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Interactivity in Digital Storytelling: An Influencing Factor of Quality of Experience

Master thesis in Electronic Systems Design
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Preface

This thesis is submitted to fullfill the requirements for a Master of Science (MSc) degree at the Norwegian University of Science and Technology (NTNU). The work related to this thesis has been done over the course of five months, from January to June 2020, and was supervised by Professor Andrew Perkis, and co-supervised by Research Assistant Øyvind Sørdal Klungre.

I would like to thank both of my supervisors, for providing valuable feedback and guidance, especially during the COVID-19 pandemic period, when everything had become different and more challenging. I would also like to thank iTrollheimen AS, for providing the storyboard and the audio story file. So the application could be built without much hassles. Also thanks Nord Universitet, for providing the stunning troll model used in the application. Lastly, I would like to thank my husband Antoine R. M. Dalod for being very supportive, during the writing period of the thesis.

Summary

Storytelling has always existed in human culture, and it has applications in many areas, including tourism and education. In recent years, thanks to the rapid development of technologies, digital tools have become part of the storytelling process, and digital storytelling is thus made possible. Interactive narratives are commonly found in digital storytelling, in which participants can become part of the story, play an active role, alter the path of the story, or generate their own contents and leave an impact on the story.

Tourism is one of the areas that could benefit from location based digital storytelling. It enriches tourist destinations, and provides an experience that is tightly connected to the specific locations.

An augmented reality (AR) application on a mobile device, was developed in Unity. It is built based on the previous prototype that tells a simple troll story in Trollheimen. In this prototype, only GPS data is used, to collect the location information of the mobile device. The application displays different media content based on the location information. The story of this prototype is improved, with more contents, and new ways of interaction and implementation. Some of the story contents were provided by iTrollheimen, and Nord Universitet.

This prototype was used to conduct experiments for proving the hypothesis: richer interactivity leads to a better Quality of Experience (QoE) in digital storytelling. 18 participants were recruited to take part in the experiments. Two variations of the prototype were made, one with richer interactivity while the other with reduced options of interaction. The participants were split up into 2 groups, and each group did the experiments with one version of the prototype. The results indicate that the richer interactivity prototype offered better Quality of Experience to the users.

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1. Background and motivation

1.1 Description of the project

Storytelling has always existed in human society. Thanks to the rapid development of technologies, digital tools have been included in the storytelling process, and the possibilities for more effective ways of telling stories are opened. There exists applications such as interactive books [16], or immersive experiences for museum and tourist sites [35][43]. With the Global Positioning System (GPS) function found in most mobile devices nowadays, the potential of location based applications are able to realized, and more and more of the applications are coming into the market. Examples of location based applications included but not limited to: location based tourists game in Porto [32], *Thirty Years War*, a location based educative application [13], *U-Kangnam*, a location based service application in Korea [21], etc. Digital tools has enabled new ways for storytelling, such as digital storytelling. Users could actively take part in the story, make decisions and actively affect how the story develops [41][37]. Grater level of interactivity is made possible, which the narrative is often non-linear [14][13].

Quality of Experience (QoE) [10] as concept has been long used in multimedia system assessment [45], its use is further increased, with the rising of augmented/virtual/mixed reality applications. QoE could be measure subjectively, or objectively [9] [31] [24] [40] [42].

This is a project provided by the company iTrollheimen, that looks at an interactive solution using augmented reality to tell Norwegian troll stories to tourists in the Trollheimen area. The project is an AR application on a mobile device, developed in Unity. It is developed based on a first prototype, prototype 1.0, made by Klungre [22], and the second prototype, prototype 1.5, made by Dalod [15]. Prototype 1.0 used motion capture to get the location information of the testing device in a room. Different media contents were played based on where the device was located. Image tracking was used so that corresponding contents were presented when different target images were scanned. Prototype 1.5 brought prototype 1.0

to an outdoor environment, and explored the methodology to utilize only GPS information, in order to build location based story. The prototype built for this project, numbered 2.0, aimed to improve the implementation of the location based troll story. There were flaws previously existed in prototype 1.5, which could significantly affect the Quality of Experience of the users in a negative way. This was overcome by introducing a scene management system, developed in Unity. The stability of the system was improved, and more story contents were added. Lastly, new ways of interaction were introduced and implemented.

1.2 Objectives of the thesis

It was shown by many research that, interactivity is a QoE influencing factor [45] [44] [25]. Lomardo and Damiano [25] also stated that, a higher level of interactivity, might have a negative effect for the characters.

A research question was thus brought up:

How does the system's interactivity level correlate with the users' Quality of Experience (QoE) in digital storytelling?

In this project, the relationship between QoE and interactivity was investigated, and a hypothesis related to the research questions was formulated:

Richer interactivity improves users Quality of Experience in digital storytelling.

2. Introduction

2.1 Digital storytelling

Storytelling as a methodology to convey information, has existed as long as there have been humans. Humans passed down information by telling each other stories, long before the creation of the writing system. It utilizes narratives to transmit information into reality, it is also a good tool in interaction, education and instruction [5][16], and it has evolved during past years. With the rapid development of new technologies, along with the innovation in graphic and computing, new opportunities have opened for new ways of telling stories.

Digital tools have been applied to storytelling as a mean in the storytelling process. Digital stories can be presented in mobile devices, or exists in a form such as interactive books like Living books [16], or be used to create an immersive experience in tourist sites and museums [35][43]. In the past years, digital storytelling has seen mainly two approaches. The first is based on stories found in traditional media, such as books and films, where the stories are often linear, but presented in a digital format. The other approach focuses on greater interactivity, which is often non linear [14][13]. Interactive narrative is an important part of digital storytelling. Ryan [36] discussed the design of interactive narrative, and the roles played by the users in these cases. For example, in a goal oriented type of plot, many users enjoy the role of being observers. In another study, Ryan [38] discussed four types of interactivity and their combinations: internal, external, exploratory and ontological, and many of them are only made possible by using digital tools. Compared with traditional narrative, the audiences are now given an active role, allowed to join the story, positively affect the story path and leave an impact [41][37], thus creating a different experience for different audiences. An example of how the audiences join and affect the story, can be seen in this commercial application of digital storytelling, *Converse Gallery* [4]. Consumers were encouraged by the sports brand Converse, to make short videos containing the spirits of the brand from their personal stories. All these stories formed one big story, and it was constantly changing, as more and more of the videos were made.

2.2 Location based media

Location based media present different contents based on the user location. It has been seen in applications such as the mobile game Pokemon Go, which utilizes location information, and guides the user through streets in the physical world to search for the next monster. In tourism, location based media provides an enriched experience, increase the interaction between the audience and tourist artifacts [21], and could possibly help in preserving culture heritage [25]. There is also potential in education. For example, *Thirty Years War* is a prototype, that aims at teaching the historical events happened in Heidelberg in Germany, in the castle of Heidelberg [13]. Because the users are often actively moving around in physical locations, it is required that the narrative need to match the users movements [25].

It is asserted by Barbas [7] that the reason why location based media often results in a unique experience, is due to the mixing of the users personal imaginary, and the collective imaginary. It is stated by Azuma [5] that, location based storytelling has the advantage of "complement the reality that exists at chosen site", as it creates an experience that's strongly tied to the specific location. In an outdoor environment, it is common to use GPS as a mean to track locations, however due to its possible poor performance in urban settings, the use of model tracking to help determining location has also been implemented [8] [34]. Indoor use of location based media requires other method such as motion capture to detect the precise location of the user.

One of the challenges for location based storytelling is that unlike other forms of storytelling, it requires the user to be present physically on site in order to get the full experience. It is thus important that the storytelling experiences are compelling enough, in order to motivate the users to participate [5]. Similar to why people still go to movie theaters, even though the same materials could be easily accessed from other means. For many tourism applications, this is naturally solved, since the participants are already on site.

2.3 Augmented reality

Augmented reality (AR) is a digital tool that can be used to enhance digital stories. There are two main ways to present AR content:

- Marker based AR

Requires the use of a target image/object or QR code to act as a marker, and AR objects are triggered when such markers are scanned.

- Markerless AR

Without the use of image/object tracking, use camera and algorithm to decide where to overlay 3D content into a scene. AR applications need a high precision for creating a seamless overlay [6], it is common to use hybrid tracking, such as GPS and other sensors, to decide where the objects should appear. For outdoor applications, the use of visual cues for improving tracking has also be proposed [17] [39].

Interactive storytelling in AR offers a bridge connecting the virtual world and the physical world. The interaction allows that the actions and decisions of the users is shown by augmenting the real world [33]. It was shown in that the use of AR enhancement improved the user experience [27], especially when it is customized for each individual user.

Unlocking Porto is a location based, AR storytelling game for tourists in Porto, Portugal [32]. The main focus of the game was to create more engagement between the tourists and the urban environment. The main narrative is around the city of Porto and its wine production tradition, but the narrative also adapts itself based on the location of the user. The user can start the game anywhere in the city, choose to either follow or ignore the path generated by the app, while discovering the city. When approaching main sights of the city, the user can enter either the AR mode, or unlock a mini game. The game eventually leads the user to the goal of the story, located at the wine cellars in Porto. Figure 2.1 shows the city of Porto, and the game interface.

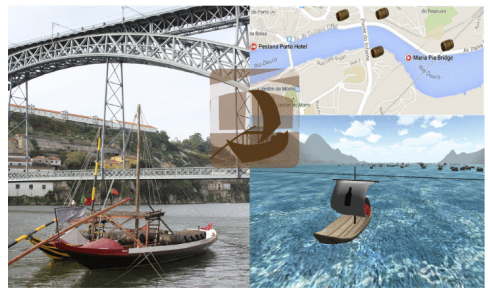

Figure 2.1: Location based game in Porto [32]

2.4 Quality of experience

Quality of Experience (QoE) is often misunderstood as Quality of Service (QoS) [30]. In the 90s, QoS was used to find out how satisfied the users were with the multimedia services and systems. Metrics that could be quantified, were chosen

for QoS measurements, such as frame rates and resolution. However, these metrics were often not able to represent user satisfaction [9]. As the users could still be not satisfied with the services, while the QoS score was high. The concept of QoE thus started to emerged, and the focus was shift to how users perceived the quantified quality of media [46].

The use of QoE to measure multimedia systems, is increased as the rising of augmented/virtual/mixed reality applications [45]. The concept of QoE consists of many concepts from other Fields, such as human-computer interaction, behavioral sciences and economics [26] [11]. Many definitions of QoE have been proposed before, such as those by institutions like ITU-T, ETSI, and Nokia [2] [3] [30].

In 2013, the underlying concepts of QoE was discussed in The Qualinet White Paper [10], and a working definition was proposed as "Quality of Experience (QoE) is the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and / or enjoyment of the application or service in the light of the user's personality and current state."

3. Methodologies

This project, Home of the Trolls, is a location-based, AR application made in Unity for iPadOS, and it is installed and run on an iPad. There is an eternal GPS device, Bad Elf GPS, attached to the iPad via the lightning port, for providing GPS information. Corresponding scenes and stories are activated and loaded, based on the received GPS information about where the users are presented. The users are able to interact with the story at each location.

Because the study is about interactivity's effect in digital storytelling, two different versions of the application were made. One provides minimum level of interactivity, while the other version offers more interaction choices. Details about the differences between these two can be found in Chapter 4.3.

3.1 Hardware and software

The hardware devices and software used for this study are presented in this section.

3.1.1 Unity

Unity is a cross-platform game engine developed by Unity Technologies. It is the world's most used 3D development platform, providing interactive content developers various tools, and the ability of rapid editing in application development. Unity does not feature 3D model building and editing. 3D models can thus be acquired either from Unity Asset Store, or importing from other 3D modeling software.

3.1.2 AR Foundation

AR foundation is a framework by Unity. It includes the core features shared by augmented reality development kits for different platforms, such as ARKit, ARCore, Magic Leap and HoloLens. In addition, features unique to Unity are also included. It allows an easy cross-platform AR application development. In order to deploy the application to the target platform, a separate package must be installed, for example, ARKit unity plugin for iOS platform.

3.1.3 ARKit

ARKit is an AR platform for iOS by Apple. By utilising the device's camera and sensors, applications produced using ARKit are able to interact with the real world, and create a more immersive experience.

ARKit is available as a plugin for Unity, combined with Unity's AR Foundation package, developers have the ability to access features supported by ARKit in Unity. Together they ensure an easy-creating AR experience with Unity for iOS.

3.1.4 iPad (5th generation)

The fifth-generation iPad is a tablet designed by Apple. It has a 9.7 inch screen, 2GB Ram and an A9 processor with embedded Apple A9 co-processor.

The iPad used for this study is provided by iTrollheimen AS. It is a WiFi model, and does not include the GPS module. Even though it has the ability to triangulate location information based on WiFi, it is usually not very accurate, also WiFi is not always available outdoors. This is solved by using an external GPS device, Bad Elf GPS for lightning connector.

3.1.5 Bad Elf GPS for lightning connector

The Bad Elf GPS for lightning connector provides an instant GPS support to the WiFi model iPad by simply plugging the device into the lightning port, without the need to go through extra configuration. Neither internet connection nor monthly subscription is required to use this service.

3.2 Storyboard

This project, Home of the Trolls, tells a fictional story about the trolls who reside in the Trollheimen area. The interactive story consists of 7 scenes, which correspond to 7 outdoor locations in Trollheimen. These scenes are linked together such that one scene leads to another. The story tells that the magical raven stones of the three trolls, Fausk, Minill and Fold, were taken by the twin trolls Boll and Bulu, and how these stones were found and brought back to their owners.

The storyboard is created and provided by iTrollheimen AS, a summary of each scene is described in the sections below.

3.2.1 Scene 1 - Welcome to Trollheimen

Trollheimen is one of the oldest area in the country, and here is where everything started. The trolls have been here longer than any of us. They are the guardians of the nature, each troll has different roll in animal and ecological processes. The

reasons why they can not be seen is because of the raven stone.

3.2.2 Scene 2 - Fausk

Fausk is angry and upset, his raven stone was taken by the twin trolls Boll and Bulu, who like to cause naughty and playful troubles. Fausk is responsible for deciding if the trees in Trollheimen are too old to live, and breaks them down into nutrition for new lives. Fausk is worried that he can not go out to work now, he then asks the help from the guests, who enter the world of trolls through this journey. Fausk wishes the guests can help finding the twin trolls, he points the direction to Minill, who is the mother of the twin trolls.

3.2.3 Scene 3 - Minill

Minill is watering a marsh. She is married to the king troll Fold, and mother of the twin trolls Boll and Bulu. She waters the marshes by twisting her hair, water drips down and keeps the humidity of the wetlands.

When she heard the shouting of Fausk, she immediately thought of the twins and their tricks. She also found out that her raven stone was taken. She suggests that the guests should go look for the father troll, Fold, for help.

3.2.4 Scene 4 - Fold

Fold is the king of the trolls, and the most powerful of them all. The birch mouse is a specie only found in Trollheimen, they gather and report information for Fold, so Fold is always the first to know about everything.

Fold already heard from the birch mouse that the guests were looking for the twin trolls. He tells the guests that his raven stone was also stolen, and he would be very appreciated that if the guests could find the twin trolls. Fold believes that Boll and Bulu are hidden in their secret cave.

3.2.5 Scene 5 - Bulu

Bulu is sitting behind a tree, he is surprised that the guests found him. Bulu says Boll and he planned to hide all the raven stones, so they could go out by themselves without the grown-ups. However, when they were hiding the stones, Boll was stuck in the hole they prepared for the chest.

3.2.6 Scene 6 - Boll and Bulu

Boll is stuck in the hole, he is calling for help.

Both the guests and Bulu help dragging Boll out of the hole. In return, Boll wishes to give the raven stones to the guests, but Bulu disagrees.

At the end, both the trolls agree that the guests could win back the stones by playing some games together.

3.2.7 Scene 7 - End

Fold appears again. He thanks the guests for their help and awards them with medals. Fold continues with a little more information about Trollheimen, and how they can now continue their job in the area.

3.3 Locations

An outdoor area located in the Norwegian University of Science and Technology (NTNU), Gløshaugen campus is defined and chosen for conducting this experiment. A path within the area is defined, as well as seven points of interests (POI) that correspond to the seven scenes in the storyboard. It is important to make sure that the POIs are at least 20 meters away from each other, due to the possible conflicts between scenes caused by the low precision of GPS. A map of the area, with the seven POIs marked, can be seen in Figure 3.1.

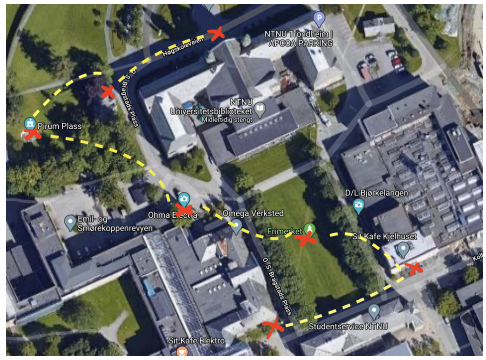

Figure 3.1: Map of the defined area in NTNU

Because the application uses GPS coordinates to determine which scene to load, it is necessary to find out the GPS coordinates of the locations above. It was shown in reference [15] that the Bad Elf GPS device measurements match the GPS coordinates from Google Maps. The coordinates of the POIs are thus taken directly from Google Maps. A list of the POIs and their GPS coordinates can be seen in table 3.1.

3.4 Prototype details

A GPS hotspot function is made in Unity, with the variables set to public, users can easily set the spawned prefab, the GPS coordinates and the activation radius

Points of Interest	GPS Coordinates
Scene 1	63.4181732, 10.4025386
Scene 2	63.4184133, 10.4039934
Scene 3	63.4186051, 10.4027965
Scene 4	63.4187945, 10.4014875
Scene 5	63.4191104, 10.3998454
Scene 6	63.4193151, 10.4007043
Scene 7	63.4196188, 10.4018661

Table 3.1: List of the POIs and their GPS coordinates

in the inspector window. Figure 3.2 shows the interface of the script. Due to the limits of GPS precision, Activation Radius is set to 15 meter in order to achieve the desired result.

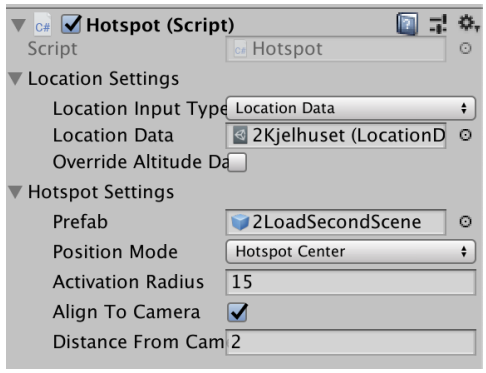

Figure 3.2: GPS Hotspot Script in Unity

When the device enters POI's activation region, the corresponding scene will be loaded. This is achieved by attaching a short scene loading script to the spawned prefab. The code can be seen in Appendix A.1.

3.4.1 Interactions: Scene 1 and 7

These two scenes aim at providing background information about Trollheimen. When the users are presented in location 1 and 7, different background music plays, the users can inspect the map, and read about some extra information if interested.

Because the experiment is conducted at NTNU, instead of in the Trollheimen area, an map of NTNU is used in this prototype.

The start page of scene 1 shows the map of NTNU, it is hand-drawn, as shown in Figure 3.3, to create an atmosphere that the users have entered the home of the trolls and will soon start the adventure. The users can also press the information button located at bottom left to access more information, as shown in Figure 3.4.

Figure 3.3: Start page of scene 1

Figure 3.4: Information page of scene 1

For scene 7, the users will be informed by the application that their journey has reached the end, as shown in Figure 3.5. More information about the area can be accessed by pressing the information button here.

3.4.2 Interactions: Scene 2 - 6

Scene 2 - 6 implemented the story as mentioned in Chapter 3.2. Each scene contains a different troll telling a piece of story. When the users enter the activation region for each scene, a troll indicator will appear in the screen, meaning that a piece of story is ready to be presented. Users can then choose a valid place to summon the troll by pressing anywhere in the screen. Any flat surface is considered as valid, such as ground, benches and tree stumps. Once the troll is placed by the

Figure 3.5: Start page of scene 7

users, if the users look at the troll by focusing the iPad camera on the troll model, a piece of story can be heard. The users have the option to reposition the trolls, as well as scale and rotate the trolls by touching the iPad screen. When the troll is telling the story, the volume of the background music is also reduced. The sound control is realized by the code in Appendix A.2.

The information button is presented at every scene, a map can be found here, as well as other information related to the troll story.

Figure 3.6 shows a troll indicator, after the camera has detected a possible valid placement. Figure 3.7 shows that after pressing the screen, the king troll Fold spawns at the place of the troll indicator. The spawning effect when tapping the screen, is realized by the code in Appendix A.3.

The Fold model is provided by Nord Universitet, the story told by Fold is provided by iTrollheimen. Other troll models used in the prototype are free assets from Unity store, and other stories are gibberish talking generated by the computer. They are used as placeholders, and will be replaced by the models made by Nord Universitet, and the audios by iTrollheimen in the future.

An overview of the elements appear in scene 2 - 6 can be seen in Table 3.2.

3.4.3 Alternative method: Object tracking

An alternative method for triggering each scene is also explored. There are others situations which is not ideal for getting accurate GPS signals, either the device has no build-in GPS module, or the GPS signal is weak. Under such circumstances, object markers can be used to replace GPS and achieve the same effect for this prototype.

Figure 3.6: Troll Indicator

Scene	Troll	Background Music	Troll Story
Scene 2	Fausk	Thunder Storm	Gibberish by computer
Scene 3	Minill	River Flowing	Gibberish by computer
Scene 4	Fold	Bird Chirping	by iTrollheimen
Scene 5	Bulu	Brook Waterfall	Gibberish by computer
Scene 6	Boll and Bulu	Sea Against Wall	Gibberish by computer

Table 3.2: Overview of elements appear in scenes 2 - 6

Any 3D object that fits the screen of a handheld device can be used as an object marker. Apple has developed a tool used for scanning objects and creating point cloud data, the tool and its documentation can be found in [1]. After importing the point cloud data to Unity, any prefab could be set to instantiate when the camera detects the object scanned in real environment. By attaching the script as mentioned in 3.2 to the prefab, any scene will be able to load.

By placing different 3D objects at the defined locations, the users will be able to load different scenes when different objects are scanned.

Figure 3.7: The king troll: Fold

3.4.4 Prototype Flexibility

This prototype provides a framework, that can be easily adapted to different locations for similar purposes. During the making of the prototype, multiple locations have been tested, other than the defined area at NTNU. These locations include POIs along a hiking trail in the wilderness, in the city center, in a suburban town etc. Scenes are able to load as long as there is GPS signal, without the need to have WiFi nearby. For using this prototype in another area, simply input the GPS coordinates in the associated game object in Unity.

3.5 Further work

For telling the complete troll story in Trollheimen, many aspects of the prototype can still be improved. The troll model and story placeholders can be replaced, once they are ready by Nord Universitet and iTrollheimen. Depends on the complexity of the story desired, methods combining GPS signal and object/image tracking can also be explored, for creating a richer story and interactivity.

4. Quality of Experience (QoE) experiments

4.1 Quality of Experience (QoE) measurements

QoE can be measured by subjective or objective methods. For subjective methods, data are collected directly from the user, in forms of questionnaires, interviews and self-evaluation etc. For objective methods, a model would need to be developed, and used to predict the QoE without subjective tests [9] [31] [24] [40] [42]. Due to the large parameters that need to be considered, for developing a model for objective testing, a subjective method was chosen to measure the QoE for this study, with the use of questionnaires, combined with observation of the participants during the experiments. ITU-T P.800 recommendation presented a methodology for conducting subjective tests [19]. When calculating QoE, Mean Opinion Score (MOS) is commonly used. It is traditionally used in telecommunication, to obtain the users' views of quality of the network [28]. The participants would answer the questionnaire, and grade their experience based on likert scale 1-5. Arithmetic mean would then be calculated for each question, and thus the data regarding the quality of experience were quantified and obtained.

In order to conduct the quality evaluation, 30 participants were planned initially. However, due to the COVID-19 situation in March and April 2019, the difficulty of having the planned number of experiments done had increased. At the end, a total of 18 participants were recruited to take part in the experiments, while ensuring all the health requirements set by the Norwegian Institute of Public Health (FHI) and NTNU were met.

To test the hypothesis, the participants were split up into two groups of 9, each group went through a different experiment setup, one with a reduced interactivity, the other one with richer interactivity.

The experiments were done individually with each participant. Before the experiment, the participants were required to read the introduction, and have the consent form signed, these documents can be seen in Appendix B. After the experiment, demographic information was collected, and each participant was asked to fill in a

questionnaire regarding his/her thoughts about the experience. The questionnaire B consists of 25 questions, each can be answered in a likert scale from 1 to 5. It is made based on the Core Elements of the Gaming Experience Questionnaire [12], Game Experience Questionnaire [18], and the questionnaire created by Klungre [22] to evaluate his prototype, which is the predecessor of the prototype used for this study. The questions were adjusted to better fit this study. Some questions regarding interactivity were added, while some questions that were less relevant were removed. The questionnaire can be divided into four parts:

- Immersion: Question 1, 2, 3, 5, 10, 19, 21
- Emotions: Question 4, 14, 15, 16, 17, 18, 20
- Usability and media: Question 11, 22, 23, 25
- Overall experience: Question 6, 7, 8, 9, 12, 13, 24

The order of the questions was randomized, when it's presented to the participants.

By computing MOS of each question, and compared them between the two experiment groups, results can be analyzed to see if the hypothesis stands. Raw data were collected using Google Forms, and MOS is calculated using Google Sheets. If the QoE of the richer interactivity group is higher, then the hypothesis is proven.

It is worth noting the possible drawbacks when applying this method for quality evaluation, since it is unknown how each participant views the distance between the alternatives for each questions, the results produced might be biased [20] [9] [29]. Also, participants might not interpret the questions in the same level, this would also affect the end results [23].

A research protocol and running plan B were written and approved, before conducting the experiments.

4.2 Demographic data

A total of 18 participants took part in the experiments. The gender distribution is shown in Figure 4.1, half of the participants were males, and the other half were females. Figure 4.2 displays the age group they belong to, majority of the participants (14) were in the range of 25-34 years old, only 4 participants were in the range of 18-24 years.

4.3 Experiment setup

This section describes the experiment procedure, and two different experiment setups: prototype with reduced and richer interactivity, in details.

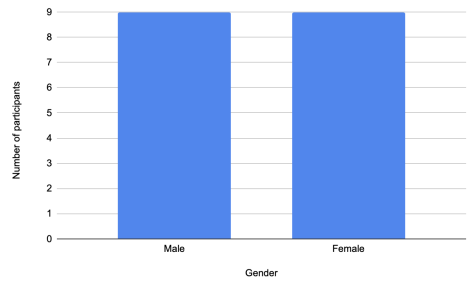

Figure 4.1: Gender distribution

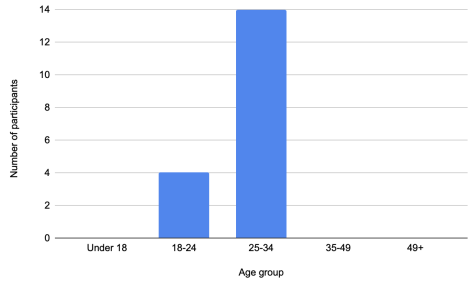

Figure 4.2: Age composition

The experiments were conducted the way, same as mentioned in the Running Plan B. Each participant received an iPad at the beginning, then walked along the predefined trail, and visited the predefined locations. A map of the trail with marked locations was included in the prototype application, the participant could look up the map conveniently anytime during the experiment. The participant used either the prototype with reduced interactivity, or the version with the richer interactivity. In both cases, the participant used the camera of the iPad to look for the troll story in each locations. The participant is accompanied by the responsible person the whole time, assistance and explanation were provided when needed.

4.3.1 Reduced interactivity

In this setup, there are only minimum interaction with the trolls. Once the users enter the areas which allow the placement of the trolls, the users can put down the troll, and the audio story will be initiated. However, the users are not able to rotate, scale and reposition the trolls as they wish. Most of the time, the trolls are appeared either too big or small, or too dark due to bad lightning. The audio story is only played, when the users focus the camera on the troll characters.

Figure 4.3 and 4.4 shows a common situation that happened, during experiments

with the reduced interactivity setup. Because the users were not able to adjust the size of the troll to fit the screen, the users often had to adjust themselves, in order to find the desired angle. The participant in 4.3 was interacting with the troll character, from a lower height. While in 4.4, because the troll character in this scene was naturally large compared with the real environment, the participant here interacted with the character by moving further away from the troll.

Figure 4.3: Experiment with the reduced interactivity prototype

4.3.2 Richer interactivity

In this set up, once the troll placement is unlocked, by the users entering the predefined locations, the users can adjust the troll, and place it at location they see fit by dragging, change its size so it fits the screen and the environment by zooming in and out, change the direction its facing to get the suitable lighting and shadow. The goal is to get the combination of size, direction that allows for the best presentation. The audio story is only played, when the users focus the camera on the troll characters.

The participant in Figure 4.5 was able to adjust the size of the troll character, so that it became suitable for taking a picture together.

Figure 4.4: Reduced interactivity prototype with a naturally larger troll character

Figure 4.5: Experiment with the richer interactivity prototype

5. Results and discussion

5.1 Results

The results from the survey is presented in this section. They are group into four different parts: immersion, emotions, usability and media, and overall experience. The MOS is plotted and presented using bar charts, with the 95 percent confidence intervals plotted as error bars.

The immersion part of the survey contains these questions:

- 1. Did the experience seem more like looking at the events/people on a movie screen or more like looking at the events/people through a window? (Like a movie screen - Like a window)
- 2. To what extent did you feel mentally immersed in the experience or distant from it? (Distant - Immersed)
- 3. To what extent did you feel you were part of the experience? (Uninvolved - Involved)
- 5. How much was the experience emotionally engaging? (Unemotional - Emotional)
- 10. Did you feel that you could explore things? (Could not explore - Could explore)
- 19. How easy was it to get back to reality after the experience? (Hard - Easy)
- 21.How strong was the sense of presence you felt during the experience? (Strong - Not strong)

Figure 5.1 displays the results from the immersion part. Because the data sample is rather small, the difference is not very significant. But it is still very clear that,

both question 2 and 5 indicates that the participants who did the reduced interactivity setup, were feeling less immersed, compared with the group with a richer interactivity. Questions 10 and 19 were also leaning towards the direction that, the richer setup is providing a slightly more immersed experience than the reduced interactivity group. In question 1 and 3, both groups scored about the same. Question 21 was an exception, which the reduced group outscored the richer group by a small margin. Overall, the results in this part favored the richer interactivity setup.

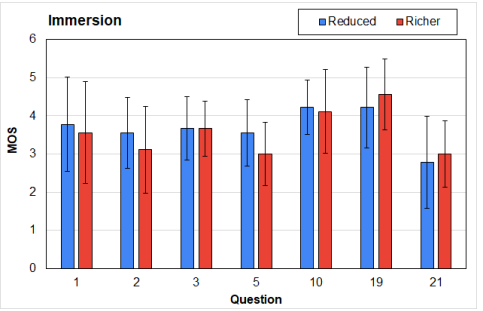

Figure 5.1: Immersion Results

The emotions part of the survey contains these questions:

- 4. How exciting was the experience? (Boring - Exciting)
- 14. How imaginative did you feel along the trail? (Unimaginative - Imaginative)
- 15. Did you feel free or pressured during the experience? (Pressured - Free)
- 16. Did you feel exhausted or relaxed after the experience? (Exhausted - Relaxed)
- 17. How did you feel during the experience? (Bad - Good)
- 18. How much in control do you feel during the experience? (Powerless - Strongly in control)
- 20. How satisfying was the experience for you? (Irritating - Satisfying)

The results for the questions regarding emotions, are presented in Figure 5.2. Most of the questions in this category scored about the same for both groups. Some differences can be found in the results for question 14, 15 and 16. In question 14, the reduced setup seemed to lead to a more imaginative experience. This could be

explained that, the users shifted the focus more in interacting with the characters in real environment, instead of performing the interaction on the iPad. The users might thus develop a stronger emotion link between the story and the real life. According to the results in question 15 and 16, the richer interactivity setup scored slightly higher. Based on the overall picture of this part, both setups could offer experiences that are full of emotions. The richer setup gained a slight advantage.

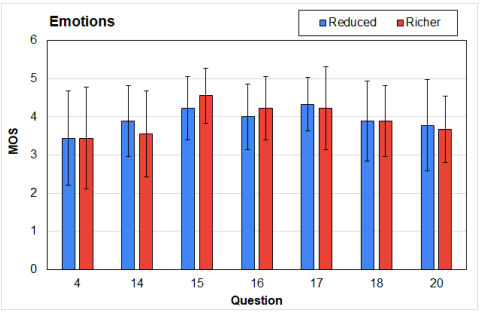

Figure 5.2: Emotions Results

The usability and media part of the survey contains these questions:

- 11. Did you find the actions you could perform clear or confusing during the experience? (Confusing - Clear)
- 22. How interesting do you think the actions you could perform in the experience? (Not interesting - Interesting)
- 23. What was more memorable from the experience? (Sound - Character)
- 25. How easy was it to use the system? (Complicated - Easy)

The results of the usability and media part are presented in Figure 5.3. These results are as expected. Question 23 shows that the richer interactivity group was more leaning towards the character, this matches the observations that, this group spent more time in general interacting with the characters. Both question 11 and 22 indicate that, the reduced interactive group thought what they could do in the prototype, was less interesting. About the same scores were recorded for question 25, because both versions are rather simple and easy to use.

The overall experience part of the survey contains these questions:

- 6. Would you evaluate the experience as dead or lively? (Dead - Lively)

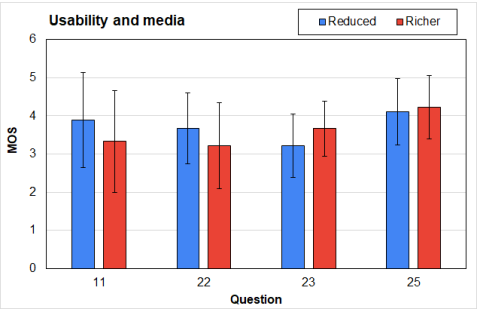

Figure 5.3: Usability and media

- 7. Did you find the experience surprising or predictable? (Predictable - Surprising)
- 8. Did the experience feel complicated or easy? (Complicated - Easy)
- 9. Was the experience motivating or demotivating? (Demotivating - Motivating)
- 12. How annoying or enjoyable was the experience overall? (Annoying - Enjoyable)
- 13. How was the experience essentially? (Poor - Rich)
- 24. How much did your experience meet your expectation? (Not at all - Very much)

The last part, overall experiences, has the result as in Figure 5.4. Almost all the questions favored the richer interactivity setup, a rather significant difference can be seen especially in question 6, where it clearly indicates that the richer interactivity setup brought a more lively experience. Only questions 8 and 12 did not lead to a better QoE for the richer interactivity group. However, the result for question 8 and 12 are expected, as more possibility for interaction would make the experience more likely to be complicated, and annoying. For question 9, both group scored the same.

5.2 Summary

The results overall suggest that the prototype with richer interactivity, offers a better experience to the users than the prototype with reduced options for interaction. There are some areas where the reduced version scores higher: there are less things

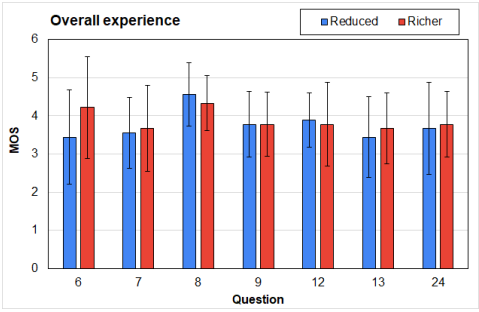

Figure 5.4: Overall experience

for the users to learn, and the system is less complicated, which leads to a less annoyance level for the user. But the advantages the richer interactivity version owns in other are, offsets the the complexity of the system, and thus overall makes the QoE better.

6. Conclusions and outlook

A quality evaluation was done using a prototype of location based digital story, to test the hypothesis: Richer interactivity leads to a better quality of experience in digital storytelling. An augmented reality application was developed with Unity in order to conduct the experiments. Two different versions of the prototype were made, one with reduced interactivity, while the other version offers richer interactivity.

18 participants were recruited for the experiments. They were separated into 2 groups, each group did the experiment with one version of the prototype.

Even though the data sample is rather small, it still indicates that the group that did the experiments with the richer interactivity prototype, had a better QoE than the group which did the experiments with reduced interactivity.

Based on the experiment results, the hypothesis is proven. A conclusion can thus be drawn: a richer interactivity leads to a better quality of experience.

A survey with larger number of participants, that covers a broader range of age, should be performed in the future, in order to reproduce and confirm the results.

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A. Unity Codes

A.1 Scene loading script

```
public string SceneName;

public void Start()
{
    SceneManager.LoadScene(SceneName, LoadSceneMode.Single);
}
```

A.2 Sound control script

```
void Start()
{

    //initialize backgroun music
    audioBackgroundMusic.loop = true;
    audioBackgroundMusic.playOnAwake = true;
    audioBackgroundMusic.volume = 1.0f;

    audioBackgroundMusic.Play();

    //initialize stories
for (int i = 0; i < audioStory.Length; i++)
{

    audioStory[i].loop = false;
    audioStory[i].playOnAwake = false;
    audioStory[i].volume = 1.0f;
}

    audioPlayAllowed = true;
```

```
}

void Update()
{
if (!placementIndicator.activeInHierarchy)
{
    OnIndicatorDeactivated();
}
}

public void OnIndicatorDeactivated()
{
    //Ray from screen center
    var screenCenter = Camera.main.ViewportPointToRay(new
Vector3(0.5f, 0.5f, 0));

    RaycastHit hit;

    bool hitTrue = Physics.Raycast(screenCenter, out hit,
10000.0f);

if (audioPlayAllowed)
{
    //when looking at something
    if (hitTrue)
    {
        //when the troll is found
        if (hit.collider.CompareTag("TrollModel"))
        {
            audioStory[0].Play();
            audioBackgroundMusic.volume = 0.1f;
            audioPlayAllowed = false;
            print("im looking at " + hit.transform.name);
            print(screenCenter.direction);
        }

    }
            //when not looking at anything
    else
```

```
    {
        print("im lookig at nothing.");
    }

}
else
{
    //when looking at something
    if (hitTrue)
    {
        //when the troll is found
        if (hit.collider.CompareTag("TrollModel"))
        {
            if (!audioStory[0].isPlaying)
            {
            audioStory[0].UnPause();

        }

    } else // when looking at something else such as shadow
plane
    {
        if (audioStory[0].isPlaying)
        {
            audioStory[0].Pause();

        }
        else
        {
            audioPlayAllowed = true;
        }

            audioBackgroundMusic.volume = 1.0f;
        }

    }
    //when not looking at anything
    else
    {
        if (audioStory[0].isPlaying)
```

```
        {
            audioStory[0].Pause();

        }
        else
        {
            audioPlayAllowed = true;
        }

        audioBackgroundMusic.volume = 1.0f;

        print("im lookig at nothing.");
        }

}

}
```

A.3 Troll spawning script

```
void Update()
{
if (objectSpawned == null)
{
    UpdatePlacementPose();
    UpdatePlacementIndicator();
    if (placementPoseIsValid && Input.touchCount > 0 &&
Input.GetTouch(0).phase == TouchPhase.Began)
{
    PlaceObject();
}

} else
{
    placementPoseIsValid = false;
    placementIndicator.SetActive(false);


    if (Input.touchCount == 2 && (Input.GetTouch(0).phase
```

```
== TouchPhase.Began ||
    Input.GetTouch(0).phase == TouchPhase.Moved))
{
    DragObject();
}

}
}


private void UpdatePlacementPose()
{

    //Ray from screen center
    var screenCenter = Camera.main.ViewportToScreenPoint(new
Vector3(0.5f, 0.5f, 0));

    //Replaced by private variable declared in the beginning
aRRaycastHits
    bool hitTrue = aRRaycastManager.Raycast(screenCenter,
aRRaycastHits, TrackableType.Planes);

    //placementPoseIsValid = aRRaycastHits.Count > 0;

if (hitTrue)
{
    placementPoseIsValid = true;
    placementPose = aRRaycastHits[0].pose;

    var cameraForward = Camera.current.transform.forward;
    var cameraBearing = new Vector3(cameraForward.x, 0,
cameraForward.z).normalized;
    placementPose.rotation =
    Quaternion.LookRotation(cameraBearing);

}
}

private void UpdatePlacementIndicator()
{
```

```
    if (placementPoseIsValid)
    {
        placementIndicator.SetActive(true);
        placementIndicator.transform.SetPositionAndRotation
        (placementPose.position, placementPose.rotation);
    }
    else
    {
        placementIndicator.SetActive(false);
    }
}

private void PlaceObject()
{

    // *** Place object based on indicator position ***
    objectSpawned = Instantiate(objectToPlace, placementPose.positio
    placementPose.rotation *
    Quaternion.Euler(0f, 180f, 0f));

    resetButton.SetActive(true);
}

private void DragObject()
{
    firstTouch = Input.GetTouch(0);

    // *** For dragging function, use screen position from
finger touch, indicator is inactive ***
    bool hitTrue = aRRaycastManager.Raycast(firstTouch.position,
aRRaycastHits, TrackableType.Planes);

if (hitTrue)
{
    Vector3 newObjectPosition = aRRaycastHits[0].pose.position;

    //always facing camera
    var cameraForward = Camera.current.transform.forward;
    var cameraBearing = new Vector3(cameraForward.x, 0,
cameraForward.z).normalized;
```

```
    Quaternion newObjectRotation = Quaternion.LookRotation(came
*
    Quaternion.Euler(0f, 180f, 0f);

    objectSpawned.transform.position = newObjectPosition;
    objectSpawned.transform.rotation = newObjectRotation;
}
    }
```

B. Experiment related documents

B.1 Introduction

NTNU
Norwegian University of Science and Technology

How interactivity affects the QoE in digital storytelling

Dear participant,

Thank you very much for your participation in this experiment. This study will last approximately 30 mins and will be rewarded with one movie ticket at the end.

During this experiment you will be using an iPad. The app installed on the iPad consists of seven scenes with different contents, many of the scenes require the usage of the camera. You will walk along a path, visit several predefined locations marked on the map, while holding the iPad, and use the camera to look at the surrounding environment. GPS information is used to determine your location, and different scenes will be triggered based on the locations.

The purpose of this experiment is to evaluate the Quality of Experience (QoE) of the system. QoE is a metric that provides measurement of the users' perception of the quality.

The experiment is divided into three main parts:

1) After signing the consent form, you can start the experiment.
2) During the experiment, you will follow a path that has 7 predefined locations. At each location there will be an event. Follow the instructions on the screen at each location.
3) After the experiment, you will evaluate your experience by filling out a questionnaire and the demographic information.

Please note, **not you are getting tested**, but **you are testing the system**!

All the data that you provide and we are recording during this experiment will be pseudonymous.

During the experiment you always have the chance to leave the study without the need to provide any reasons. In case you have questions during the experiment at any point, please feel free to ask the experimenter.

And now: Have fun during the experiment!

Experimenter:Xiao Dalod Tel: 45 08 19 21

B.2 Consent Form

NTNU
Norwegian University of Science and Technology

Consent form

I have read the information for the study *How interactivity affects Quality of Experience in digital storytelling*. I will participate in this study. I was informed that the following data will be obtained today during this study from me: Demographic information, Questionnaire. I approve that all recorded data will be saved and will be used pseudonymously (e.g. identification data will stored separately from recorded data and only be accessible to a small circle of authorized personnel) for research analysis. All data I give will be handled confidentially. All information will be used for research purposes only. Personal data will not be given to any third party.

I am aware that participating in this study is voluntary and I can withdraw anytime without giving any reason. Doing so I will not suffer in any disadvantage.

Additionally, I am aware that I will handle everything confidentially, I hear and see today, and I will not give any information to other people.

Name: _____

Date: _____

Signature: _____

Experimenter: Xiao Dalod Tel: 45 08 19 21

B.3 Research Protocol

1. Synopsis

Digital storytelling provides opportunities for the users to be more engaged in the story. Instead of passively receiving what is being delivered to the users, now the users can interact with the story characters, also have a decision in when and where to start the story. This study investigates how interactivity will affects the users QoE.

The prototype uses GPS to determine the locations of the users, and different stories and interactions will become available based on this information.

2. Introduction / Background

Storytelling has always existed in human society. Thanks to the rapid development of technologies, digital tools have been included in the storytelling process, and the possibilities for more effective ways of telling stories are opened. With the use of GPS, now it is possible to include location information as one of the elements, and offer the users an experience that it is closely related to the defined locations. Digital tools also provide the users new ways of interacting with the digital artifacts. But what do these changes bring in terms of quality of experience? This study will investigate if interactivity plays an important roll in digital storytelling, and makes the overall experience more enjoyable.

3. Hypothesis

Possible hypothesis:

Interactivity improves users QoE in digital storytelling.

4. Methodology and design

A path connecting 7 outdoor points at NTNU (or other places) will be defined, and used for testing the prototype. iPad will be used.

Group 1

The participants walk along the designed path, at each location there will be a different story, the user can place the troll model at places they desire and watch the story.

Group 2

The participants walk along the designed path, at each location there will be a different story, the user can place the troll model at places they desire and watch the story, in addition, they also have the possibility to interact with story elements (scaling/rotating the characters, pause/start the audio etc).

During the testing, the participants actions will be observed.

After the experience, the participants will fill out a questionnaire.

5. Results (Analysis, discussion)

Results based on the analysis of the questionnaires.

The hypothesis is proven if the satisfaction score is higher for group 2.

6. Priority and Timetable

13/04 - 17/04 Gathering participants for testing

20/04 - 02/05 Testing in Gløshaugen

04/05 - 08/05 Analysis of test results

10/06 Deadline for thesis submission

B.4 Running Plan

Running Plan

One person will be responsible for conducting the experiment. The participant and the responsible person meet at the entrance of EL-Bygg, at Gløshaugen. There will be a table where the iPad, introduction, consent forms and a pen are placed on. Before the experiment starts, the responsible person disinfects the iPad and the pen with 70% ethanol and wipes, and the participant also disinfect his/her hands. The participant is then directed to read the introduction. After the reading is finished, the participant can sign the consent form and start the experiment.

The participant then can start the app, HoT, on the iPad, and follow the predefined path and visit story points using the map found in the app. During the experiment, the responsible person follows the participant and can provide help verbally if needed, while keeping at least 1 meter distance in between, the participant can also ask questions anytime.

When the participant reaches the end point, he/she will be informed by the app and the responsible person that the experiment is finished. He/she will then be instructed to close the app, and open the web browser, Safari, and the questionnaire will be loaded automatically. The participant can fill out the questionnaire and the demographic information on the iPad.

After this is done, the participant will be thanked, and he/she will get one cinema voucher as a reward for his/her effort. The responsible person then must make sure to record which type of experiment is done by the participant, the one with more interaction, or less interaction.

B.5 Survey

Home of Trolls Survey

* Required

1. Did the experience seem more like looking at the events/people on a movie screen or more like looking at the events/people through a window? *

Mark only one oval.

	1	2	3	4	5	
Like a movie screen	◯	◯	◯	◯	◯	Like a window

2. To what extent did you feel mentally immersed in the experience or distant from it? *

Mark only one oval.

	1	2	3	4	5	
Distant	◯	◯	◯	◯	◯	Immersed

3. To what extent did you feel you were part of the experience? *

Mark only one oval.

	1	2	3	4	5	
Uninvolved	◯	◯	◯	◯	◯	Involved

4. How exciting was the experience? *

Mark only one oval.

	1	2	3	4	5	
Boring	◯	◯	◯	◯	◯	Exciting

5. How much was the experience emotionally engaging? *

Mark only one oval.

	1	2	3	4	5	
Unemotional	◯	◯	◯	◯	◯	Emotional

6. Would you evaluate the experience as dead or lively? *

Mark only one oval.

	1	2	3	4	5	
Dead	◯	◯	◯	◯	◯	Lively

7. Did you find the experience surprising or predictable? *

Mark only one oval.

	1	2	3	4	5	
Predictable	◯	◯	◯	◯	◯	Surprising

8. Did the experience feel complicated or easy? *

Mark only one oval.

	1	2	3	4	5	
Complicated	◯	◯	◯	◯	◯	Easy

9. Was the experience motivating or demotivating? *

Mark only one oval.

	1	2	3	4	5	
Demotivating	◯	◯	◯	◯	◯	Motivating

10. Did you feel that you could explore things? *

Mark only one oval.

	1	2	3	4	5	
Could not explore	◯	◯	◯	◯	◯	Could explore

11. Did you find the actions you could perform clear or confusing during the experience? *

Mark only one oval.

	1	2	3	4	5	
Confusing	◯	◯	◯	◯	◯	Clear

12. How annoying or enjoyable was the experience overall? *

Mark only one oval.

	1	2	3	4	5	
Annoying	◯	◯	◯	◯	◯	Enjoyable

13. How was the experience essentially? *

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Rich

14. How imaginative did you feel along the trail? *

Mark only one oval.

	1	2	3	4	5	
Unimaginative	◯	◯	◯	◯	◯	Imaginative

15. Did you feel free or pressured during the experience? *

Mark only one oval.

	1	2	3	4	5	
Pressured	◯	◯	◯	◯	◯	Free

16. Did you feel exhausted or relaxed after the experience? *

Mark only one oval.

	1	2	3	4	5	
Exhausted	◯	◯	◯	◯	◯	Relaxed

17. How did you feel during the experience? *

Mark only one oval.

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Good

18. How much in control do you feel during the experience? *

Mark only one oval.

	1	2	3	4	5	
Powerless	◯	◯	◯	◯	◯	Strongly in control

19. How easy was it to get back to reality after the experience? *

Mark only one oval.

	1	2	3	4	5	
Hard	◯	◯	◯	◯	◯	Easy

20. How satisfying was the experience for you? *

Mark only one oval.

	1	2	3	4	5	
Irritating	◯	◯	◯	◯	◯	Satisfying

21. How strong was the sense of presence you felt during the experience? *

Mark only one oval.

	1	2	3	4	5	
Strong	◯	◯	◯	◯	◯	Not Strong

22. How interesting do you think the actions you could perform in the experience? *

Mark only one oval.

	1	2	3	4	5	
Not interesting	◯	◯	◯	◯	◯	Interesting

23. What was more memorable from the experience? *

Mark only one oval.

	1	2	3	4	5	
Sounds	◯	◯	◯	◯	◯	Characters

24. How much did your experience meet your expectation? *

Mark only one oval.

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very much

25. How easy was it to use the system? *

Mark only one oval.

	1	2	3	4	5	
Complicated	◯	◯	◯	◯	◯	Easy

26. Do you have suggestions for improvements? Explain here: (Optional)

Demographic information

27. What is your gender? *

Check all that apply.

- [ ] Female
- [ ] Male
- [ ] Prefer not to say

28. What is your age? *

Check all that apply.

- [ ] Under 18
- [ ] 18-24
- [ ] 25-34
- [ ] 35-49
- [ ] 50-64
- [ ] 65+