Measuring Presence in Augmented Reality

by

Mathias Fornitz Eriksen

AALBORG UNIVERSITY
DENMARK

Aalborg University Copenhagen

Aalborg University Copenhagen

Frederikskaj 12,

DK-2450 Copenhagen SV

Semester Coordinator: Stefania Serafin

Secretary: Lisbeth Nykjær

Semester:
MED10, 4th semester, M.Sc. in Medialogy

Title:
Measuring Presence in Augmented Reality

Project Period:
1 February 2018 — 31 June 2018

Semester Theme:
Master's thesis

Supervisor(s):
Olga Timcenko

Members:
Mathias Fornitz Eriksen

Copies:
Digital Only

Pages:
52

Finished:
31 June 2018

Abstract:

Augmented reality has in the latest couple of years been made more available to consumers and developers. Companies like apple and google are targeting mobile platforms as platforms for displaying augmented reality. Though Augmented reality have become more available the main focus of research has been on technical implementations. Augmented reality seeks to integrate virtual objects into the real world to create a mixed reality. This concept strongly relates to presence. This project therefore seeks to investigate the relationship between Augmented reality and the sense of presence.

An application with a short narrative conveyed through a character in three different types of environment was created. Results showed that the level of presence is higher when the narrative is conveyed utilizing an Augmented reality environment than when no environment was used. No significant difference was found between a virtual environment and the augmented realty environment. This indicates that augmented reality could be used in future projects that utilizes presence.

Table of content

1 Introduction

Augmented Reality (AR) superimposes virtual elements on top of the real world in real time. This means that as opposed to Virtual Reality (VR), that tries to bring the user into the virtual world, AR brings the virtual world to the user. In the last couple of years companies like Apple, Amazon, Facebook and Google have been working on making AR more accessible for both developers and consumers. This is done through targeting mobile phones as a platform for AR. While early prototypes of using mobile phones as handheld AR displays were developed in 2004 [1], the limitations of the hardware meant that the capabilities of these methods were very limited. The evolution of the hardware in mobile phones have however created the basis for higher fidelity applications with better tracking. This opens the possibility of creating AR applications, that can create a seamless integration of virtual elements in the real world. This can in turn mean that when using AR applications, on a phone, the users becomes less aware of the technological limitations of the phones and thereby less aware of the mediation of the virtual elements. The concept of users becoming less aware of a medium relates to the concept of presence as described by Lombart and Ditton [2]. On field of application for presence research is in psychotherapy (e.g. exposure therapy). One reason for using virtual objects or environments in psychotherapy is that a patient can be exposed to conditions that causes fear or anxiety without exposing them to real danger. Goldiez and Dawson [3] defines presence as:

> *"a psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience."*

In relations to AR this would mean that virtual objects displayed through the AR system is to some extend perceived as real objects placed in the real environment. The focus of presence studies has mainly been targeted towards VR. This means that even though much work has been made in the field of presence, not all can be used in an AR context. The focus of this report will therefore be on presence in AR. Another important aspect of presence is that it needs an appropriate form to be experienced [3]. Diemer et al. [4] argues that this can be through the use of a narrative. The under lying narrative creates an emotional response in the users which helps them create the illusion of what is being mediated is real.

1.1 The Problem Statement

We will therefore investigate what influence an AR environment have on the level of presence when users are presented with a narrative. The problem statement therefore becomes as follows:

> *"Will a narrative mediated through AR yield a higher level of presence than a narrative mediated through non-AR"*

2 Analysis

The focus of this chapter will be based on the three research areas of the problem-statement. The first area will revolve around what Augmented reality (AR) is and how it works. The next area will investigate presence and how it is connected to AR. The last area from the problem statement is narratives and how these can be used in an AR setting to test presence.

2.1 Augmented Reality

In order to better understand the possibilities of AR we must first understand what it is and how it differs from virtual reality (VR). In this subchapter, we will find a definition of AR and investigate the different methods of creating AR systems. This will be used to define a set of design requirements.

2.1.1 Defining Augmented Reality

Augmented reality (AR) differs from virtual reality (VR), in that AR superimposes virtual elements on top of the real world, and VR immerses the user in a completely virtual world that might mimic real world properties. This means that AR lies somewhere between the real and the virtual world. Milgram et al. [5] describes AR as being placed on a continuum between Reality and virtuality:

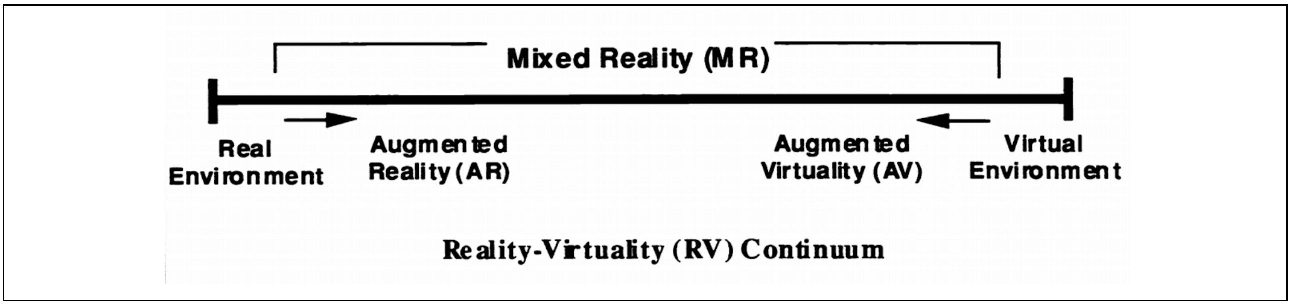


Figure 1: The reality-virtuality continuum model as presented by Milgram et al. [5].

The area between the completely real and completely virtual is described as mixed reality. Additional Augmented Virtuality (AV), in which the real environment is used to augment the virtual, can also be placed on this continuum. The difference between AR and AV lies in where the primary part of the interaction and experience lies [6]. where AR enhances the real environment with virtual features, AV users the real environment to enhance the virtual. this means that AV like VR transports user into the virtual. However, since the purpose of this report is to investigate the relationship between the incorporation of virtual elements in the real world and the user's sense of presence we will focus on AR. Krevelen and Poelman [7] defines three criteria used to identify an AR system:

- Combines real and virtual objects in the real environment
- Aligns real and virtual objects with each other
- Allows for interaction in real time in three dimensions

Milgram et al. [5] argues that another important aspect to MR, and there by AR, is the method used to convey physical stimuli. Many different methods have been used in Augmented reality research and we will therefore investigate the possibilities associated with some of these methods.

2.1.2 Display Techniques for Augmented Reality

While VR manly operates with head-mounted displays (HMD), AR can use several different display techniques. These techniques occupy three different positions between the real environment and the user (see fig 2) each have a varying degree of intrusiveness [8]. In this section, we will however only focus on the most common methods. The three main used techniques are, see-through HMDs, projection-based displays and handheld displays [9].

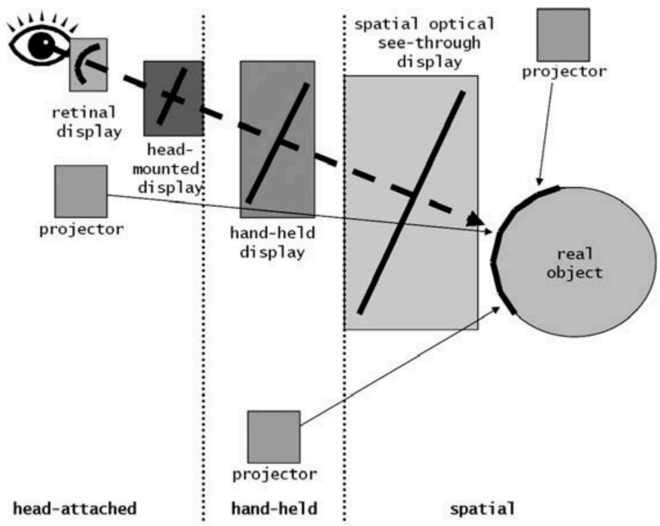


Figure 3.1. Image generation for augmented reality displays.

Figure 2: The different display methods and their relation to the user.

Much of the early work with AR have been using see-through HMDs, but as mentioned earlier, the advances in mobile technology have meant that the restrictions associated with handheld displays researchers might have faced, have been overcome. The advantages and disadvantages of the different display types should therefore be considered. This is both to investigate the problems we may encounter as well as give an understanding of how possible differences between the display types might have affected the earlier research.

See-through Head-mounted Displays:

The see-through HMDs operate by letting the user see the real world through the screen of a HMD. This can be achieved either by having a transparent screen or by displaying a live video of the real-world environment on a screen. Optical See-through (OST) uses a transparent surface to display the virtual elements on. This means that the user does not lose any of the sensory data that they normally get from their eyes, e.g. binocular depth cues, when using the HMD. Another advantage is that the user does not experience an offset in the view as they might have if a camera had been used to capture a live video of the environment. However, since the screen is see-through a problem that can be encountered is in the blending of real and virtual objects. The projection losses contrast and brightness when projected on the see-through screen. An example of this technology is the Lenovo AR headset [L1].

Figure 3: Image of the Lenovo AR headset retrieved form bluecity [L2].

The alternative to OST is the Video see-through (VST) technique. VST do not use a transparent screen and it therefore allows for easier adjustments to the mediation of real environment. This can be used in cases where real objects should be removed or alter from the scene. Another Advantage is the possibility of post processing, that e.g. can be used to blend virtual and real objects. This method has been used by Steptoe et al. [10], in which they found that a stylization of real objects could decrease participants ability to judge whether an object was real or not. VSTs do have ever also have certain disadvantages that the OSTs do not. One of the most apparent problem is that if the HMD losses power the user will not be able to see through it, which might not be desirable in certain situations. This could e.g. be in medical applications of AR in which a doctor should be able to continue working even if the HMD loses power. Common for both techniques are that they are immerses the user in the mixed reality. this means that the user is not able to see beyond the screen onto the real environment in which the virtual objects do not exist.

Projection-based Displays:

This type of display works by projecting an image on a physical surface instead of a screen [8]. This means that the number of people able to see the displayed is only limited by the size of the object allowing for an easier multi-user experience. The size of the object, together with the shape and colour of the object, also restrict what is able to be projected on to the surface [8]. If the surface is moved the set-up needs to be re calibrated [11]. Depending on where the projector is located there is also the risk of shadows, either from other objects in the room or by the users, being cast onto the projected image [8].

Handheld displays:

Handheld displays have the main advantage that it is more available than the other techniques [8] [9] [11]. The number of mobile phones usable as AR displays will only increase as the mobile technology becomes better. Schmalstieg and Wagner [12] argues that we are more comfortable with using this type of displays as handheld smart devices have become an integral part of our daily life. While mobile phones as AR displays uses the VST technique, solutions for OST displays have also been proposed [11] [8]. Bimber and Raskar, however, argues that VST is the preferred method [8] when researching AR. There is, however, also certain disadvantages associated with handheld displays. This is for instance that the method does not allow for a complete hands-free experience [8], and therefore is a bulkier solution than head-worn displays [11]. The limited screen size also restricts the field of view [8], which means that users will not be immersed in the mixed reality.

2.1.3 Requirements for the Augmented Reality Application

In order to develop a prototype application, we will have to define a list of requirements that the application must fulfil. These requirements will later be used in the design phase. The first list of requirements can be derived from the definition of AR:

- Must allow for interaction in three dimensions
- Must allow for interaction in real time
- Must combine virtual and real objects seamlessly

We should also consider how users should interact with the application. Here it is both important to consider what is afforded by AR as well as handheld devices. AR allows for interaction with real objects which can be used to manipulate virtual objects. This would create natural interactions with a haptic feedback. The use of a handheld devise however limits this option. The application should therefore allow for interactions that is do not require the user to use both hands. An alternative would be to use voice commands. This would especially make sense when interacting with virtual agents. It would however be to extensive to in cooperate meaningful voice interactions with agent for this application. A much simpler method that utilizes the mobile phones touchscreen could instead be used. Although this might not be a natural way of interacting with real object, it seems as a good alternative. In order to not occupy to much of the user's attention it should be kept simple and natural. This leads to additional requirements to consider:

- The interaction with the application should support the affordances of both AR and handheld devices
- The interface should be both simple and neutral

While the different display types use different techniques to achieve the suspension of disbelief, presence do not only rely on the mechanism that mediates the experience. Therefore, we need to understand the basic aspects presence in order to create a meaningful environment for the application.

2.2 Presence

In this section, we will investigate the definitions of presence as described by Lombard and Ditton [2] and Ijsselsteijn [13]. These definitions will be used to determine which parts of presence relates to AR and how the feeling of presence can be achieved.

2.2.1 Defining presence

Presence can be defined as degree of which a user is unaware of the role of the underlying technology in the mediation of an experience. VR is approaching a state where the virtual elements no longer seems mediated [2]. The users experience the virtual environments in which they are transported as being natural and real. While VR is designed to transport the user into the virtual world, the goal of AR is to transport virtual elements into the real world. This means that in order to achieve the same experience of non-mediation the virtual elements must seem naturally incorporated into the real environment. With the advance in mobile technology, we are now able to render more realistic objects, and with the users of real world tracking, superimpose them on the real world. The illusion of non-mediation is what defines presence. Lombard and Ditton define six dimensions of presence [2] that relates to both the believability of the virtual elements as well as the social aspects of these:

Type of Presence	**Description of Presence**
Conveyance of social cues	The degree to which any given medium has the capacity to transmit information that is perceived by a participant and used in the interpretation of the message
Fidelity of rep-resentation	The degree to which a communication medium creates imagery and other sensory input that has high fidelity relative to the target person, place, or thing that is the focus of communication
A transport Mechanism	The degree to which a medium can give a user a sense that they are transported elsewhere (i.e., “you are there”) or bring a place or objects to the user’s location (i.e., “it is here”)
Immersion in a space	Either physical immersion (i.e., immersing sensory organs into physical devices like head mount displays and headphones) or psychological immersion (i.e., creating a sense that one is inside the space)
Social actor in a medium	When an observer treats a character in a medium as a social actor regardless of whether that actor can respond or is controlled by a human actor (e.g., watching and talking back to a TV anchor)
Computers as social actors	When people treat inanimate objects that do not resemble human actors (e.g., computers) in a socially sound manner

Table 1: The types of presence as presented in “An Examination of a Theory of Embodied Social Presence in Virtual Worlds” [14].

The transport mechanism is sub divide into three categories; “You are there”, “It is here” and “we are together”. The second of these sub-categories describing the illusion that virtual objects or character is present in the same environment as the user, which strongly relates to the purpose of AR. Lombard and Ditton [2] presents two examples of the effects of this happening. The first example describes how young children in some cases fail to recognize the distinction between the virtual and the real. In an experiment with objects shown on a monitor, children aged 3-4 believed that the objects could come out of the screen. The second example describe the feeling that early cinema goers had when they saw a moving locomotive on the screen. When they saw it approach them, they failed to recognize that it was just a black and white image on a screen and they therefore panicked and fled. While we arguably would not act the same way as we did in the early days of cinema, these examples indicate that the ability to distinguish between the virtual and the real is based on previous experiences and that we still to some extent might fail to recognize the underlying mediation even with the knowledge of the mechanism that is used.

Ijsselsteijn [13] argues that instead of the six types, two broader categories can be used. Here the distinction lies between Physical and social presence. Physical presence describes the feeling of being physically present in the virtual environment, whereas social presence describes the feeling of being together with another entity. He argues that for a user to experience a physical presence there is no need of for other entities to exist in the environment and that likewise for a user to experience social presence there need not be a virtual environment. When both types of presence are experienced, Ijsselsteijn calls it co-presence, which is the feeling of being together in a shared virtual space.

2.2.2 Determinants of Presence

With the base understanding of what constitute presence we can focus on the factors that influences the users sense of presence. This will both serve as criteria for the design of the AR application as well as the factors that will be used to evaluate the sense of presence achieved when using the application. IJsselsteijn et al. [15] and Usoh [16] defines a set of factors that influences the sense of presence:

Influencing factor	**Description**
Fidelity of sensory information	The number of sensory dimensions and the and the quality of the information that the system is able supports. E.g. Spatial sound, binocular depth cues and high-resolution displays.
Content and environmental autonomy	The user's ability to interact with objects and actors in the virtual environment as well as the actor's ability to acknowledged the presence of the user.
Consistency and self-representation	The similarity between the appearance of the replicated body and the users own body as well as the translation of bodily functions. This means that there should be a consistency between action in the real environment and actions in the virtual environment. If the user moves their head in real life, the virtual head should move as well, leaving the user with the appropriated sensory information.
User Characteristics	Factors unrelated to system, such as the user's concentration level and motoric skills, as well as the user's motivation towards and prior experience with the system.
Ease of use	The simplicity of and learning curve related to the user's possible actions.

Table 2: Presence influencing factors

Diemer et al. [4] argues that another factor that influences presence is the emotional response to the experience. In experiments with anxiety and fear inducing elements in VR, results show a correlation between presence and emotional response to these elements. This means that if a group of test participants is e.g. afraid of spiders and they experience a spider in a VR environment they will feel more present then they would in the same environment without the spider. This, however, would also mean that if the group of test participants were not afraid of spiders they would not experience the same increase in presence. Another way of achieving an emotional response is through a narrative. Gorini et al. [17] introduced a narrative to a VR experience, which led to an increase in presence. Test participants had to find a sample of rare blood in a VR hospital environment. Half the Test participants were told that the blood was to be used to save the lives of sick children. These participants rated their sense of presence higher than the other participants who were not given this information. This can arguably be said to relate to the "user characteristics" factor, as the type and strength of the emotional response is based on the individual user more so than the system. This is because the users might have a varying degree of response to the narrative. The results however indicate that the narrative of the experience should be considered. These considerations of what creates the basis of a presence inducing experience can be formed into the following design requirements:

- The application should be designed around the determinants of presence
- The application should be designed around a narrative

Both Ijsselsteijns and Lombard and Dittons work was made from an VR perspective. This means that they touch upon dimensions of presences that is not relevant for AR research. This raises the question of whether it makes sense to put presence in an AR context. We will therefore need to define what presence in AR is and what parts of presence is present in AR.

2.2.3 Presence in Augmented reality

In a study by Steptoe et al. [10], they found that test participants acted upon the presence of virtual objects in AR. The participants were presented with virtual boxes in a real environment and when they had to navigate the environment they either stepped over the boxes or navigated around them. This strongly indicates that there, to some extent, was an experience of non-mediation, which Lombard and Ditton [2] describes as the core of presence. This was experienced even though the test subjects were not immersed in a virtual environment. When comparing this to the transportation aspect of Lombard and Dittons six dimensions of presence [2] we see that, the test participants must have felt that the objects were there with them. This can be seen as the "it is here" or "we are together" aspects of the transportation dimension. In order for the "you are there" sensation to be experienced the system will have to be further along the virtuality direction of the reality-virtuality continuum [5], which results in the system to belong in the augmented virtuality section of the mixed reality systems.

Goldiez and Dawson [3] argues that certain aspects of presence should be disregarded, as they are an integral part of AR. They argue that the concept of the self (as described by Ijsselsteijns) is one of these aspects. VR tries to make the users forget about the real world and make them build a mental model of the virtual world in order to achieve a sense of presence. This means that by translating bodily functions into the virtual world and thereby transport the user to the virtual world the sense of presence is achieved. By providing the user with a full body avatar with simple arm movements Slater [18] found an increase in the users' presence in VR. This relates to the *Consistency and self-representation* factor. A complete translation of the body and movement of the user is however difficult to replicate in real time [19]. This means that there often is a mismatch of the users' body parts, motion and physical scale [19]. This problem can lead to users of VR feel motion sickness. This is not the case for AR. AR have an advantage in that the users uses their real body and it therefore do not have to be replicated. Moreno et. al. [20] argues that this also mean that the users in VR assumes the role of the virtual avatar whereas in AR they themselves becomes the avatar. The Consistency factor of presence in AR can instead be said to lie in the alignment of the virtual objects with the real environment. The virtual objects should follow real life physics and have real life properties. This e.g. means that the objects displayed in AR should have a shadow. In a study by Sugano et. al. [21] they found that displaying objects with a shadow resulted in a higher level of presence. This was even if the shadow was not photorealistic or did not fit the light condition of the room. This might also mean that physical conflicts between virtual and real have a negative effect on presence. This is supported by a study by Kim et. al. [22] in which they found that test subjects that saw characters that displayed actions that contradicts reality reported a significant lower sense of presence than when the characters displayed normal behaviour. In their test one condition showed virtual humans that was able pass through real objects. As this is clearly a physical conflict between virtual and real it should be avoided in the application which can be done by keeping the environment free of obtruding objects. AR is not only affected by real life objects but is also affected by other outsider influences. This is because one of the main disadvantages of using AR is that it is not a completely immersive medium and therefore outside influences might impact the users sense of presence [3]. We should therefore seek to minimize outside influence. From this we can define three additional design requirements:

- Objects in should display real life properties
- The environment should be kept free of obtruding objects
- Minimize outside influences in the testing environment

In another study by Kim et. al. [23] they proposed another method to solve the problems with the obtruding objects. The found that if the characters instead of ignoring the objects, and there by display the physical conflict, asked the test subjects to move the objects so they no longer would be in the way, the test subjects would experience a higher level of presence. This could also relate to the autonomy factor of presence. If the virtual characters ask the test subjects to do something, they acknowledge they existence, and thereby strengthen the illusion of them being in a shared space.

2.3 Narratives

As mentioned earlier, Diemer et al. [4] and Gorini et al. [17] argues that existence of an underlying narrative effects the sense of presence. We should therefore investigate how such a narrative can be constructed. One of the factors that influences the sense of presence is how the actors in the narrative respond to the existence of the user. This means that the characters should acknowledge the user and involve them in the narrative. A way to achieve this is by making the narrative interactive. We should therefore consider how interactivity effects a narrative.

2.3.1 Interactivity and Narrative Structures

Ryan [24] have explored what it means to a narrative when interactivity is introduced. She investigated the effect at three different levels, the plot, the discourse and the story level. As we want a method for the users to feel in charge of the outcome of the story, we only need to look at interactivity on the story level. Ryan proposes three different narrative structures, the tree, flowchart and maze structure (Figure 4). These structures can be combine in multible ways to form more complex structures. We will however only focus on the base structures to determind wich is most suitable for this project.

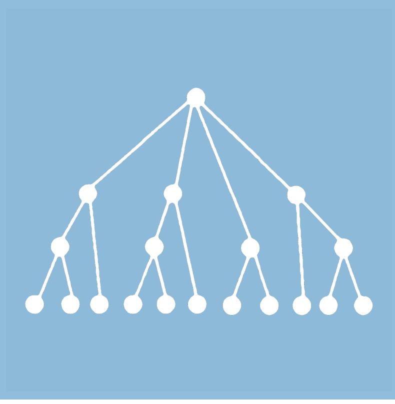
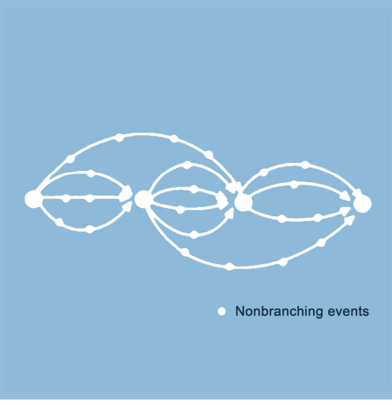
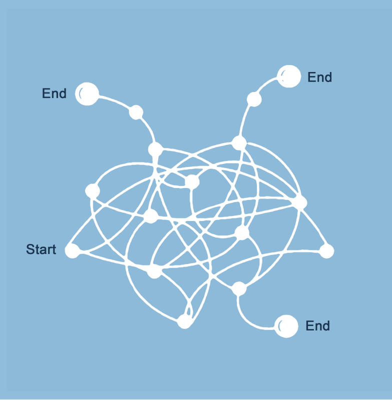
Tree	Flowchart	Maze
		
The tree structure has numerus different endpoints based on the readers choices. The three does not allow a reader to jump from one branch to another.	The flowchart structure has one endpoint but different ways for the reader to reach it. This is done by having the strands of the story meet at later points.	The maze structure like the tree structure have multiple endpoints but is interconnected in such a way that only the last choices determine which one is reached.

Figure 4: the three narrative structures as presented by Ryan [24]

Each of the structures have certain disadvantages to consider. The tree structure while offering the reader complete control, it suffers from an exponential growth from the different endings. This would mean that a story should be made specifically of each branch of the tree. The flowchart solves this by having the branches converge. This structure however suffers from the authors not being able to know which story points have been visited by the reader. This means that after two or more branches have converged the narrative should not refer to events specific for certain branches. An example of this could be if the reader in one story branch eats a poisonous mushroom while in another branch do not, the reader should not encounter a story event where they experience the negative effects form eating the mushroom after the two branches have converged. Lastly the maze structure like the tree structure offers the reader complete control and like the flowchart structure does not suffer from the exponential growth. It, however, suffers from the from the same problem, with the authors not knowing where the reader has been, as the flowchart structure. Each of these structures should be considered when designing the narrative for the application.

2.3.2 Interactive Narratives in Augmented Reality

A problem that arises when narratives are presented in AR is that they are limited by their connection to the real environment. VR and traditional media can transport users around to different environment whereas AR is limited by the physical environment in which the experience takes place. This means that the narrative should be limited to what is afforded by the immediate environment. If the user is located in a living room, a narrative about people at the beach might seem disjointed and therefor ruin the illusion of the narrative being real.

Another aspect to consider is how the users should interact with the narrative. A technique that is commonly used is presenting a user with a set of predefined response options, that will transport the user to the next section of the narrative [20]. This method fits with the structures presented by Ryan [24]. Here the response options could be presented whenever the narrative diverge into multiple branches. Moreno et. al. [20] argues, however, that this method does not fit with AR. They as, mentioned earlier, argue that in VR the user assumes the role of an avatar whereas in AR the user becomes the avatar. The restrictions of the response options would distance the user from the avatar which they are supposed to become. They instead argue that a physical interface should be used. In their experiment they present a remediation of the tea party from Alice in wonderland. Here they use a tea cup as the interface and allows the user to interrupt the narrative at any time by interacting with the other characters using the tea cup. While this type of physical interface makes sense when using an HMD, the use of a handheld device as mentioned earlier limits this option. This means that even though Moreno et. al. [20] argues that the use of response options is unsuitable for AR, it might be the most suitable for AR on a handheld device. Moreno et. al. [20] argues that another aspect that might ruin this illusion is if the story time becomes disconnected from the real time. This could e.g. happen if the narrative comes to a halt as a result from the user remaining inactive. The characters should therefore act independently in order to drive the narrative forward even if the user is inactive. Form this we can define a list of design requirements regarding the narrative:

- An appropriate narrative structure should be used to convey the narrative
- The narrative should be afforded by the immediate environment
- An appropriate form for interacting with the narrative should be chosen
- The characters should act independently

2.4 Summary of Design Requirements

Throughout the analysis a list of requirements for the design have been defined. The requirements concern both the design of the application as well as the design of the underlying narrative. These requirements should be used to guide the design process. There will however be a stronger focus on the most important of the requirements, as some of the requirements would be to extensive to fully incorporate. The complete list of requirements a listed below:

Narrative design requirements:

- The application should be designed around a narrative
- An appropriate narrative structure should be used to convey the narrative
- The narrative should be afforded by the immediate environment
- An appropriate form for interacting with the narrative should be chosen
- The characters should act independently

Application design requirements:

- The application should be designed around the determinant of presence
- Must allow for interaction in three dimensions
- Must allow for interaction in real time
- Must combine virtual and real objects seamlessly
- The interaction with the application should support the affordances of both AR and handheld devices
- The interface should be both simple and neutral

The requirements regarding the interactions with the narrative and the affordances of both AR and handheld devices are to some extent either contradictory or out of the scope of this project. An appropriate interaction with the narrative would not distance the user from their role. This could be solved by using physical props as a mean to interact with virtual characters. This would however not be afforded by the use of a hand-held display. Another solution would be to use voice commands, but this would however be to extensive. In the next chapter I will discuss the design choices that was made and the reason behind these.

3 Design

In order to answer the problem statement, we will investigate the sense of presence in three conditions; in augmented reality (AR), in a virtual environment (VE) and in a control condition without an environment. The design requirements can be group into two topics. The first topic concerns the narrative and how it should be structured. The second topic regards the design of the application and how the interactions with it should be designed. In both of these sections we will present the design solution chosen to fulfil the design requirements established from the analysis.

3.1 Narrative Design

As the narrative should fit the immediate environment, and this would be the place where the test takes place, we would have to design the narrative around this environment. To limit the outside influences that might distract the users, and therefor influence their sense of presence, we will conduct the test in a controlled environment. the narrative therefore has to be afforded by the controlled environment. Further the narrative should be able to be presented in three sections. This is so that we can present the user with the narrative in each of the tree condition. The chosen narrative is in the form of a murder mystery.

A summary of the narrative is as follows:

A wealthy business owner named George Miller is throwing a dinner party. The guests include his wife Natalie Miller, his best friend Nathan Reed and his neighbour Connor Redwood. While they are eating George suddenly falls over with froth around his mouth. It is clear that he has been poisoned. When the police arrive, they arrest the three guests and brings them to the police station for questioning. Each of the suspects have a motivation for the murder. As Natalie is married to Georges she would inherit all of his wealth. Nathan besides being Georges best friend is also his business partner meaning that with George gone he would be in control of the company. Conor is the neighbour of George and Natalie and is the owner of a large farming enterprise that he wants to expand. He, however, needs the land owned by George, who was not willing to sell.

Character	Relations to the victim	Motivation for the murder:
Connor Redwood	Neighbour of the victim	Would be able to buy the victims' property to expand his enterprise
Natalie Miller	Wife of the victim	Would inherit all the wealth from the victim
Nathan Reed	Best friend and business partner	Would be in complete control of the company

Table 3: Overview of the charecters fromthe narrative.

With this approach we can present the user with a suspect in each of the three conditions, and with the questioning of the suspects taking place at the police station the physical environment seems appropriate. The users have to individually interview the three suspects to determine which of them is the murderer. The narrative structure should therefore allow the users to ask different questions when interrogating the suspects while at the same time be confined to the current suspect. The narrative structure most closely resembling this and therefore chosen for this application is based on the flowchart structure. The users have different ways of reaching the choke point without the possibility to move back to a previous suspect.

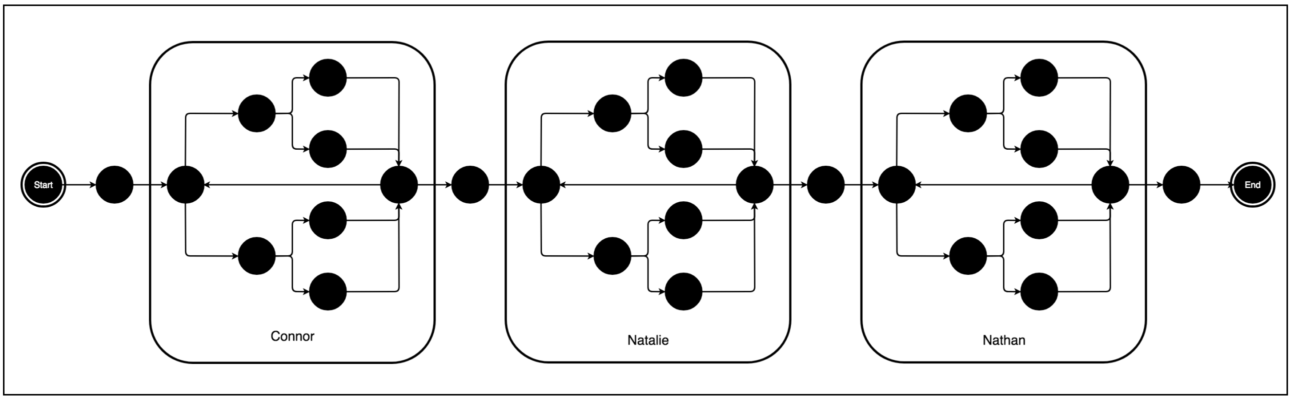


Figure 5: A simplified model of the narrative structure

The narrative is split up into three sections, with each section corresponding to one of the characters. The narrative structure of each of these sections is designed to be identical. While this choice might make users more aware of the underlying narrative structure, which could lessen the illusion of it being real, it was chosen in order to make the experience across the sections as similar as possible.

3.2 Application Design

The design of the application concerns both the design of the environments, in which the characters should appear, as well as the interaction modality that should be used to interact with them. In this section we will cover both of these topics, starting with the design of the environment. Three different versions of each of the sections were made in order to match the three conditions. This means that each of the three characters (Connor, Nathalie, and Nathan) could be seen in each of the three environment conditions (Augmented reality environment, Virtual environment and the control environment).

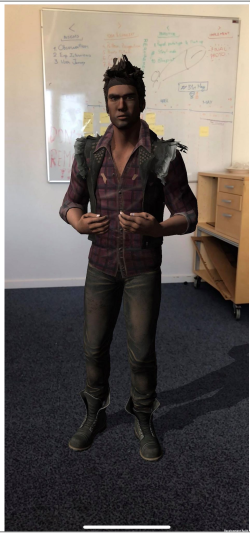
Augmented Reality version	Virtual Environment version	Control version
		

Figure 6: Connor in each of the three conditions

While the control condition does not have any environment to consider, the two other does. In the AR version the integration with the real environment means that certain features of the character should match what is found in the real world. The light used to illuminate the character should have the same tone and strength as other light in the room. The character should also have a shadow that falls on the ground like a real person would have.

The virtual environment was made with few objects. This was both not to distract the users as well as not to offer addition narrative clues that might affect the user's emotional response through an emergent narrative. All virtual objects resemble furniture that could be found in the real environment. The section of the room in which the user starts is kept free. This is so that a user does not walk through any objects unintended. While the user is not supposed to look behind themselves the back wall has still been furnished in order to make the room look more realistic in case they did so.

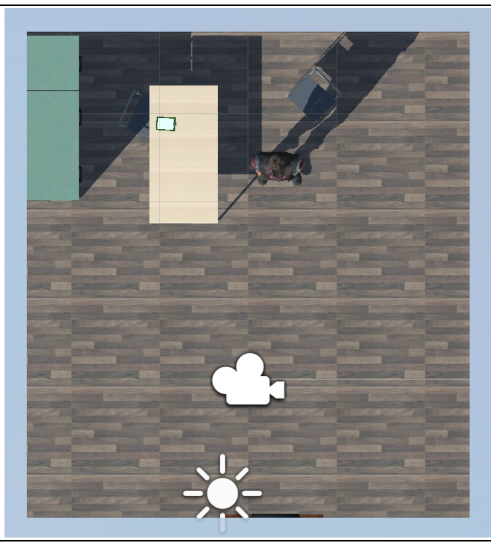


Figure 7: Isometric view from inside the virtual room

From the design requirements we can see that the applications should allow two types of interactions with the characters. The user should be able to interact in three dimensions in real time. Two types of movements can happen in three dimensions are translational movements (e.g. up and down) and rotational movements (rotations aground an axis). All of these movement was tracked. This means that no matter how the user turned themselves or the phone, the application would allow this and handle it instantaneously. The same type of tracking was used across all conditions to ensure that the experience was similar. The other interaction type was how the users should interact with the characters. The method chosen was in the form of response options. This is even though Moreno et. al. [20] argues that they should not be used in AR. The reason for choosing this method was that a natural interface either would be out of the scope for this project (e.g. voice recognition and sentence analysis) or would not fit all of the condition and/or display type (e.g. haptic interface). The design requirements state that the interface for the response options should be both simple and neutral. This was in order not to confuse the users as well as not to move their focus from the narrative and the characters. The response options were therefore chosen to be presented by two buttons in neutral colours, which would only appear whenever users would have to choose a response.

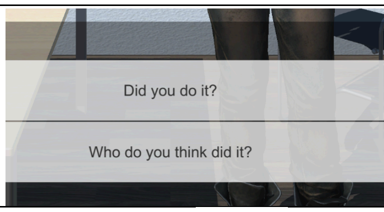


Figure 8: Dialoug response options

4 Implementation

In this section we will cover the most important aspects of how the designs from the previous chapter was implemented. The topics of the implementation concern both the character creation as well as the technical implementation of the application.

4.1 Characters and animation

In order to create the characters three different programs was used. One for create the character models, one for animating them and one for exporting them to a usable file type for unity. The three characters for the application was made using Reallusion's Character Creator [L3], which allows for the creation of humanoid characters from base male and female models. This is done through morphing the bone and muscle structure of the base models. The base models are pre-rigged and with facial blend shapes that can be used when animating the character expressions. Character creator also offers the possibility to add simple clothing options to the characters. The three models can be seen below:

Connor Redwood	Natalie Miller	Nathan Reed
		

Figure 9: The three character models

The characters were animated using Reallusion's iClone [L4], which offers several different methods for creating character motions. A method available in iClone is the use of motion puppets. These are pre-made animations that is able to be applied to the rigs from Character Creator and edited in a timeline. This means that it is possible to cut out sections of the pre-made animation and transition between different animation cuts to match the desired motions. While this method strictly limits the possible motions that the characters can express, it is far less time consuming than using motion tracking (e.g. using the Microsoft Kinect or the Rokoko smartsuit).

The facial animation was animated using iClones lip-sync to estimate lip movements. These animations were adjusted with the lips editor to make more believable mouth movements. The lips editor uses a combination of lip-dental shape, tongue position and mouth width to mimic phonemes. This means that it is possible to structure the mouth movement using the pre-made lips movements from the lips editor without manually animating the mouth to each corresponding sound. Below can be seen the different lip options with their corresponding phonemes.

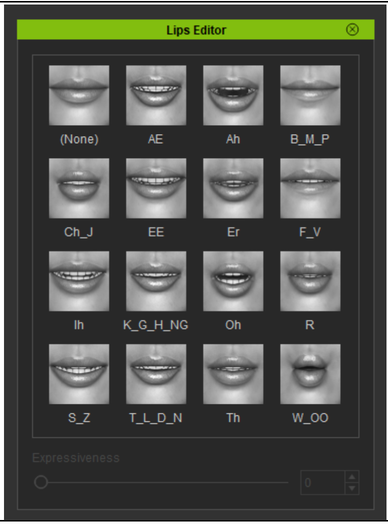


Figure 10: Lips edditor from iClone

As iClone is used for creating animations and not for export of animation clips another program was needed before the characters could be used in unity. The animation and character models were therefore exported as FBX files using 3DXchange [L5]. This meant that both the model and the animation could be used in the unity 3D project. The animation clip contains information of the translations of the rig over a period of time. This however also meant that the characters were unable to follow the users with their head when running the animation in the application. Unity offers the ability to mask out the parts of the animation. While this normally would have solved the problem, this was however not possible to do in this case. This is because the section of the animation that should be masked out would be the head section, but the head contains information about the lip movements. It was therefore decided that in order to keep the lip movements the head will not follow the users.

4.2 Technical implementation

The application was made using Unity 3D together with apples ARKit. The application was built for apples iPhone X using XCode. In this section some of the most important aspects of the technical implementation and the development of the application will be presented. These aspects revolves around how ARKit tracks the environment, how this was utilized in the application, how characters were placed in the real environment in the AR condition and how the animations for the characters were structured.

4.2.1 Tracking

The world tracking should be consistent across the three versions. This means that a method that could be applied to all of them were needed. The chosen method was the tacking included with apples ARKit. ARKit allows for tracking in six degrees of freedom. These are the three rotational axes of the device as well as the three translation axes (figure 11). this means that the device can both be moved around the room as well as be tilted in any direction with the virtual objects still being displayed correctly in the right place.

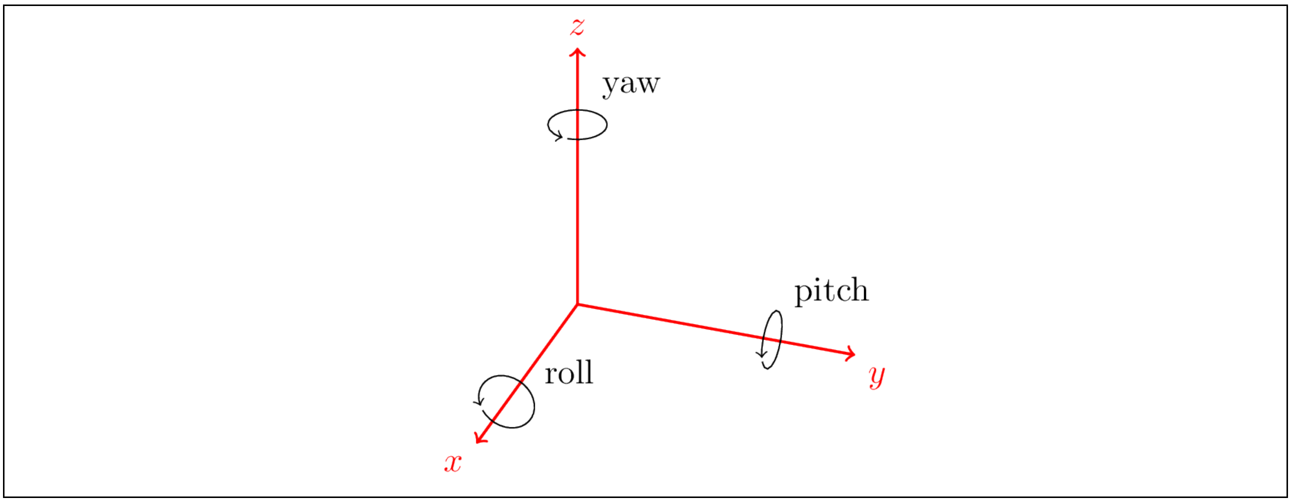


Figure 11: the rotational and translational axes tracked by ARKit [L6]

The way this ARKit achieves this is through visual-inertial odometry. A method which uses the camera of the device to capture a video feed, in which feature points are extracted to estimate the geometry of the scene. ARKit does this by applying the video feed from the camera of the device to a texture and use it as background of a camera in the unity scene. The image from the unity camera is then analysed for flat surfaces. The problem with this method is that feature points should be visible by the camera at all times in order to track its translation. While this method make sense when adding virtual objects to the real environment, a problem arises when the tracking is used for a virtual environment. The surface detection will start to analyse the virtual environment that lies on top of the real environment. A method around this by using an additional camera in the unity scene, which only renders the virtual objects, and make the tracking camera ignore these objects.

4.2.2 Placing characters in Augmented Reality

The characters should be placed in the real environment in a location that makes sense. It was therefore chosen that this should be done manually at the start of experience. Although it was possible for the application to automatically place the character, this sometimes gave problems in the development as the features extracted is not controlled and the character therefore could appear in unwanted places.

In order to place the characters in the real environment the UnityARHitTestExample script included in the ARKit plugin was modified. The new script should allow placement of the character on the ground but only before the interaction with the characters begin. this is done by touching the screen where the character should be place. If the position of the touch corresponds to a detected plane the character will be moved to that location. This is done by checking if the screen has been touched and if there is a game object that should be moved attached to the script. The type of the touch is then checked to see if it is either a touch that has just begun or if the finger has been moved across the screen. The screen coordinates of the touch are then translated into view space and stored as an ARPoint (a struct from ARKit).

```
if (Input.touchCount > 0 && m_HitTransform != null) {
    var touch = Input.GetTouch (0);
    if (touch.phase == TouchPhase.Began || touch.phase == TouchPhase.Moved) {
        var screenPosition = Camera.main.ScreenToViewportPoint (touch.position);
        ARPoint point = new ARPoint { x = screenPosition.x, y = screenPosition.y };
```

Code Snippet 1:

Since the lower section of the screen is dedicated to the menu any touch in that area will be disregarded. This is done by checking if the touched is happening above the middle of the screen.

```
if (touch.position.y > Camera.main.pixelHeight / 2) {
```

Code Snippet 2

The types of anchors that that the object is allowed to be placed on is included in an array. In this case it is on any previously detected planes, new horizontal planes or feature points. Other types of anchors that is not included are infinite planes and vertical planes.

```
ARHitTestResultType[] resultTypes = {
    ARHitTestResultType.ARHitTestResultTypeExistingPlaneUsingExtent,
    ARHitTestResultType.ARHitTestResultTypeHorizontalPlane,
    ARHitTestResultType.ARHitTestResultTypeFeaturePoint
};
```

Code Snippet 3

Then the view space point is checked to see if it corresponds to any of the include anchor types. In this case there are three included anchor types that should be checked for, meaning that the function will run three times starting with the first type in the array.

```
foreach (ARHitTestResultType resultType in resultTypes) {
    if (HitTestWithResultType (point, resultType)) {
```

Code Snippet 4

This is done through a Boolean function that moves the object and returns true if the view space point corresponds to an anchor. If nothing is found the function returns false and try with another anchor type.

```
bool HitTestWithResultType (ARPoint point, ARHitTestResultType resultTypes) {
    List<ARHitTestResult> hitResults =
        UnityARSessionNativeInterface.GetARSessionNativeInterface ().HitTest (point, resultTypes);
    if (hitResults.Count > 0) {
        foreach (var hitResult in hitResults) {
            m_HitTransform.position = UnityARMatrixOps.GetPosition (hitResult.worldTransform);
            m_HitTransform.rotation = UnityARMatrixOps.GetRotation (hitResult.worldTransform);
            return true;
        }
    }
    return false;
}
```

Code Snippet 5

The look-rotation of the character is calculated by creating a vector form the character object to the camera, using only the x and z coordinates. The reason for not using the y-coordinates is that this would create an unwanted rotation around the z-axis. Thus, the formula becomes as follows.

$$V = (cam_x - obj_x, 0, cam_z - obj_z)$$

In unity these arguments are stored as the transformation position of the main camera and the transformation position of the object that should be moved. The look direction is stored as the objects forward direction meaning that by changing this we change the direction it looks.

```
m_HitTransform.forward =
                        new Vector3 (Camera.main.transform.position.x - m_HitTransform.position.x,
                                     0,
                                     Camera.main.transform.position.z - m_HitTransform.position.z);
```

Code Snippet 6

4.2.3 Structuring the Animations

Each of the characters have a total of 8 animations; seven interaction animations and an idle animation. The animations are manged by the unity animation controller, with transitions between the idle animation and each of the interaction animations. The transitions are controlled by triggers. This means that when a trigger is activated the animation switches from the idle animation to interaction animation. The transitions towards the interaction animations have no exit time meaning that the switch will happen instantaneously, whereas the transition back to the idle animation have an exit time meaning that the animation will finish before it switches back to the idle animation.

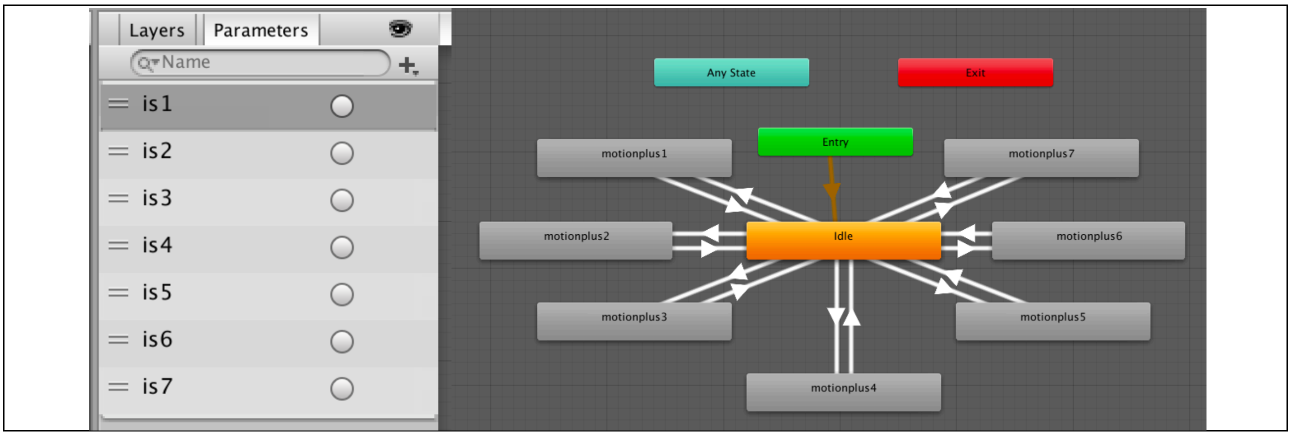


Figure 12: Animation controller

The triggers are manged by node objects. These objects also contain information about which animation is running, which audio clip should be played and which text should be displayed in the dialog option in order to reach the node itself. There are two types of node objects, the one containing the uses options and, the ones containing the characters' response. All the nodes are managed by a manager-object that also makes sure that the menu (the buttons and their background) is only visible when the user should make a choice.

5 Method

In order to answer the problem-statement we both need an appropriate method for assessing presence in augmented reality (AR) and a method for conducting the experimental test. In this chapter, we will therefore investigate the proposed methods of measuring presence and design an appropriate experimental test.

5.1 Measuring Presence

Several different approaches to measuring presence have been proposed. The majority of presence research, however, uses a post-test questionnaire [15] [25]. These questionnaires fall under the categories of subjective measures as the test subject themselves have to evaluate their experience. The alternative to subjective measures is objective measures. In this subsection, we will go through some of the most used proposed methods for measuring presence from both categories in order to narrow down and select a suitable method.

5.1.1 Objective Measures

The main advantage of using objective measures is that they are not affected by the test-subjects' subjective interpretation [25]. Most of the proposed methods for objective measurements are psychophysiological measures, such as heart rate and skin conductance. The problem with psychophysiological measures in an AR setting is that the test subject has to wear measuring devices. In a VR environment, this does not pose the same problem as in an AR environment. In AR, the real environment should be kept free of obtrusive objects, as these both limit the test participants movability and can pose as a problem for the tracking system. An alternative to psychophysiological measures is behaviour measures, such as facial expressions or postural response. Especially the facial expression measurement makes sense when working with AR on handheld displays as most newer phones have a front facing camera. A problem with this is however even though the method of using facial expressions have been proposed there is a lack of research regarding this topic. Another problem is that some of the AR SDKs' (e.g. ARKit) do not allow the use of both the front and back cameras on the phone. The main disadvantage of using objective measures is that it can be hard to know exactly what is measured [25]. Especially with presence measures as it is a combination of many factors that constitute the sense of presence.

5.1.2 Subjective Measures

As mention earlier the subjective measures uses the test-subjects own interpretation of the experience. Both methods of peri- and post-tests have been suggested. The advantage of using a peri-test method is that when a test-subject has to evaluate their experience they are not biased by their memory. This is because our judgement of an experience will be influenced more by factors closer to the end of an experience (the recency effect). The main method of evaluating presence during an experience uses some form slider to indicate the level of presence. Since both hands often will be used to hold a hand-held AR device, and the use of an analogue measurement device will limit the users' movability, this method does not seem fit in this context. Instead the method could also be applied as a post-test method. Van Baren and IJsselsteijn [25] argues that this type of cross-modality matching is especially effective when trying to assess topics that are not easily verbally scalable. The problem here however becomes that it heavily relies on the test-subjects' subjective interpretation of presence. This leaves the method of post-test questionnaires which as mentioned earlier is the most common method. A huge advantage is that the questionnaires are easy to compare and often have a high face validity. Van Baren and IJsselsteijn [25] presents a list of criteria such a questionnaire should fulfil:

- Understanding of presence should not be assumed by directly asking respondents how present they feel
- Questions should avoid addressing two issues in on question
- Response options should ideally be consistent across items
- Presence is likely to be a multidimensional construct; questions should reflect this and tap a range of characteristics
- Questions should not make reference to specific media systems and content properties
- A general presence measure should be piloted on participants of a range of media systems/contents
- Questionnaires should be piloted with a sufficient number of subjects

The list of criteria as presented in "Measuring Presence: A Guide to Current Measurement Approaches" [25].

These criteria will serve as a guide for selecting the questionnaire that will be used. Since most of the questionnaires have been designed for VR their applicability to AR needs to be investigated.

5.2 Presence Questionnaire for Augmented Reality

In order to find a suitable questionnaire for AR we will investigated some of the most used methods. An extensive list of questionnaires has been made by van Baren and IJsselsteijn [25]. Most of the questionnaires uses Ijsselsteijn definition of presence. Of these the ones concerning physical presences (such as the Slater-Usoh-Steed (SUS) questionnaire) often does not fit with an AR setting. This is because the often try to assess the quality of the remediation of the self, inside the virtual space. The focus of the SUS questioner revolves around three themes [25]:

1. The extent to which the users feel that they are being physically in the VE
2. The extent to which the VE becomes more dominant than reality for the user
3. The extent to which the VE is remembered as a place the users visited

Although the SUS is one of the most widely used questionnaires when measuring presence [3], the themes used seem to revolve around the "You are there" type of presence. Another presence questionnaire widely used is the ITC-Sense of Presence Inventory (ITC-SOPI) which already has been used for AR. In a study by Tang et al. [19] they used it to compare presence in AR and VR. They, however, found ITC-SOPI unsuitable for AR as the questions is targeted towards an all virtual experience. Instead we can, as Gandy et al. [26] and Stevens et al. [27], modified the existing Presence Questionnaire (PQ) and Immersive Tendencies Questionnaire (ITQ) presented by Witmer and Singer [28]. Although this questionnaire is also design for physical presence in VR it has previously been reworked for AR. These two questionnaires will therefore be used in a similar fashion as the base of the assessment in this project. The method proposed by Stevens et al. [27] is to maintain the focus of the questions and thereby preserve their conceptual constructs. The subscales presented by Witmer and Singer [28] for the PQ and ITQ, which is used by Stevens, is as follows:

Presence Subscales	
Influencing factor	**Description**
Involvement-Control	perceived control of events in the VE responsiveness of the VE to user-initiated actions how involving were the visual aspects of the VE how involved in the experience the participant became
Natural	the extent to which the interactions felt natural, the extent to which the VE was consistent with reality, how natural was the control of locomotion through the VE
Interface Quality	whether control devices or display devices interfere or distract from task performance the extent to which the participants felt able to concentrate on the tasks.
Additional Presence Subscales	
Influencing factor	**Description**
Resolution	The perceived quality of visual feedback
Auditory	The perceived quality of auditory feedback
Haptic	The perceived quality of haptic feedback
Immersive Tendencies Subscales	
Influencing factor	**Description**
Focus	Tendency of the user to maintain focus on current activities
Involvement	Tendency of the user to become involved in activities
Game	Tendency of the user to play video games

Table 4: Subscales of the Presence Questionnaire and the Immersive Tendencies Questionnaire

Not all of the factors presented in the PQ will be present in the application for this project. I will therefore neglect the questions associated with these factors. This is e.g. the Haptic factor as haptic feedback is out of the scope of this project. In order to rework the questions into ones that can be used in this case, I followed the criteria presented by van Baren and IJsselsteijn [25]. Based on the items form PQ and the questionnaire presented by Gandy et al. [26], I derived a list of questions based on the subscales presented earlier:

Augmented Reality Presence Questionnaire	
Factor	**Questionnaire Item**
Involvement-Control	1. How compelling was your sense of moving around inside the environment? 2. How involved were you in the experience? 3. How compelling was the experience?
Natural	4. How natural did moving around in the environment feel? 5. How natural did interacting with the character feel? 6. How much did your experiences seem consistent with your real-world experiences?
Interface Quality	7. How much did the control devices interfere with the performance of assigned tasks or with other activities? 8. How aware were you of the control device? 9. How distracting was the control mechanism?
Resolution	10. How closely were you able to examine objects? 11. How well could you examine objects from multiple viewpoints?
Auditory	12. How well could you localize sounds? 13. How well could you identify sounds?
Focus	14. How good are you at blocking out external distractions when you are involved in something? 15. How mentally alert do you feel at the present?
Involvement	16. Do you ever become so involved in a movie that you are not aware of things happening around you? 17. Do you ever get scared by something happening on a TV show or in a movie?
Game	18. Do you ever become so involved with a video game that it is as if you are inside the game rather than moving a joystick and watching the screen? 19. How often do you play games?

Table 5: Derived questions for the questionnaire

The questions presented here is used to determine both the users level of presence and their overall tendency to experience presence. The presence level can be used to compare the test participants experience of the conditions while the tendency to experience presence can be used to compare the groups.

5.2.1 Validation of questionnaire items

As the questionnaire was based on the PQ and ITQ with some of the items being reformulated to better fit AR they could have lost some of the face validity they previously had. This can be due to a question that is meant to represent an address one thing but is interpreted differently by the participants. In order to assess the face validity of the questionnaire items a semi structured interview with two participants was conducted. They each went through the test before the interview was conducted. The participants were asked what the test was about, and how they interpreted each question. Both of the participants answers did not deviate from the intended interpretation of the questions, which means that, at least to some extent, that the items measure what they are supposed to measure.

5.3 Experimental test

With the method for measuring presence established, the procedure of the test has to be chosen. It is important that the procedure itself does not influence the test participants. In the next section I will present the chosen method together with the reasons why I chose that method.

5.3.1 Test procedure

As the induvial user characteristics, both in the form of motivation towards the system as well as the emotional response to the narrative, influence the sense of presence, the test method chosen is a within group design. This means that the users will try each of the test conditions (Augmented reality environment, Virtual environment and the control environment). The order of which the conditions are exposed to the user should be randomized to eliminate any potential influence connected with the ordering. With the tree conditions this means that there are 6 possible combinations.

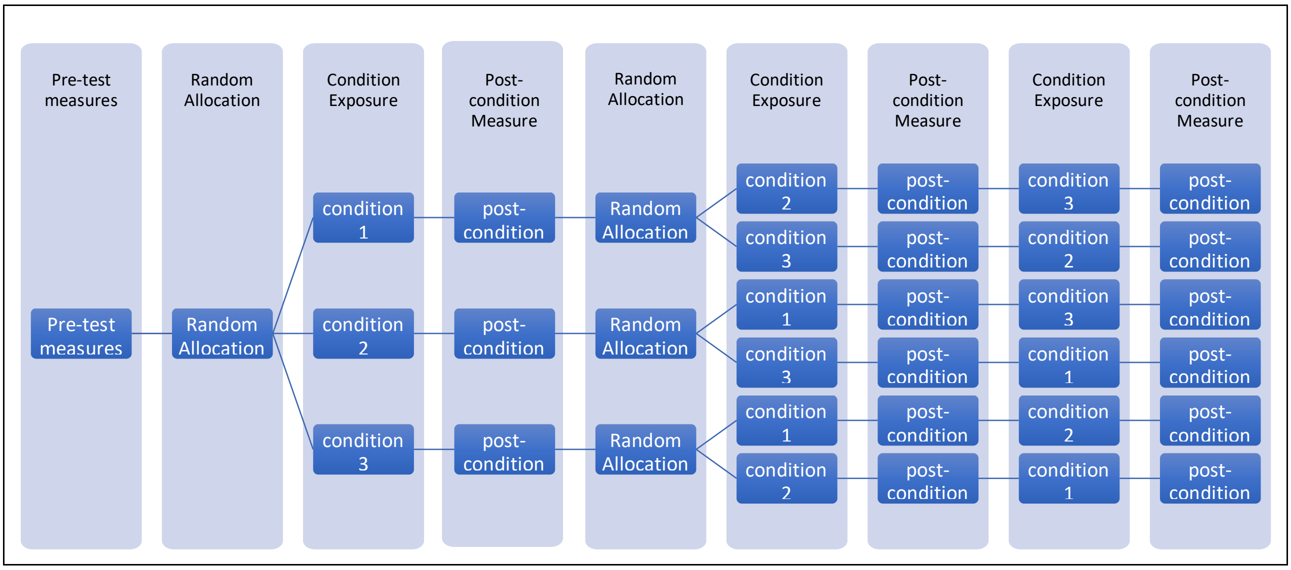


Figure 13: model of the 6 different exposure orders

The section of the questionnaire derived from the immersive tendencies questionnaire (ITQ) can be addressed before the test subjects begin interacting with the application. This is because the answers should not change during the test as the questions revolves around their general tendencies to becoming immersed in an experience. The rest of the questions (those addressing presence) should be asked directly after they have been exposed to an experiential condition. The questions addressing presence will be used to calculate a presence score for each participant. The ITQ will be used to determine if there are any outlying participants how do not fit with the rest. Further it will be used to determine if any of the exposure orders are overrepresented with either participant scoring higher or lower than the average which would mean that they might not judge the experience on the same basis as the rest of the participants.

5.3.2 Hypothesis

In order for the test to answer the problem statement, a hypothesis has to be formulated. With the problem stamen being: “Will a narrative mediated through AR yield a higher level of presence than a narrative mediated through non-AR?”, a dependent and an independent variable can be found. The dependent variable is the level of presence, which will be calculate through the use of the items regarding presence from the questionnaire, the independent variable is the system used to mediate the narrative, (Augmented reality environment, Virtual environment and the control environment). This leads to the following hypothesis:

H0: “A narrative mediated through Augmented Reality will yield the same level of presence as when a narrative is mediated through non-AR”

H1: “A narrative mediated through Augmented Reality will yield a lower level of presence than a narrative mediated through non-AR”

H2: “A narrative mediated through Augmented Reality will yield a higher level of presence than a narrative mediated through non-AR”

6 Results and Findings

In this section, the results from the experimental test will be presented and analysed. This will be done by investigating whether the data is parametric and choosing an appropriate statistical test.

6.1 Descriptive statistics

The experiment was conducted on 30 test participants (25 male and 5 female) aged 23-29 at Aalborg university CPH. The participants were allocated into one of six exposure orders determining which conditions each of the narrative sections would appear in. The mean Immersive tendency (IT) score was calculated for each group of exposure order to indicate any imbalances in the participant distributions.

Exposure order	IT score mean	Standard deviation
C, V, A	4,37	0,95
C, A, V	4,53	0,40
V, C, A	4,53	0,46
V, A, C	4,20	0,87
A, V, C	4,37	0,95
A, C, V	4,57	0,85

Table 6: immersive tendency scores of each exposure order

The mean IT score of each of the conditions are roughly equal an it is therefore unlikely that the Immersive tendencies of the participants have an effect on the results. An average presence score was calculated for each participant in each condition from the Likert items derived from the presence questionnaire (PQ).

Condition	Sample size	PQ score mean	Standard deviation
Augmented Reality	30	4.45641	0.81205
Virtual Environment	30	4.26154	0.68224
Control	30	3.80513	0.62745

Table 7: Descriptive statistics with outliers

The results were plotted in a notched box-plot. From the plot we can see that the samples for the control condition contains two outliers. These are indicated by the red crosses. As the outliers are not good representation of the general perception of the experience and therefore could influence the results they should be removed.

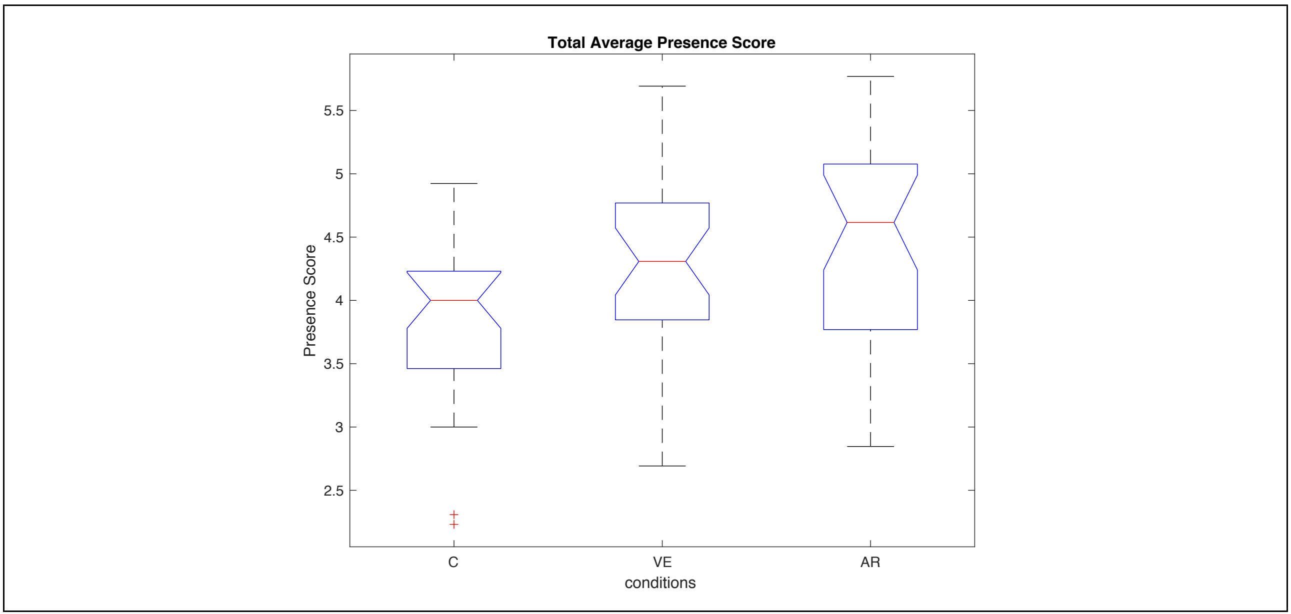


Figure 14: Notched box plot of the presence score in the three conditions

The outlying scores are from participants P22 and P27 which scored the condition much lower than the other participants. Their scores are therefore removed in all three conditions to ensure that the sample sizes are equal. This reduced the sample size in each condition to n=28.

Condition	Sample size	PQ score mean	Standard deviation
Augmented Reality	28	4.55495	0.74384
Virtual Environment	28	4.34890	0.61019
Control	28	3.91484	0.48530

Table 8: Descriptive statistics without outliers

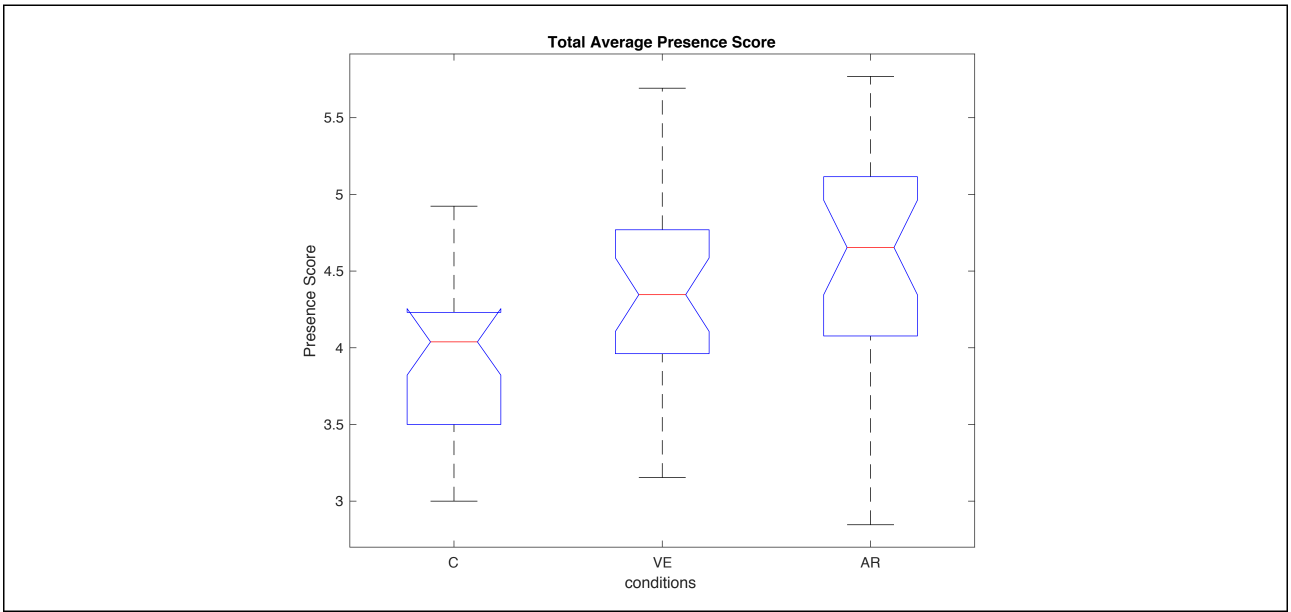


Figure 15: Notched box plot of the presence score in the three conditions without outliers

6.2 Inferential Statistics

With the dependant variable being the level of presence, and the independent variable being the three conditions the most suitable test seem to be the one-way analysis of variance (ANOVA). Because each participant was exposed to each of the different conditions it should be the repeated measures ANOVA. The ANOVA test is a parametric test and it therefore needs to fulfil a set of assumptions.

- the samples should be normally distributed
- the variance of differences between conditions must be equal (sphericity)

Before preforming the ANOVA test, we first need to investigate if these assumptions are violated. In the next couple of sections, the assumptions will be addressed with a fitting test.

6.2.1 Test for Normality

The first assumption for the ANOVA test is that the samples should be normally distributed. In order to see an indication of whether or not this is the case a histogram of the samples can be drawn.

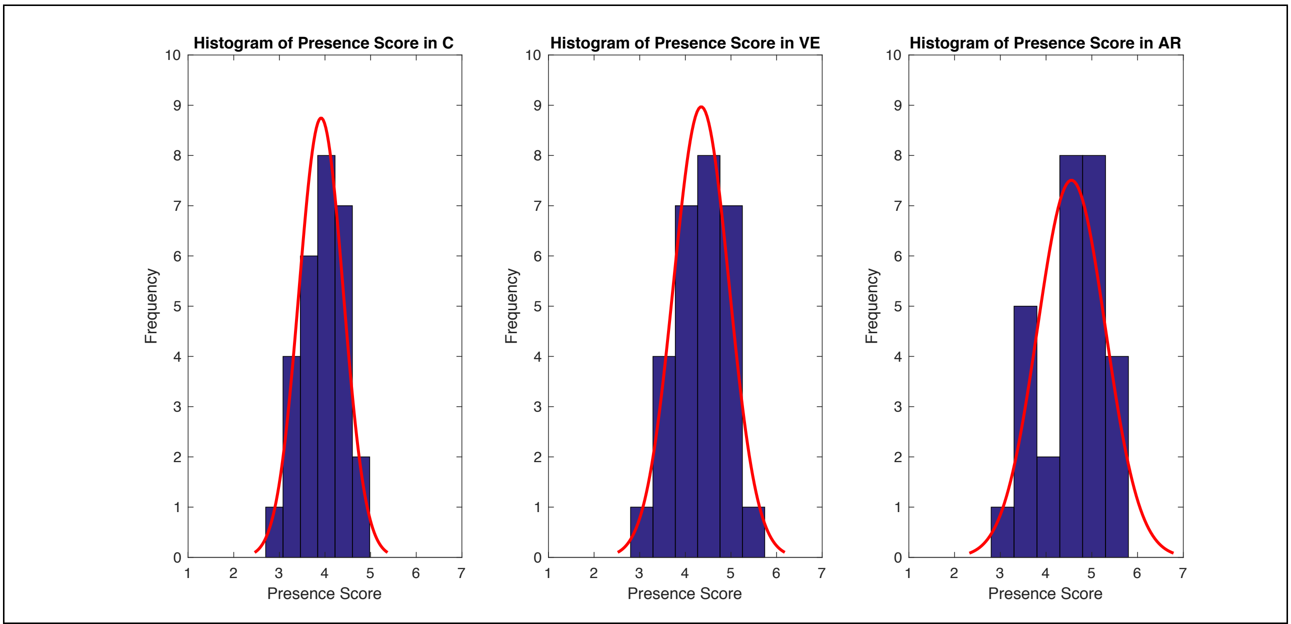


Figure 16: Histogram of the presence score in each condition

Although the histograms give a good indication that the data is normally distributed it does not tell whether or not it is different enough to cause a problem. If the data is significantly different from a normal distribution, it would mean that one of the assumptions of the ANOVA is violated.

The Anderson-Darling test was therefore used to check if the samples belongs to normal distribution. The hypothesis for the Anderson darling test is as follows:

H_0: the sample data do belong to a normal distribution

H_1: the sample data do not belong to a normal distribution

When applied to the samples from the test the following results are produced:

Condition	H	P-val
Augmented Reality	0	0.3585
Virtual Environment	0	> 0.9900
Control	0	0.3245

Table 9: Results from the Anderson-Darling test.

The Anderson-Darling test fails to reject the null hypothesis that the data belongs to a normal distribution for all three conditions. we can therefore assume that the data do belong to a normal distribution which means that the first assumption for the ANOVA test has been fulfilled.

6.2.2 Test for Sphericity

The second assumption for the ANOVA is that the differences between conditions are equal. This is also known as sphericity. if the participants had only participated in on condition the assumption had instead been that the two groups should have equal variance. Since the two measures are related, because the same participants were measured multiple times, the assumption is instead that the relationship between on pair of conditions are roughly the same as the relationship between another pair. The test used was Mauchly's test for sphericity with the following hypothesis:

H0: The variance of the differences between conditions are equal

H1: The variance of the differences between conditions are not equal

H	W	ChiStat	Degrees of freedom	p-value
0	0.98828	0.3066	2	0.85787

Table 10: Results from Mauchly's test of sphericity

The results from Mauchly's test indicates that the assumption of sphericity has not been violated. This means that both assumptions for the ANOVA test have been fulfilled.

6.2.3 Repeated Measures One-way ANOVA

With both assumptions fulfilled the ANOVA test can be performed to see if there are any significant differences between the conditions. The hypothesis for the test is:

H0: there is no significant difference between the three conditions

H1: there is a significant difference between the three conditions

	Sum of Squares	Degrees of freedom	Mean of Squares	F	pValue	pValueGG	pValueHF	pValueLB
effect	5.979	2	2.9895	15.558	4.6158e-06	5.1436e-06	4.6158e-06	0.0005126
Error	10.376	54	0.19215					

Table 11: results from the analysis of variance test

The ANOVA test show that there is a significant difference (P<0.05) between the conditions. We however still need to calculate the effect size of the ANOVA test which can be done with the following formula:

$$\omega^2 = \frac{MS_M - MS_R}{MS_M + \left((n-1) * MS_R\right)}$$

The resulting effect size is thus ω = 0.45 which is a large effect. The results from the ANOVA does, however, not tell where the difference lies. Therefore, a post hoc test is needed.

6.2.4 Pairwise comparison

The chosen post hoc test for the ANOVA is a pairwise comparison using a dependant T-test. This like the ANOVA compares the data to see if there is a significant difference.

H0: there is no significant difference between the conditions

H1: there is a significant difference between the conditions

		H	p	Standard deviation	Degrees of freedom	t
Augmented Reality	Virtual Environment	0	0.0865	0.6129	27	1.7789
	Control	1	1.7678e-05	0.6511	27	5.2026
Virtual Environment	Augmented Reality	0	0.0865	0.6129	27	-1.7789
	Control	1	6.3378e-04	0.5944	27	3.8638
Control	Augmented Reality	1	1.7678e-05	0.6511	27	-5.2026
	Virtual Environment	1	6.3378e-04	0.5944	27	-3.8638

Table 12: results from the pairwise comparison.

In order to calculate the effect size of the t-test the following formula was used:

$$r = \sqrt{\frac{t^2}{t^2 + df}}$$

The calculated effect size for the AR and control condition is r = 0.71 and for the VE and control condition r = 0.60 which both are large effects. This compares well with the effect size from the ANOVA test which also was large.

7 Discussion

In this chapter I will try to identify and discuss the meaning of the results. Elements that might have influenced the experiment and results will be presented together with possible solutions or methods to avoid these influences in the future.

7.1 Results

The results showed that there was a significant difference between the presence level of the control condition and the two other conditions. There was however no significant difference between the augmented reality (AR) condition and the virtual environment (VE) condition. There are several reasons why this could be all related to the nature of the control condition and is lack of an environment. The VE condition and the AR condition had an environment in which the character appeared. Since we are used to a surrounding environment the lack of one, which is the case for the control condition, is contradicting our expectations. Further Mennecke et al [14] argues that the environment in which the experience takes places is important because it conveys more meaning than just objects in space. We assign meaning to an environment even if we have not previously been there. The lack of an environment in the control condition means that not only was there no environment to assign meaning to there were also a disjointed representation of the character that deviates from what would be expected from reality.

Doing the test certain differences between the behaviour of the participants in each condition was observed. These differences might also have influenced the results. One of these observations was that users in the VE condition was looking around the virtual room instead of at the virtual character. This might have affected the participants by supporting an emergent narrative contained in the environment. Some of the participants said they were searching the virtual room for clues further supporting this.

When looking at the individual subcategories from which the presence score was calculated, the score for interface quality was on average scored highest in the control condition. while the difference was quite small and could be due to random noise it is quite interesting to consider as it supports the claim by Moreno et. al. [20]. They argue that certain types of interfaces and interaction modalities are not suitable for AR as they create a disjointed interaction between the user and the real. This means that in AR the distance between the mediated and the real becomes bigger.

	Control	VE	AR
Involvement-Control	3,98	5,07	5,07
Natural	3,65	4,26	4,58
Interface Quality	3,43	3,30	3,26
Resolution	4,23	4,79	5,45
Auditory	4,63	4,54	4,79
Total	3,91	4,35	4,55

Table 13: mean scores for the subscales without outliers

There was no significant difference between the AR condition and the VE condition. This also could be due to several reasons. One reason is that the two conditions could engender different kinds of presence. The VE condition supports the transportation aspect of presence in the form of "you are there". The test participants might feel that they to some extent are transported into the virtual environment. On the other hand, the AR condition transports the character to the user supporting the "it is here" aspect of presence. Another reason is that the effect size of moving the narrative from the VE to AR is simply too small to detect with the number of participants in the test. It can also be speculated that certain aspects of the design of the test might have influenced all of the results.

7.1.1 Character influence

One of these aspects is the use of multiple different characters in the test. The characters were designed to look different, in order to fit the narrative. This might however have influenced the participants as they might identify with or be influenced by one character more than others. A comparison between the characters was therefore made.

.

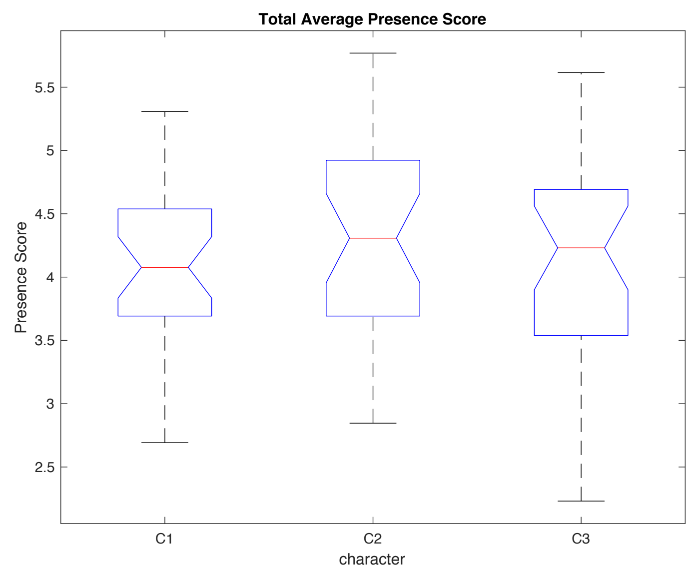


Figure 17: Notched box plot of the presence score for the three characters.
C1 = Connor Redwood, C2 = Natalie Miller, C3 = Nathan Reed.

From the box plot we can see that the groups are roughly equal. When preforming an ANOVA test the results show that there is no significant difference between the groups, F=1.0587, P(0.35) > 0.05. This means that it is unlikely that the characters had a large effect on the results from the between conditions test. While the choice of presenting the user with different characters might not have noticeably influenced the result, another method to completely avoid this would be to only have one character. If this was the case another problem could however arise. This have to do with the design of the narrative. By having the three different characters same base narrative could be used for all of them. This might not be the case if there only was one character. If the narrative was designed around the dramatic curve or the three-Act model, and then cut in to three sections as a way of supporting the use of only one character the results might instead be influenced by which section contained the climax of the story. Instead of using the repeated measures model the participants could instead only be presented with on condition. this would however require a larger sample size. Both in order to have the same number of measures in each condition as well as overcome the effect from the user characteristics (motivation towards the system and the narrative).

7.1.2 Repeated measures model

Another aspect of the repeated measures model that was not considered and might have influenced the results is, as mention by one participant (P9), that the participants over time would be tired from holding up their arm. This is one of the disadvantages of using a handheld display and even if none of the other participants mentioned this it might still have influenced their results. As the participants hold up their arm they will become more aware of the display as it becomes straining. another aspect related to the repeated measures model is that the participants could become aware of the underlying narrative structure. This would especially be the case in the later sections of the narrative as the same structure was used in all three. This is also mentioned by one participant (P23), who during the test was able to identify the core of the answers for the character in the last section of the experience even before starting to interact with the character.

7.1.3 Tracking differences

Another difference is in the way the world tracking was able to track the environment. The same tracking method was used in all three conditions, the participants did however behave differently. In the AR condition the participants look at the floor more often than the other conditions. Since the test was conducted in a room with plain white walls this meant that the tracking had more features to use when estimating its world position. In the control condition the users would look directly at the face of the character meaning that the camera would have fewer feature points to track from. This means that the resolution factor of the presence score could have been influenced, as this factor relates to how close and from how many viewpoints the participant was able to view the virtual characters. It should however also be mention that even though the AR condition benefitted from participance looking at the ground, it was also the only condition that had to align the character with the environment. if the tracking did not track correctly in the AR condition the character would glide across the floor, whereas in the VE and control condition the was only used to move the viewpoint of the participant. This mean that it would be more noticeable in the AR condition than the other conditions.

7.2 Answering the problem statement

In order to answer the problem statement, “Will a narrative mediated through AR yield a higher level of presence than a narrative mediated through non-AR”, three hypotheses was created.

H0: “A narrative mediated through Augmented Reality will yield the same level of presence as when a narrative is mediated through non-AR”

H1: “A narrative mediated through Augmented Reality will yield a lower level of presence than a narrative mediated through non-AR”

H2: "A narrative mediated through Augmented Reality will yield a higher level of presence than a narrative mediated through non-AR"

The level of presence was high in AR than the control condition but not higher than VE condition which means that it was only possible to reject the H1 hypothesis. It is therefore only possible to answer the problem statement to a certain extent. The level of presence is higher when a narrative is mediated through an Application that incorporates the character into the real world through augmented reality than if the character is represented without a relation to an environment. The level of presence is however not significantly higher if the character is represented in a virtual environment.

7.3 Future works

Through the experimental test addition features for improving the prototype and methods was found. In this section I will present some of the changes that should be consider for the future.

7.3.1 Prototype

Feedback from the test revealed issues with the implementation that decrease the participants sense of presence. These issues should therefore be addressed to increase the general sense of presence throughout the experience.

Light

The prototype was not able to analyse the room for the direction of the light. This means that the shadows would always be cast behind the character even if there was a light source behind them. While Sugano et al. [21] states that simply having the virtual objects have shadows would increase presence even if they did not fit the light conditions of the room. It was therefore decided that neglect this aspect of the implementation. One participant (P1) did however mentioned that the shadow of the character did not fit the room:

"*Light source in the room did not correspond with the light that was cast on the character*"

This might have resulted in that participant becoming more aware of the mediation. future test should therefore account for the light condition in the test environment either by having the application be able to amylase the room and match the light direction or by matching the light in the room to the predefined light of the application.

Narrative structure

The narrative structure of the implementation was made rather simple. It was possible for the test participant to visit the same nodes multiple times meaning that the participant would hear the same dialog when they did so. Two participants mention this (P4, P10).

"It's annoying that you have to go through the same dialog several times to explore all options"

"Should have option to ask about connor/wife, without repeating same question"

Another participant (P23) became aware of the underlying structure of the narrative which might also have had an influence on the presence level. More complex narrative structures could be designed in order improve the experience of the narrative.

Player Acknowledgement

Another design choice was to neglect the feature of having characters acknowledgement the participants by looking at them. Five participants (P1, P10, P13, P15, P21) did however mention, that they felt that the characters should look at them, when they were interacting with them. This relates to the influencing factors described by IJsselsteijn et al. [15] and Usoh [16]. The reason why the acknowledgement from the characters influences presence is that it confirms the existence of the participants in the environment. Another participant (P18) mentioned that the character could move closer to the camera. This would also be a way for the character to acknowledge the existence of the participant. This however also pose a problem with clipping. If the user moves the camera to close to the character the camera might clip though it because there is no physical constrain to avoid this. Doing the experience, it was observed that participants were closely examining the characters, this sometimes resulted in some of the clipping when the animation contained big movements. This should also be considered when designing the player acknowledgement features of the characters.

7.3.2 Method

Other areas of improvement relate to the method of the test. These topics did not affect the sense of presence but relates more to how the test was conducted.

Repeated measures model

Although the repeated measures model was chosen to avoid the subjective interpretation of the system it also came with certain disadvantages. These being the effects of having to hold up the arm for extended periods of time to interact with the system as well as the effects related to character influence. It should therefore be considered if an independent measures model should be used instead.

Questionnaire validity

The validity of the questionnaire should also be addressed. Although the face validity to some extend has been addressed by conducted a semi structured interview more test should be conducted. the questionnaire should also be expanded in order for it to be used in other situations where presence should be measured in AR.

7.4 Relevance in the field

The research of Augmented reality has mainly focused on the technical application, including tracking techniques and display methods. This project instead focused on the application of augmented reality in the context of presence. Much of the earlier research regarding presence have been targeted towards virtual reality. The results from this project indicates that the use of AR is at least as good as the use of non-AR (hereunder VE) for achieving presence. This means that investigations of what impact the use of the real environment have on systems that utilizes presence. This could e.g. be in the field of psychology where the use of one environment might have a different result than when using another. It could be that we applied different meaning to experiences that happen in a distant environment than we would do if the same experience happened in our living room.

8 Conclusion

This aim of this project was to investigate the sense of presence and its relation to Augmented reality. This was done though an analysis of the different methods for utilizing augmented reality as well as the aspects of presence that relates to augmented reality. An application containing three different environments for conveying a narrative was created. The three environments were an augmented reality environment, a virtual environment and a control condition without an environment. The sense of presence was measured in each condition using a modified version of Witmer and Singer's presence questionnaire. The experiment (n=30) did show a significant difference between the Augmented reality condition and the control condition but no significant difference between Augmented reality condition and the virtual environment condition. These results indicate that an application using augmented reality to convey a narrative is at least as good as one utilizing a virtual environment for achieving the sense of presence.

Bibliography

[1] [M3], M. Mohring, C. Lessing and O. Bimber, “Video See-Through AR on Consumer Cell Phones,” *ISMAR '04 Proceedings of the 3rd IEEE/ACM International Symposium on Mixed and Augmented Reality,* 2004.

[2] [M1], M. Lombard and T. Ditton, “At the heart of it all: The concept of presence,” *Journal of computer-mediated communication,* 1997.

[3] [M10], B. F. Goldiez and J. W. Dawson, “Is Presence Present in Augmented Reality Systems?,” *Proceedings of Presence 2004. VII. International Workshop on Presence,* 2004.

[4] [M8], J. Diemer, G. W. Alpers, H. M. Peperkorn, Y. Shiban and A. Mühlberger, “The impact of perception and presence on emotional reactions: a review of research in virtual reality,” *Frontiers in Psychology Volume 6,* 2015.

[5] [M9], P. Milgram, H. Takemura, A. Utsumi and F. Kishino, “Augmented reality: a class of displays on the reality-virtuality continuum,” *Proceedings of SPIE. Volume 2351: Telemanipulator and Telepresence Technologies ,* 1995.

[6] [M11], I. Wagner, W. Broll, G. Jacucci, K. Kuutii, R. McCall, A. Morrison, D. Schmalstieg and J. J. Terrin, “On the role of presence in mixed reality,” *Presence: Teleoperators and Virtual Environments, 18,* 2009.

[7] [M13], D. V. Krevelen and R. Poelman, “A Survey of Augmented Reality Technologies, Applications and Limitations,” *The International Journal of Virtual Reality, 9 (2),* 2010.

[8] [M14], O. Bimber and R. Raskar, Spatial augmented reality: merging real and virtual worlds, A. K. Peters, Ltd, 2005.

[9] [M12], F. Zhou, H. B. L. Duh and M. Billinghurst, “Trends in Augmented Reality Tracking, Interaction and Display: A Review of Ten Years of ISMAR,” *IEEE International Symposium on Mixed and Augmented Reality,* 2008.

[10] [M15], W. Steptoe, S. Julier and A. Steed, “Presence and Discernability in Conventional and Non-Photorealistic Immersive Augmented Reality,” *IEEE International Symposium on Mixed and Augmented Reality,* 2014.

[11] [M27] and D. van Krevelen, “Augmented Reality: Technologies, Applications, and Limitations,” 2007.

[12] [M17], D. Schmalstieg and D. Wagner, “Experiences with handheld augmented reality,” *Proceedings of 6th IEEE and ACM International Symposium on Mixed and Augmented Reality,* 2007.

[13] [M16], W. IJsselsteijn and G. Riva, “Being there: The experience of presence in mediated environments,” *Riva, G., Davide, F., & Ijsselsteijn, W. (eds.), Being there: concepts, effects and measurement of user presence in synthetic environments,* 2003.

[14] B. E. [M4] Mennecke, J. L. Triplett, L. M. Hassall, Z. J. Conde and R. Heer, “An Examination of a Theory of Embodied Social Presence in Virtual Worlds,” *Decision Sciences Journal of Innovative Education Volume 42, Issue 2,* 2011.

[15] [M18], W. A. IJsselsteijn, H. de Ridder, J. Freeman and S. E. Avons, “Presence: Concept, determinants and measurement,” *Proc. SPIE 3959, Human Vision and Electronic Imaging V,* 2000.

[16] [M20], M. Usoh, E. Catena, S. Arman and M. Slater, “Using presence questionnaires in reality,” *Presence-Teleoper. Virtual Environ. 9,* 2000.

[17] [M28], A. Gorini, C. S. Capideville, G. D. Leo, F. Mantovani and G. Riva, “The Role of Immersion and Narrative in Mediated Presence: The Virtual Hospital Experience,” in *Cyberpsychology, Behavior, and Social NetworkingVol. 14, No. 3*, 2011.

[18] [M5], F. Maringelli, J. McCarthy, A. Steed, M. Slater and C. Umiltà, “Shifting visuo-spatial attention in a virtual three-dimensional space,” *Brain Res Cogn Brain Res,* 2001.

[19] [M6], A. Tang, F. Biocca and L. Lim, “Comparing Differences in Presence during Social Interaction in Augmented Reality versus Virtual Reality Environments: An Exploratory Study,” *Proc the International Workshop on Presence,* 2004.

[20] [M29], E. Moreno, B. MacIntyre and J. D. Bolter, “Alice’s Adventure’s in New Media: An Exploration of Interactive Narratives in Augmented Reality,” in *Conference on Communication of Art, Science and Technology (CAST'01)*.

[21] [M30], N. Sugano, H. Kato and K. Tachibana, “The Effects of Shadow Representation of Virtual Objects in Augmented Reality,” in *Proceedings of the Second IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR’03)*, 2003.

[22] [M31], K. Kim, G. Bruder and G. Welch, "Exploring the effects of observed physicality conflicts on real-virtual human interaction in augmented reality," in *Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology*, 2017.

[23] [M32], K. Kim, G. Bruder and D. Maloney, "The Influence of Real Human Personality on Social Presence with a Virtual Human in Augmented Reality," in *Proceedings of the Combined International Conference on Artificial Reality & Telexistence and Eurographics Symposium on Virtual Environments (ICAT-EGVE)*, 2016.

[24] [M21] and M. Ryan, "Toward an Interactive Narratology," in *Avatars of Story*, Minneapolis: University of Michigan Press, 2006.

[25] [M22], J. v. Baren and W. IJsselsteijn, "Measuring Presence: A Guide to Current Measurement Approaches," 2004.

[26] [M25], M. Gandy, R. Catrambone, B. MacIntyre, C. Alvarez, E. Eiriksdottir, M. Hilimire, B. Davidson and A. C. McLaughlin, "Experiences with an AR Evaluation Test Bed: Presence, Performance, and Physiological Measurement," *IEEE International Symposium on Mixed and Augmented Reality,* 2010.

[27] [M24], B. Stevens, J. Jerrams-Smith, D. Heathcote and D. Callear, "Putting the virtual into reality: assessing object presence with projection-augmented models," *Presence, 11 (1),* 2002.

[28] [M26], B. G. Witmer and M. J. Singer, "Measuring Presence in Virtual Environments: A Presence Questionnaire," in *Presence: Teleoperators and Virtual Environments Volume 7 Issue 3*, 1998.

[29] [M2], N. Ravaja, T. Saari, M. Turpeinen, J. Laarni, M. Salminen and M. Kivikangas, "Spatial presence and emotions during video game playing: Does it matter with whom you play?," *Presence: Teleoperators & virtual environments,* 2006.

Links

[L1] Lenovo – Starwars Jedi Challenge
https://www3.lenovo.com/dk/da/jedichallenges

[L2] Bluecity – Lenovo AR headset
https://www.bluecity.dk/elektronik/catalog/product/view/id/177389/s/lenovo-ar-headset-star-wars-jedi-challenges-with-lightsaber-controller-and-tracking/

[L3] Reallusion - Character Creator
https://www.reallusion.com/character-creator/

[L4] Reallusion - iClone
https://www.reallusion.com/iclone/

[L5] Reallusion - 3DXchange
https://www.reallusion.com/iclone/pipeline.html

[L6] Stackexchange - Axes illustration
https://tex.stackexchange.com/questions/118055/circular-arrow-in-3d-to-indicate-a-unit-axis-rotation

Appendix A - Results

Appendix A - Results

Demographics

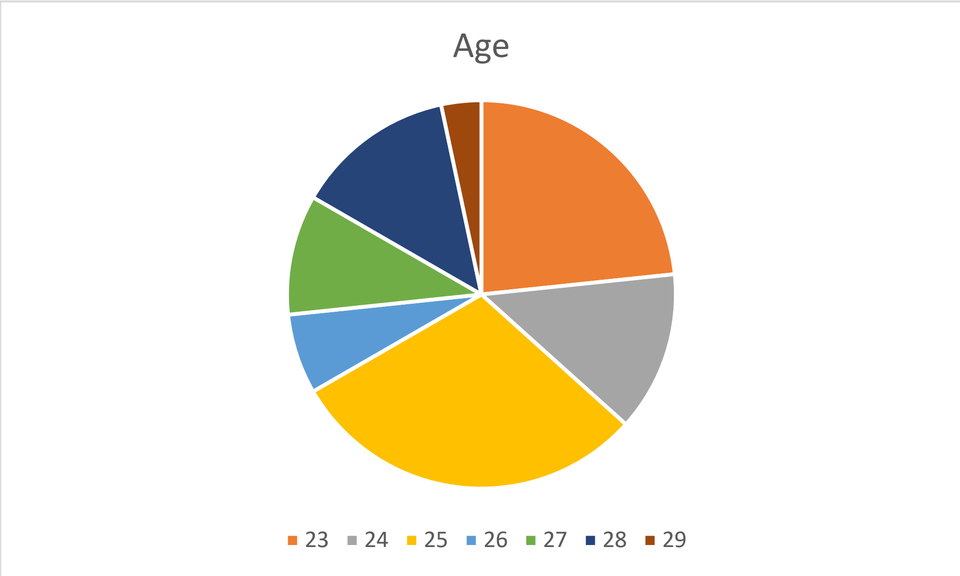
Participant Number	Exposure order	Age	Gender
P1	C, V, A	23	Male
P2	C, A, V	25	Male
P3	V, C, A	25	Male
P4	V, A, C	23	Male
P5	A, V, C	28	Male
P6	A, C, V	26	Male
P7	A, V, C	24	Male
P8	A, C, V	25	Male
P9	V, C, A	23	Male
P10	V, C, A	26	Male
P11	C, V, A	27	Female
P12	C, A, V	27	Male
P13	A, V, C	28	Male
P14	A, C, V	25	Male
P15	V, A, C	25	Male
P16	V, C, A	25	Male
P17	C, A, V	28	Male
P18	C, V, A	25	Female
P19	C, A, V	29	Male
P20	A, V, C	24	Female
P21	A, C, V	23	Female
P22	V, A, C	23	Male
P23	V, C, A	27	Male
P24	C, A, V	24	Male
P25	C, V, A	28	Male
P26	V, A, C	24	Male
P27	V, A, C	25	Female
P28	C, V, A	23	Male
P29	A, V, C	23	Male
P30	A, C, V	25	Male

A = augmented reality condition, V = Virtual environment condition, C = control condition

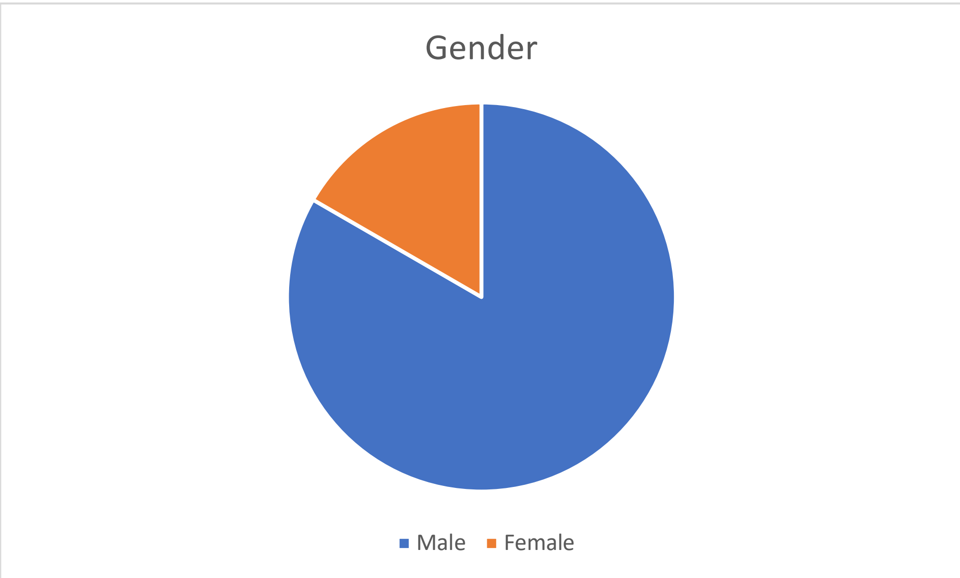
Exposure order	Number of Participants
C, V, A	N = 5
C, A, V	N = 5
V, C, A	N = 5
V, A, C	N = 5
A, V, C	N = 5
A, C, V	N = 5

A = augmented reality condition, V = Virtual environment condition, C = control condition

Age



Gender



IT

	How good are you at blocking out external distractions when you are involved in something?	How mentally alert do you feel at the present?	Do you ever become so involved in a movie that you are not aware of things happening around you?	Do you ever get scared by something happening on a TV show or in a movie?	Do you ever become so involved with a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?	Do you ever become so involved with a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?
P1	5	4	6	2	4	2
P2	2	5	3	5	3	5
P3	5	4	7	5	6	4
P4	5	4	5	3	2	1
P5	2	5	7	6	6	2
P6	5	4	6	2	5	5
P7	7	5	7	4	7	2
P8	5	6	7	2	6	2
P9	2	2	6	4	5	7
P10	2	5	4	2	5	7
P11	2	4	2	5	4	1
P12	2	5	5	6	4	5
P13	6	7	5	3	6	6
P14	6	5	7	7	5	5
P15	2	6	6	7	6	6
P16	3	5	5	3	3	5
P17	2	5	5	5	6	7
P18	6	3	6	6	2	2
P19	3	3	6	6	6	5
P20	5	3	6	4	1	2
P21	4	4	4	5	1	1
P22	3	6	2	2	1	5
P23	5	3	7	5	5	5
P24	2	6	5	5	3	6
P25	6	4	6	4	6	5
P26	5	6	3	2	5	5
P27	3	3	7	7	5	3
P28	4	5	7	6	5	7
P29	2	3	5	4	2	1
P30	4	6	5	3	4	6

PQ - AR

	How compelling was your sense of moving around inside the environment?	How involved were you in the experience?	How compelling was the experience?	How natural did moving around in the environment feel?	How natural did interacting with the character feel?	How much did your experiences seem consistent with your real-world experiences?	How much did the control devices interfere with the performance of assigned tasks or with other activities?	How aware were you of the control device?	How distracting was the control mechanism?	How closely were you able to examine objects?	How well could you examine objects from multiple viewpoints?	How well could you localize sounds?	How well could you identify sounds?
P1	6	6	5	6	4	5	3	3	3	6	6	5	6
P2	5	5	5	5	5	3	5	6	3	5	4	4	5
P3	6	6	5	7	6	7	2	5	3	6	7	3	5
P4	3	5	5	3	3	4	3	2	3	6	6	2	4
P5	6	5	4	6	3	2	3	4	2	5	6	6	7
P6	5	6	5	5	4	4	6	6	6	5	5	6	6
P7	5	7	6	6	5	5	2	2	2	6	7	4	4
P8	2	5	3	3	4	5	1	5	1	5	5	3	5
P9	5	6	5	5	4	2	5	6	6	7	6	5	5
P10	4	2	3	3	2	3	3	5	3	5	4	3	4
P11	7	7	7	6	4	3	4	4	2	7	7	7	7
P12	7	6	6	7	6	6	1	1	2	6	7	6	5
P13	4	5	5	6	3	2	3	4	2	6	5	4	7
P14	2	5	4	4	3	4	3	3	3	4	4	2	4
P15	4	2	6	3	2	2	2	4	4	6	6	6	6
P16	3	3	3	2	3	2	3	5	2	2	2	2	5
P17	7	7	6	7	6	7	2	5	2	7	7	6	6
P18	7	6	6	7	6	5	2	2	2	5	7	5	5
P19	6	5	6	6	5	5	2	4	2	6	6	5	6
P20	4	4	3	4	5	3	4	3	1	4	4	5	1
P21	5	3	4	6	6	4	3	5	3	5	6	3	3
P22	2	4	3	4	3	3	2	5	2	5	4	2	4
P23	6	5	5	6	5	5	5	5	3	4	4	4	4
P24	6	6	5	5	4	5	2	6	2	6	6	5	5
P25	6	6	6	5	4	4	2	1	2	5	5	3	4
P26	6	6	6	7	6	6	2	4	2	6	6	5	5
P27	2	2	2	3	1	1	2	3	3	6	5	4	3
P28	7	7	7	7	5	6	2	5	2	6	6	6	7
P29	5	3	3	5	5	4	2	6	2	7	7	5	6
P30	5	4	5	6	4	2	4	6	6	2	4	5	6

PQ - VE

	How compelling was your sense of moving around inside the environment?	How involved were you in the experience?	How compelling was the experience?	How natural did moving around in the environment feel?	How natural did interacting with the character feel?	How much did your experiences seem consistent with your real-world experiences?	How much did the control devices interfere with the performance of assigned tasks or with other activities?	How aware were you of the control device?	How distracting was the control mechanism?	How closely were you able to examine objects?	How well could you examine objects from multiple viewpoints?	How well could you localize sounds?	How well could you identify sounds?
P1	5	5	5	5	3	4	3	3	3	5	6	4	6
P2	5	6	4	5	5	4	5	5	3	4	5	4	4
P3	5	4	6	7	2	4	3	7	2	4	2	3	4
P4	5	6	6	5	2	2	3	2	4	4	5	1	5
P5	7	6	5	6	5	4	1	3	2	7	7	6	7
P6	4	5	4	4	3	3	5	5	5	4	4	5	5
P7	6	7	7	6	6	5	2	1	1	6	7	4	4
P8	7	5	6	6	4	3	1	2	1	7	7	2	2
P9	2	5	3	3	4	3	6	7	5	3	4	4	3
P10	4	5	5	3	3	2	2	5	3	4	3	4	5
P11	6	6	6	5	2	4	4	5	3	5	6	6	6
P12	7	7	6	4	6	4	1	1	1	5	7	5	4
P13	6	6	5	4	3	3	3	4	2	4	5	4	7
P14	3	5	3	4	3	4	3	3	3	4	4	4	4
P15	4	5	6	6	5	2	4	6	4	5	5	7	6
P16	4	4	3	5	3	4	2	5	3	2	2	2	4
P17	5	4	5	3	6	6	2	5	2	5	4	6	6
P18	5	7	7	5	5	4	2	2	2	6	6	3	5
P19	4	5	5	4	6	4	2	5	2	5	6	5	6
P20	3	5	4	2	5	4	2	1	1	4	2	4	4
P21	5	4	4	4	4	4	4	5	5	5	5	3	3
P22	3	5	4	3	5	2	2	5	2	4	3	3	3
P23	3	2	4	2	2	1	6	5	4	4	4	4	4
P24	5	5	5	5	5	3	2	6	2	5	3	4	4
P25	6	6	5	5	5	4	2	2	2	4	3	3	4
P26	5	5	4	5	5	6	3	3	6	5	4	5	6
P27	2	2	2	3	1	2	2	4	3	5	5	2	2
P28	7	7	7	7	6	7	1	5	3	5	6	6	7
P29	6	4	4	6	5	5	1	7	2	7	7	7	6
P30	6	5	6	7	6	3	2	7	7	6	5	4	4

PQ - Controll

	How compelling was your sense of moving around inside the environment?	How involved were you in the experience?	How compelling was the experience?	How natural did moving around in the environment feel?	How natural did interacting with the character feel?	How much did your experiences seem consistent with your real-world experiences?	How much did the control devices interfere with the performance of assigned tasks or with other activities?	How aware were you of the control device?	How distracting was the control mechanism?	How closely were you able to examine objects?	How well could you examine objects from multiple viewpoints?	How well could you localize sounds?	How well could you identify sounds?
P1	3	3	3	3	5	3	4	6	4	4	6	3	6
P2	2	4	4	5	4	3	3	5	3	3	5	4	4
P3	5	5	5	3	3	3	4	6	2	5	4	3	5
P4	2	5	5	3	3	4	2	2	3	1	6	2	3
P5	2	3	2	3	4	1	2	2	1	7	6	6	7
P6	3	2	3	3	2	3	5	5	4	2	2	4	4
P7	5	5	6	4	5	4	2	3	2	6	5	4	4
P8	2	5	2	1	3	2	6	6	3	5	3	5	5
P9	5	5	4	3	4	4	4	6	6	2	3	5	6
P10	3	2	3	4	3	3	2	5	3	5	5	3	3
P11	5	7	6	4	6	5	1	3	2	2	2	5	6
P12	4	6	4	4	6	4	2	2	2	5	4	6	4
P13	2	3	3	2	2	2	4	4	3	3	1	4	6
P14	2	4	3	4	3	3	3	3	3	4	3	3	4
P15	5	6	4	6	3	2	2	5	4	6	6	6	6
P16	4	3	3	5	3	2	3	5	4	3	3	2	5
P17	6	5	6	6	4	5	2	5	2	6	5	6	6
P18	3	6	6	4	5	3	2	4	1	5	6	4	3
P19	4	5	5	4	6	5	2	6	3	4	4	4	6
P20	4	5	4	4	4	4	1	1	1	4	4	5	5
P21	4	5	4	5	5	4	4	5	4	4	5	3	4
P22	1	2	3	1	2	1	1	5	1	5	2	2	4
P23	4	5	4	4	2	3	4	6	5	4	4	4	5
P24	2	3	3	5	4	3	2	6	3	5	5	4	5
P25	5	5	5	6	4	4	2	2	2	4	3	4	6
P26	3	2	4	2	3	2	5	6	5	2	2	4	5
P27	1	2	2	1	1	1	2	3	3	4	4	3	2
P28	3	5	4	3	6	6	2	6	2	4	3	5	6
P29	4	4	3	3	3	2	1	7	1	7	7	7	6
P30	6	3	3	5	4	1	4	4	4	7	6	4	5

Participant Number	Exposure order			
P1	C, V, A		The characters eyes did not follow me when i move which is a bit OFF-putting	Light source in the room did not correspond with the light that was cast on the character
P2	C, A, V			
P3	V, C, A			
P4	V, A, C	The question-selection boxes are not a very natural way of interacting with the character	It's annoying that you have to go through the same dialog several times to explore all options It would feel more natural if the character looked at me - were less static.	
P5	A, V, C			
P6	A, C, V			
P7	A, V, C	Was pleasantly surprised by how the character was tracked in the environment.	I prefered the first environment, where virtual and real mixed together	Experienced some clipping when walking through the character. Furthermore, I didn't quite like the dark environment compared to the previous ones. I'd rank the real environment as the highest, the virtual as the secondary, and the black environment as the least pleasant. In respect to sound, I tried moving the viewing point, but didn't notice any change in direction.
P8	A, C, V	Der skulle måske have være flere personer i rummet, så man kunne høre forskel på dem	Det samme som før	
P9	V, C, A	It was difficult to hear all the words sometimes. Perhaps there should have been subtitles and/or headphones	Very distracting that my arms get tired by holding up the phone.	The character was not as tall on the picture as he would have been in real life.
P10	V, C, A	Animations were delayed, but made sense with what the character was saying	Animations were not as fluent here. Feels weird that the character doesn't look at you, or follow you around	Should have option to ask about connor/wife, without repeating same question. Character doesn't look at you.
P11	C, V, A			Interaktionen med personen ville føles meget mere naturlig hvis man følte man fik øjenkontakt.
P12	C, A, V			
P13	A, V, C		FIX SKYBOX, and make the character look at the camera, when the user is in front of said character.	
P14	A, C, V			
P15	V, A, C		It was a bit strange that she wasn't looking at me but just straight ahead, and that she was so small compared to the real room. Also you had to ask some questions again in order to ask questions further in the dialogue tree.	
P16	V, C, A			
P17	C, A, V			
P18	C, V, A		I first noticed that I was able to move around and examine objects closely in this session, so the previous responses might be biased by that.	It would be even more 'real world like' if the characters would move towards the player when you moved around in the environment
P19	C, A, V	I didn't consider walking around :)	This time I did move around a bit, which made some answers much more positive	I think I looked at everything from a bird's eye perspective more than the other conversations, which kind of pulled me out of it a bit - it was a bit weird.
P20	A, V, C	I did not move around		

P21	A, C, V		maybe have the actor look at you and follow you around when you move	i was taller than the guy, he did not look at me and i therefore felt the gap between us even more.
P22	V, A, C	I did not look around or explore the environment I was set in. I was only focused on the character placed in front of me.	I did not walk around the character presented, which means that I didn't examine it from multiple points of view.	
P23	V, C, A	The questions were not interesting. You could only ask the character for motive of himself and the other, nothing about means or orppotunity, or incosistencies in his or the other caracthers story, nor cinfront him with evidence.		The test with the black void was very distracting.
P24	C, A, V			
P25	C, V, A	Not other than the questions seems more fitting to VR experiences		
P26	V, A, C			
P27	V, A, C			
P28	C, V, A			
P29	A, V, C			
P30	A, C, V	I did not try to move at all while in the environment	It was less distracting with the control device this time,	The control device, while interacting with the experience, kinda caused me to break the experience... So i guess i became quite aware and distracted by the control device this time.. But to be fair, i also went full medialogy on it and broke it,... sorry

Appendix B - Character comparison

Condition	Sample size	PQ score mean	Standard deviation
C1	30	4.45641	0.81205
C2	30	4.26154	0.68224
C3	30	3.80513	0.62745

Anderson-darling test

Condition	H	P-val
Augmented Reality	0	0.9696
Virtual Environment	0	0.6664
Control	0	0.5136

Mauchly's test

H	W	ChiStat	Degrees of freedom	p-value
0	0.93511	1.8786	2	0.39089

ANOVA test

	Sum of Squares	Degrees of freedom	Mean of Squares	F	pValue	pValueGG	pValueHF	pValueLB
Effect	0.60868	2	0.30434	1.0587	0.35352	0.35036	0.35352	0.31202
Error	16.673	58	0.28747					