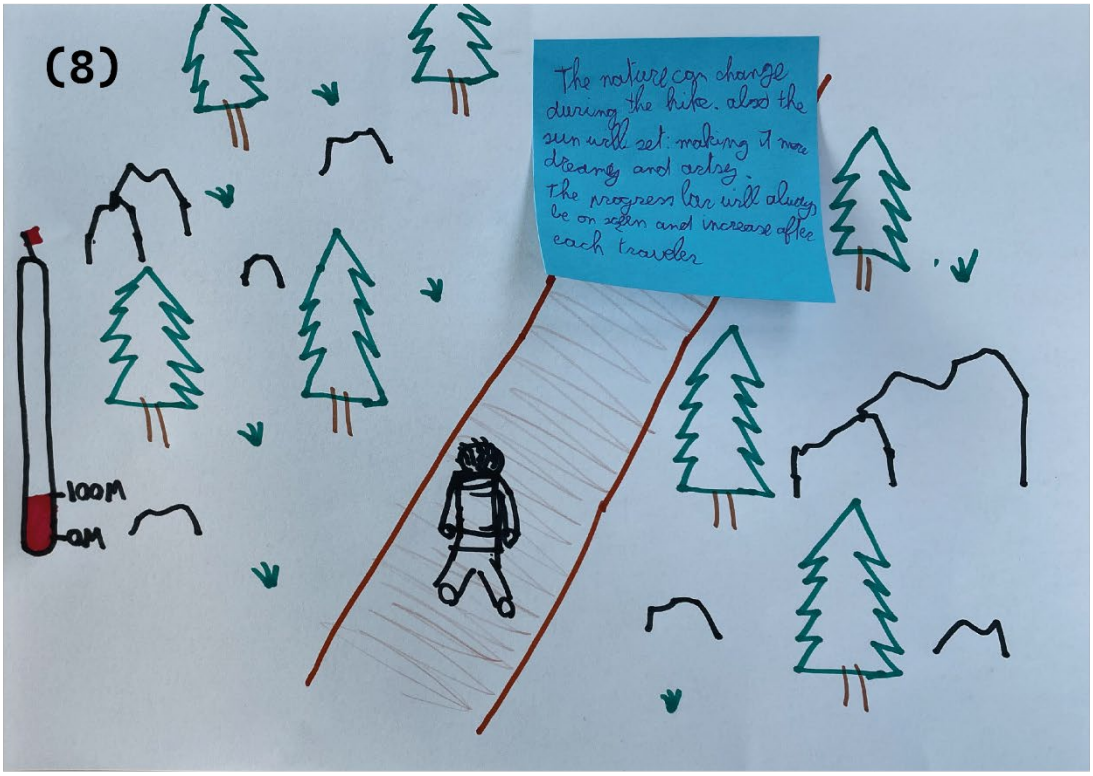

(3)
Player find another traveller that wants to talk
or

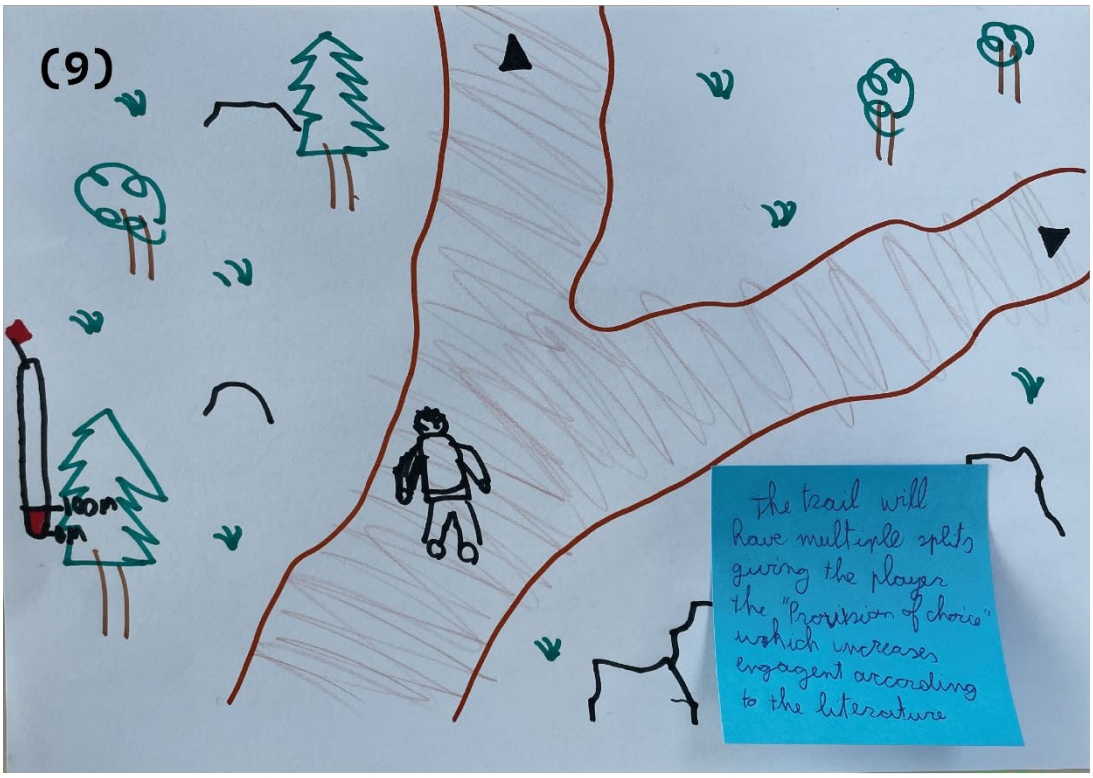

(4)
The traveler tells a dreamy story
Some text

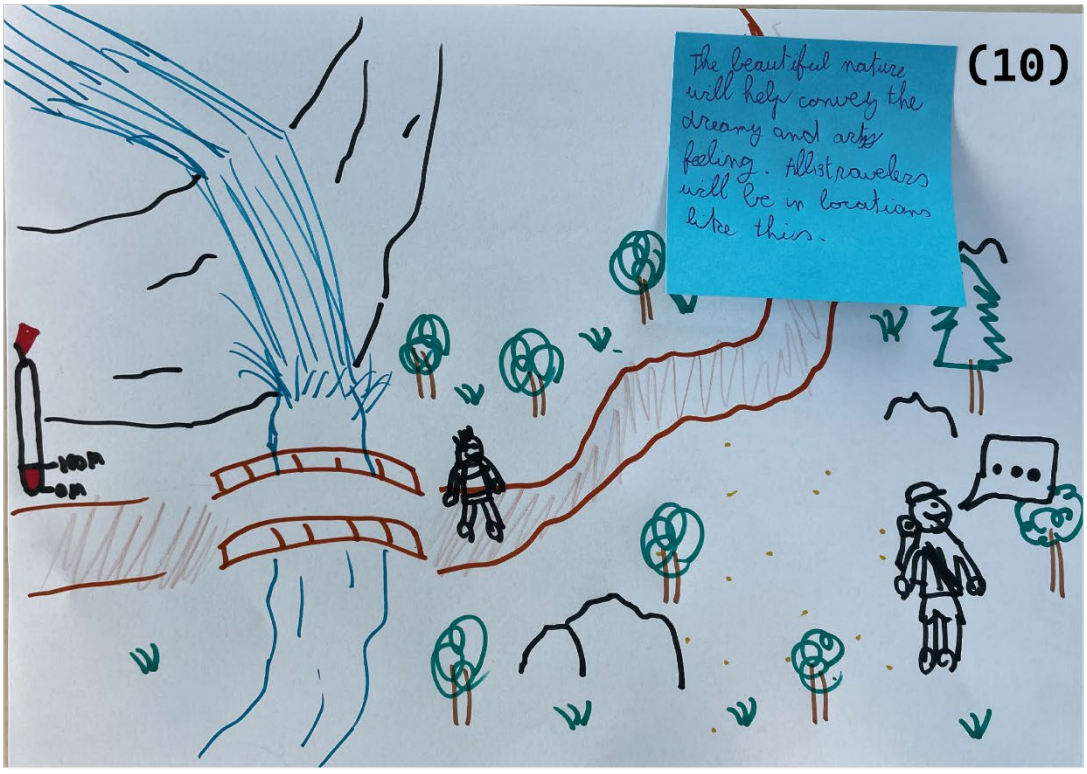

(5)
LISTEN TO THE SENTENCE
The traveler say the hearing test sentence. The wind will be the noise. It will be dreamy and a lot mysterious

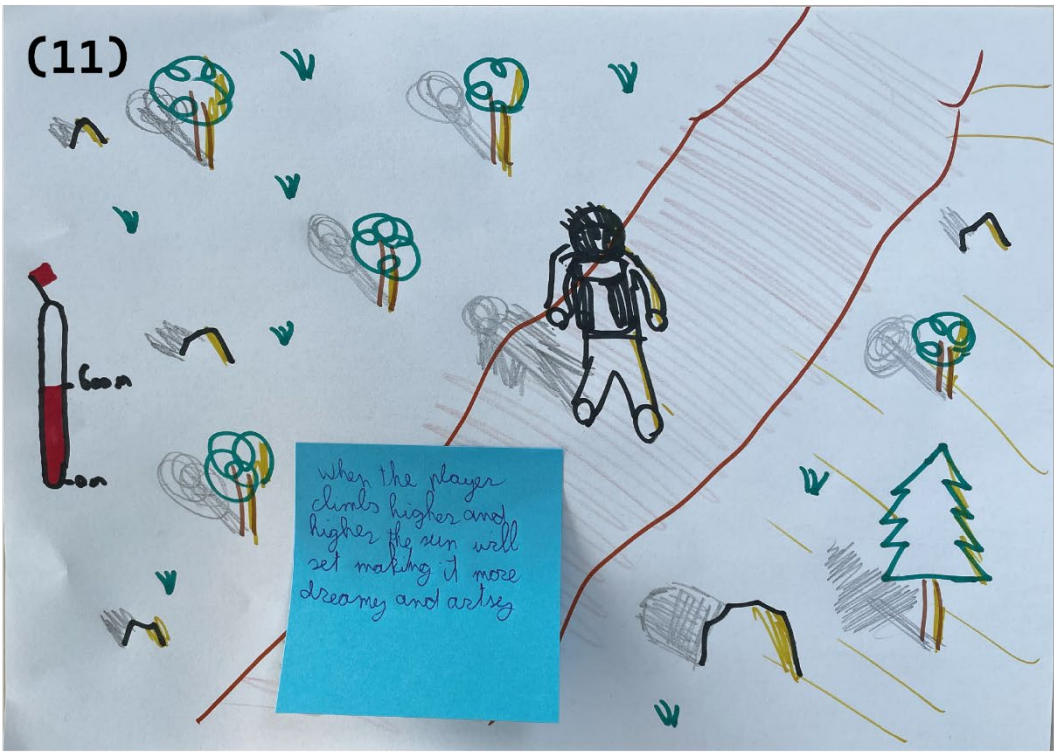

(6)
REPEAT THE SENTENCE
The player repeat the sentence in real life into their sound recorder in the game. The background will be library during this scene


The player continues on the trail. But it is very windy in this area now → builds on the mysterious/dreamy art and style. the travelers smile.
(7)


(8)
The nature can change during the hike. also the sun will set making it more dreamy and artsy.
The progress bar will always be on screen and increase after each traveler
100M
0M


(9)
The trail will have multiple splits giving the player the "Provision of choice" which increases engagent according to the literature


(10)
The beautiful nature will help convey the dreamy and arty feeling. All 3 travelers will be in locations like this.


(11)
600m
0m
When the player climbs higher and higher the sun will set making it more dreamy and artsy


(12)
1500 m
0m
There is a grave on top of the mountain. At the highest points its also dark already the nothern light and the stars feel dreamy. This the end of the game

Appendix C: Personas

Two personas are made to illustrate the use of the hearing test game.

Persona 1

Jens Wieffer

Age: 52
Education: Civil Engineering HBO
Occupation: High School Science Teacher
Location: Rotterdam, Netherlands

Teacher with hearing loss

Jens is a teacher at a high school in Rotterdam. A few years ago, he started to notice he was unable to hear all of his students' questions, especially those in the back of the classroom. He is concerned he might not be able to perform his profession if he does not find help. So after discussing this with his wife, he seeks aid at the Amsterdam UMC where he conducts frequent hearing tests to get advice and help from the doctors at the hospital. The frequent hearing tests are quite repetitive and do not capture his real daily life listening problems, he thinks.

Frustrations

- Hearing loss makes teaching difficult
- Frequent boring hearing tests
- Advice given doesn't help in daily life

Motivation

- Wants to keep teaching
- Wants to get help with his hearing loss

Persona 2

Karlijn Slot

Age: 41
Education: PhD Audiology
Occupation: Audiologist Amsterdam UMC
Location: Amsterdam, Netherlands

Teacher with hearing loss

Karlijn is working at the Amsterdam UMC and is specialised at audiology. She is often the person who helps the patients to conduct a hearing test. After these tests, Karlijn gives the patients advice to help them face their hearing loss. She has a lot of experience in this topic, but the laboratory hearing tests make it difficult for her to give effective advice from time to time. She is looking into ways to make the current hearing test simulate the real world more.

Frustrations

- Advices are not always helping

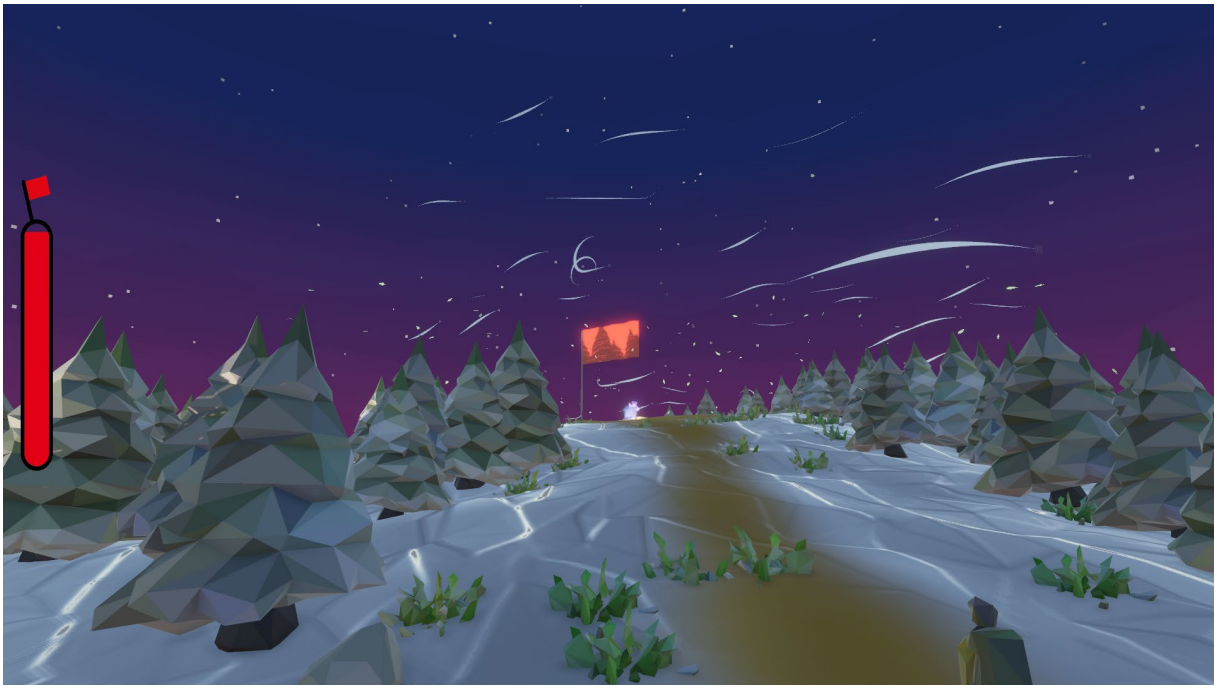
Motivation

- Wants to help people
- Want to use new hearing tests

Appendix D: More screenshots of the game

In this section, more screenshots of the game environment will be shown, to illustrate the art style.


LUISTER NAAR DE ZIN

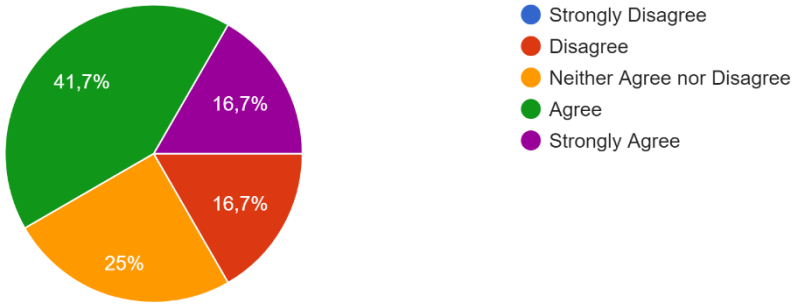


Appendix E: Survey results per question

In this Appendix, the results of the playtesting survey will be shown per question. The survey was conducted in Google Forms in random order of questions.

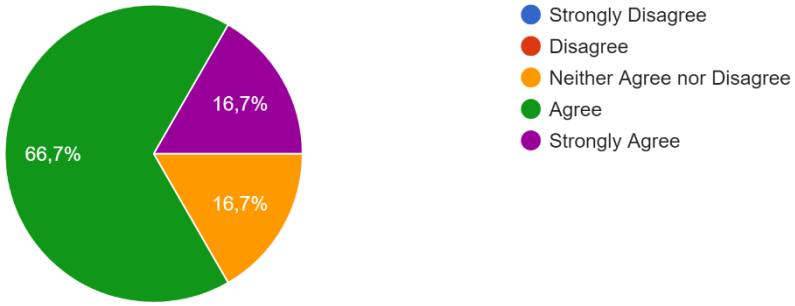
I lost myself in this experience

12 antwoorden



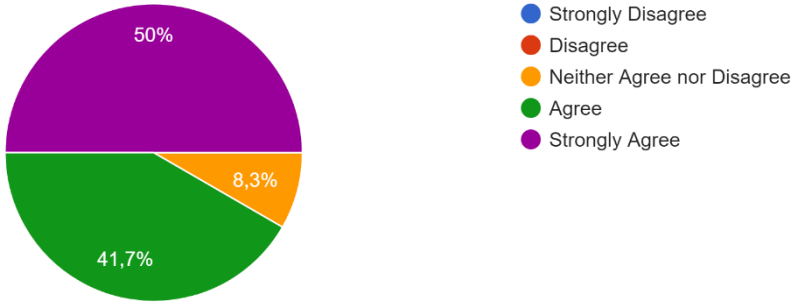
The time I spent in the game just slipped away

12 antwoorden



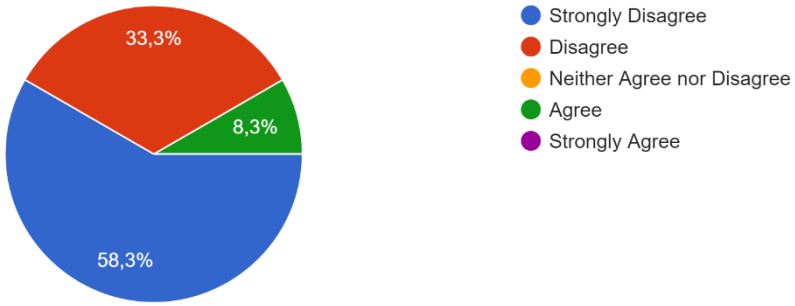
I was absorbed in this experience

12 antwoorden



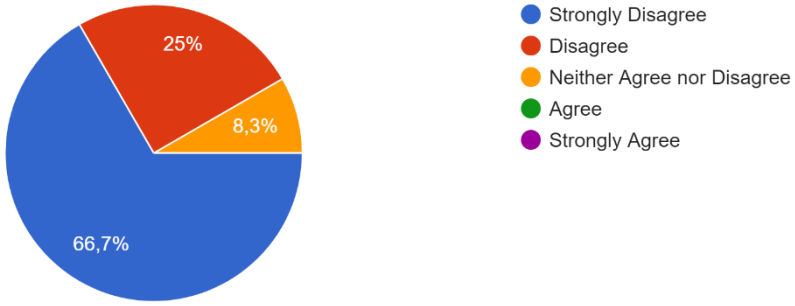
I felt frustrated while playing the game

12 antwoorden



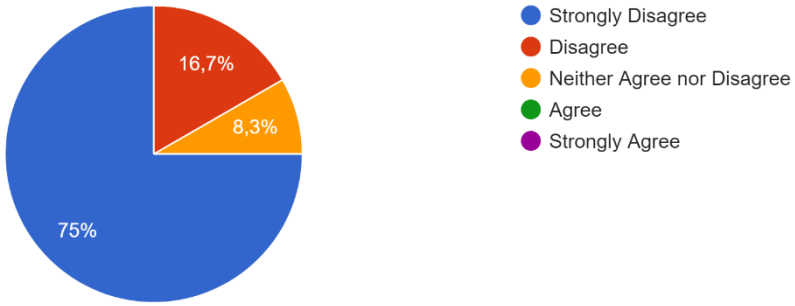
I found the game confusing to use

12 antwoorden



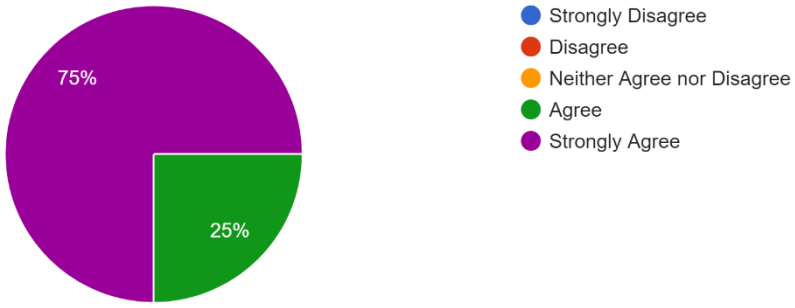
Playing this game was physically demanding

12 antwoorden



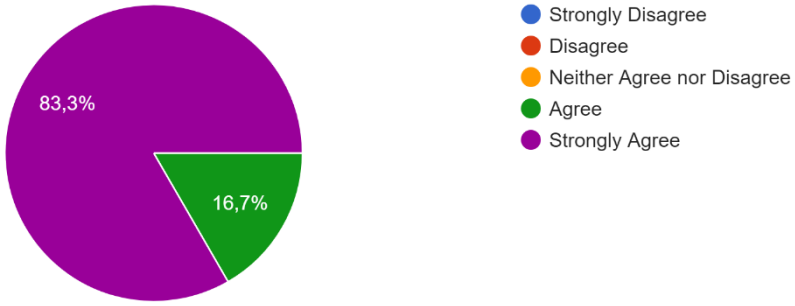
The artstyle of the game was attractive

12 antwoorden



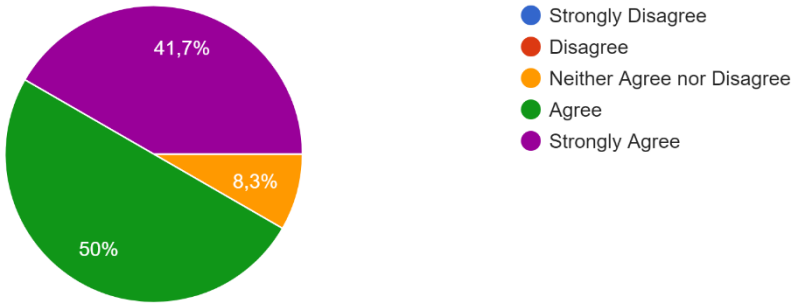
The game was aesthetically appealing

12 antwoorden



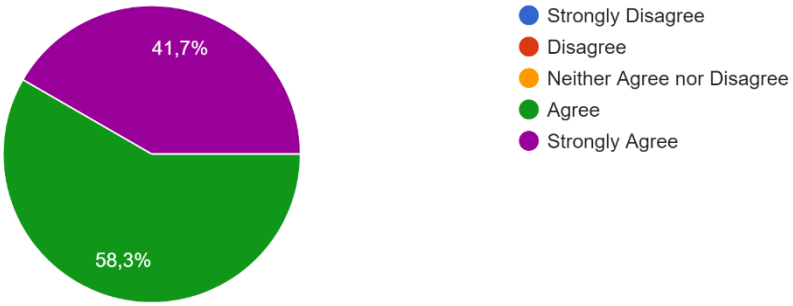
The game appealed to my senses

12 antwoorden



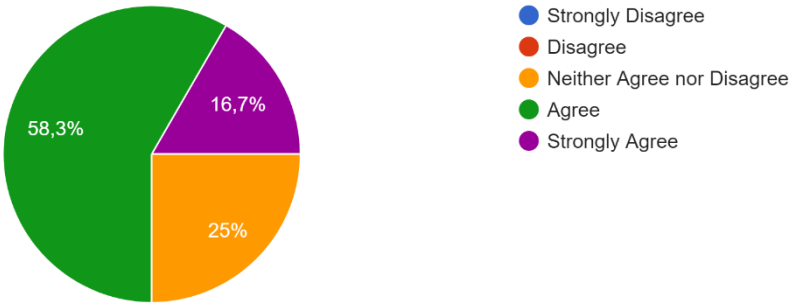
Playing the game was worthwhile

12 antwoorden



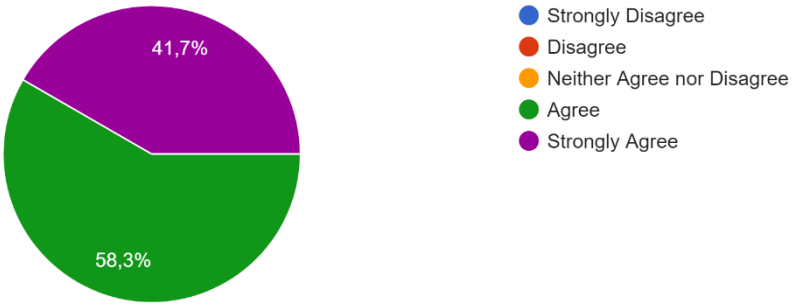
My experience was rewarding

12 antwoorden



I felt interested in this experience

12 antwoorden



References

[1] Versfeld, N., Daalder, L., Festen, J., Houtgast, T. (2000). Method for the selection of sentence materials for efficient measurement of the speech reception threshold. *The Journal of the Acoustical Society of America.* 107. 1671-1684. https://doi.org/10.1121/1.428451

[2] Deterding, S., Dixon, D., Khaled, R., Nacke, L. (2011). From game design elements to gamefulness: defining "gamification". *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments.* 9-15. https://doi.org/10.1145/2181037.2181040

[3] Libbi, C.A. (2021). When life gives you lemons : designing a game with and for autistic girls. https://purl.utwente.nl/essays/88356

[4] Bitrián, P., Buil, I., Catalán, S. (2021). Enhancing user engagement: The role of gamification in mobile apps. *Journal of Business Research*, volume 132, 170-185. https://doi.org/10.1016/j.jbusres.2021.04.028.

[5] Wang, X., Goh, D., Lim, E., Liang, A., Chua, A. (2017). Examining the Effectiveness of Gamification in Human Computation. *International Journal of Human-Computer Interaction*. 33. http://dx.doi.org/10.1080/10447318.2017.1287458

[6] Huotari, K., Hamari, J. (2017). A definition for gamification: anchoring gamification in the service marketing literature. *Electron Markets 27*, 21–31. https://doi.org/10.1007/s12525-015-0212-z

[7] Walsh, A. (2014). The Potential for Using Gamification in Academic Libraries in Order to Increase Student Engagement and Achievement. *Nordic Journal of Information Literacy in Higher Education*, 6(1), 39–51. https://doi.org/10.15845/noril.v6i1.214

[8] https://bootcamp.uxdesign.cc/starbucks-gamifying-the-coffee-buying-experience-212acc6b40eb

[9] Kniestedt, I. (2023). Engagement in Applied Games. *https://doi.org/10.4233/uuid:e6fedd21-5130-4311-a4bd-e1d5a87b89ec*

[10] Kuipers, D., Wartena, B., Dijkstra, A., Prins, J., Pierie, J. (2013). Design for Transfer. *International Conference on Serious Games Development and Applications*. 8101. 239-246. http://dx.doi.org/10.1007/978-3-642-40790-1_23

[11] Sardi, L., Idri, A., Fernández-Alemán, J. L., (2017). *A systematic review of gamification in e-Health. Journal of Biomedical Informatics*, Volume 71, 31-48. https://doi.org/10.1016/j.jbi.2017.05.011

[12] Whyte, E.M., Smyth, J.M. & Scherf, K.S. (2015). Designing Serious Game Interventions for Individuals with Autism. *J Autism Dev Disord* 45, 3820–383. https://doi.org/10.1007/s10803-014-2333-1

[13] "Microsoft Flight Simulator." [Online]. Available: https://www.flightsimulator.com/

[14] O'Brien, H.L., Toms, E.G. (2010). The development and evaluation of a survey to measure user engagement. *Journal of the American Society for Information Science and Technology*., 61: 50-69. https://doi.org/10.1002/asi.21229

[15] O'Brien, H.L., Cairns, P., Hall, M. (2018). A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. *International Journal of Human-Computer Studies,* 112. 28-39. https://doi.org/10.1016/j.ijhcs.2018.01.004

[16] “Zombies, Run!” [Online]. Available: https://zrx.app/zombies

[17] “How To Use Leaderboards to Socially Reinforce Performance Results | Authentic Recognition.” (2022, April 22). [Online]. Available: https://authenticrecognition.com/how-to-use-leaderboards-to-socially-reinforce-performance-results/

[18] “How to Create a Mii.” *Nintendo of Europe AG*. [Online]. Available: https://www.nintendo.com/en-gb/Support/Nintendo-Switch/How-to-Create-a-Mii-1497985.html

[19] Andrade C. (2018). Internal, External, and Ecological Validity in Research Design, Conduct, and Evaluation. *Indian journal of psychological medicine*, 40(5), 498–499. https://doi.org/10.4103/IJPSYM.IJPSYM_334_18

[20] Weisser, A., Buchholz, J., Oreinos, C., Badajoz-Davila, J., Galloway, J., Beechey, T., Keidser,G., (2019). The Ambisonic Recordings of Typical Environments (ARTE) Database. *Acta Acustica united with Acustica*. 105. 695-713. http://dx.doi.org/10.3813/AAA.919349

[21] Plomp, R., and Mimpen, A. M. (1979). Improving the reliability of testing the speech reception threshold for sentences. *Audiology.* 18, 43–52. https://doi.org/10.3109/00206097909072618

[22] Pielage, H., Plain, B.J., Saunders, G.H., Versveld, N.J., Lunner, T., Kramer, S.E., Zekveld, A.A. (2023). Copresence Was Found to Be Related to Some Pupil Measures in Persons With Hearing Loss While They Performed a Speech-in-Noise Task. *Ear and Hearing 44(5):p 1190-1201. https://doi.org/10.1097/aud.0000000000001361*

[23] Seol, H., Kang, S., Lim, J., Hong, S., Moon, I. (2021). Feasibility of Virtual Reality Audiological Testing: Prospective Study. *JMIR Serious Games 2021.* https://doi.org/10.2196/26976

[24] “EarGames 3D Audio Games.” *Eargames*. [Online]. Available: https://www.eargames.com/

[25] Sergiy Korchan. (2021). “Functional Ear Trainer.” *App Store.* [Online]. Available: https://apps.apple.com/nl/app/functional-ear-trainer/id1088761926?platform=iphone

[26] “Hearing Test App | Hearing Loss & Auditory Processing Issues.” [Online]. Available: https://www.soundscouts.com/en-gb/

[27] “Sonification Sandbox.” [Online]. Available: http://sonify.psych.gatech.edu/research/sonification_sandbox/

[28] Mader A.H. and Eggink W. (2014). “A Design Process For Creative Technology”, *Proceedings of the 16th International conference on engineering and product design education*, Enschede, The Netherlands, pp. 568-573. https://research.utwente.nl/en/publications/a-design-process-for-creative-technology

[29] “Lucidspark | Virtual Whiteboard Where Ideas Ignite.”[Online]. Available: http://www.lucidspark.com/

[30] “How to Make a Visual Novel Game in 10 Minutes – Python Ren’Py Tutorial.” (2021, June 22). *FreeCodeCamp.org.* [Online]. Available: https://www.freecodecamp.org/news/use-python-to-create-a-visual-novel/

[31] “Unity.” [Online]. Available: https://unity.com/

[32] “Meshy.” [Online]. Available: https://www.meshy.ai/

[33] “Mixamo.” [Online]. Available: https://www.mixamo.com/#/

[34] “REAPER”. [Online]. Available: https://www.reaper.fm/

[35] Schell, J. (2020) The Art of Game Design: A book of lenses. *Boca Raton: CRC Press*.