Goldsmiths College
University of London

BSc (Hons) Computer Science
Department of Computing

Can virtual reality headsets aid in creating a more realistic facial composite?

Author:
Angela Pham

Supervisor:
Dr. Michael Zbyszynski

Acknowledgements

To all my loved ones

Abstract

Facial composites within the law enforcement are graphical representations that can aid in finding a suspect. Composites are usually based on a witnesss recollection of another persons facial characteristics. Generating graphical images can lead to potential conviction to apprehension of a criminal offender.

The past few decades has seen major technological advancement of virtual reality. Once seen an experience only available to those would have to travel to experience it, much like a cinema, it has now become readily available to most rst-world users through means such as smart phones and games consoles.

This paper looks to discuss whether or not virtual reality can help to recreate more realistic looking facial composites with the intention of them being used in the crime sector.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

Facial composites within the law enforcement are graphical representations that can aid in finding a suspect. Composites are usually based on a witnesss recollection of another persons facial characteristics. Generating graphical images can lead to potential conviction to apprehension of a criminal offender.

Taylor, who pioneered 2D facial reconstruction, noted that forensic art can than be traced back to more than a hundred years [14] and that an early example can be traced from Scotland Yard when a £200 wanted poster was created for the capture of Percy Lefroy Mapleton who committed murder of Isaac Frederick Gold.

The past few decades has seen major technological advancement of virtual reality. Once seen an experience only available to those would have to travel to experience it, much like a cinema, it has now become readily available to most first-world users through means such as smart phones and games consoles.

Many see virtual reality as a means of escapism, but there are some situations in which virtual reality can assist in real-life situations. An example of this is within the healthcare system. Lange et al[15] conducted studies on elderly participants and found that their motor capacity could be improved

through the use of technology.

This paper looks to discuss whether or not virtual reality can help within the law enforcement setting when generating facial composites.

1.2 Motivation

The main beneficiary of this paper is mainly anyone within the law enforcement field. Other people that can benefit from this paper include software developers who are looking to create a piece of software that allows the general public who have little none knowledge in creating realistic 3D models, solely for graphic representations and not for complex animation and rigging.

1.3 Aims and Objectives

The aim of this paper is to investigate as to whether the use of virtual reality headsets can aid in creating a more realistic facial composite.

The objectives include conducting an investigation as to whether or not using a VR headset creates a different facial composite compared to using the standard facial composite software used. The composites generated will then be compared against the real-life photo to see which has a closer match, using appropriate software. Research in creating a 3D composite will also be made to see if there is any future potential of VR has in the forensic field and what the current limitations are.

1.4 Overview of chapters

The structure of this thesis is as follows:

Chapter 2: Literature Review

In this chapter, discussions the past current methods use to generate facial composites and what the key requirements are needed to create an effective piece of software. After that we discuss the role that virtual reality currently has within the police field and the future potential. There is also

emphasis on what makes a good facial composite will be reviewed and how VR headsets can improve the current systems implemented.

Chapter 3:Research and Design
Regarding research, this chapter outlines the current scope of the research and what research approach and method was used in this paper
Chapter 4 includes a description of what each scenario should comprise of. For our investigation, the use of multiple types of software and hardware will be used. This chapter also discusses any justification behind using certain things within the project. Chapter 4 discusses the final version of the investigation and how it was conducted.

Chapter 4: Results and Discussion
All of the results and findings are then compared and summarised within this chapter. One of the sections will include an in-depth discussion on the what the results mean regarding virtual reality and facial composites. Strengths and weakness of the experiment carried out are also discussed. There is also a discussion on several types of current software and the potential they have in creating an effective 3D facial composite.

Chapter 5: Conclusion and future work

For this last chapter, we evaluate the experiment conducted and what can be done in the future to further improve the results and what problems now arise from the research and can be investigated.

Chapter 2

Literature Review

2.1 Example of current facial composite systems

Facial composites were typically hand drawn for many years to create a visual representation of a suspect from a witnessess memory. The advancement of technology, paved way for a faster recollection of identifying and illustrations of alleged criminals. Evofit is the current leaders (from 2001) in creating facial compositions. It does this by creating a database of features, filtering specific facial parts, and blends the parts seamlessly through the use of sketching techniques.

It was able to achieve this through years progression and updates made by intensive years of research and reviewers. The application uses an evolution based method of identifying suspects, which is done through an initial description but then changed slightly to create an accurate portrayal. For example, once a victim or witness describes the basic features of the face, the application would then create multiple copies but change a facial feature each time. The creation of multiple facial composites with the ability to change an image in the slightest way had not been attempted before with traditional sketches; this led to the a higher rate of suspect identification by police forces around the world.

In Sri Lanka, during the year of 2014, 92.86% [10] of facial composites sketches were deemed as a failure . One of the potential reasons for this was the fact they all of the forensic sketches were hand drawn. Facial composites

are generated for the purpose of being shown to the public to aid in the effort of finding the suspect. Currently, a majority of these composites are generated using a computer and are based on an eyewitnesses description. This relies on a member of the general public being able look at the image and being able to recognise similar facial characteristics of a person that they know or have seen. This means that the composites can contribute significantly towards court proceedings, which can lead to prosecution of a suspect. Creating a composite can help with eyewitness confidence.

2.2 Whole face approach

Systems such as EigenFit and EvoFIT have advantages when compared to feature based systems, due to the composites having a more realistic appearance.

EigenFIT uses the Active Appearance Model (AAM) in order to generate facial composites. This approach is mainly used to match and track faces.

2.2.1 EvoFIT

EvoFIT[1] is a system that is has used by multiple constabularies worldwide. It has led to arrests in multiple crime cases including but not limited to but including rape, aggravated robbery and theft. The EvoFIT composite system works by displaying a face with all of its components and then based on the witness choice similar composites that are within the same type of array are displayed for the witness to select again, this process is repeated until the closest likeness is achieved. During 2002, EvoFIT was initially said to perform poorly when compared to other composite systems[12]. However, a decade later Frowd et al noted that recently, arrests are made in 75% of cases when EvoFIT is used and lead to a conviction rate of one in five[13]. They also reported that in 2010 60% of the tests lead to an identification of a subject when used by Humberside Police.

2.3 Feature based methods systems

S Gibson et al stated that the problems with feature based methods such as Photofit and E-fit are that faces are recognised as a whole and not as the

sum of their constituent features and, the appearance of the suspect looking unrealistic [**?**]. When witnesses are recalling a description of a suspect due to the nature of describing a feature individually, this leads to a potential of making the feature more exaggerated.

Chapter 3

Research Methodology and Design

3.1 Scope of research

The current scope of research into creating a more realistic composite with the assistance of virtual reality headset has not yet been made. The investigation in this paper will be mainly focus on the if virtual reality at its current state can be of assistance in creating composites. In regards to virtual reality headsets, there are different levels of immersion that can be made which may have a impact on the realism of a composite. For the investigation we will look to fully immersive with the use of Virtually Naked.

3.2 Ethical Considerations

Before conducting all of experiments, written consent letters were given to each of the subjects and told them that the participation was voluntary. This was to reassure participants that they had no obligation to participate. Subjects were also told that all their details would be treated in confidence and that there would be no identifiable information retained.

3.3 Requirements for the experimental environment

This section will provide information into what resources are need to conduct the experiment These include:

3.3.1 Software

In order to perform the experiments, the following software was used to conduct an effective study:

FACES 4.0 [2]
During the initial stages of our test the use of a current system that it has been implemented within the police field was desired. Based on the studies, the use of a feature-based system isnt necessarily ideal, however to time constraints and software that was readily available, FACES 4.0 was chosen. FACES 4.0 is a program that allows users to easily choose facial features from rich database with a simple click of a button. Using this software will allow there to be a baseline that can be compared against different potential ways of creating a facial composite.

Black Desert Online [3]
Black Desert Online is a free to play MMORPG that will be used for the purposes of the investigation. More specially, its Character Creation mode will be used in creating a facial composite in 3D. The main advantage of using a in-game character creator over modelling software is due to the ease of use. When considering that large amount of population may not have any prior knowledge in creating a rigged model in software applications such as Blender and Maya, the choice of using a facial composite using a software from a game is more advantageous towards the investigation. Due to time limits, the option of creating a program within Unity that allowed users to manipulate rigged models to make it more user-friendly were scrapped.

Virtual Desktop[4]
Virtual Desktop is an application that allows for users to view their desktops in a VR setting. For the purposes of the investigation, it will be used to create an 3D environment in surrounding the Windows desktop. The prime

use of this will be to distinguish if there are any differences when working in a virtual environment and using a virtual reality headset.

Oculus Home Oculus Avatars **[5]**
The Oculus Rift already haves several features pre-installed. For the purposes of the experiment. The part in which the Oculus user can create an avatar for themselves will be used. Facial composites created will not be considered when gathering results. Notes will be taken regarding the ease of the user interface and how effective it could be when creating an environment that will allows facial composites to be generated in a virtual environment.

Virtually Naked 0.8 **[6]**
Virtually Naked is notes the goal of its software being a photorealistic rendering of naked people at VR framerates. For the experiment, the main focus of using this will be to compare how it feels to create a complete body character with the user being within the 3D environment. This will be the most fully immersive experience out of all the tests conducted. This means that the user can move around the whole model physically or move the model using their controls. The use of the Rift controllers will be used solely to do everything in regards to customising the character. The user will also be able to move around (to an extent) and rotate the character by using the grab action on the controller. Question regarding the software will be gathered and compared.

3.3.2 Hardware

The hardware used during the ivestigation were the following:

Computer
For the investigation the following computer was used. The display monitor and mouse were also required. The computer specifications is as follows: Intel i7-6700k, 24GB RAM, 1TB SSD, Nvidia Titan X 12GB, running on Windows 10 Pro. The monitor is an ultra-wide 28 screen, connected via display port, on a resolution of 1920 x 1800The resolution used was 2160 x 1200 (1080 x 1200 per eye). Interaction through the virtual reality headset was provided by the bundled motion controllers.

Oculus Rift and Controllers

When discussing different variants of virtual reality systems, the types of displays used tend to fall into different classes. These classes are dependent on the level of immersion or presence that the user feels, when using the system. Costello classed each of these various implementations into three distinct categories; non-immersive, semi-immersive and fully immersive. These levels of immersion presence are dependent on several parameters which were noted as level of interactivity, image complexity stereoscopic view, field of regard and the update rate of the display.

Semi-immersive systems tend to use a larger display to increase the users sense of immersion. An example of this would be a flight simulator, which would consist of a large display and chair but no other types of specialist hardware. Fully immersive VR can be seen in environments like the CAVE (Cave Automatic Virtual Environment). These environments typically consist of multiple projections on the floors and walls, speakers, tracking sensors, sound, video and some type of visual headset. One benefit for use of a CAVE is that multiple people can experience it at the same time. Also, in the interest of our investigation, it is not a requirement for multiple users to experience the same thing at the same time. The use of a head-mounted display (HMD) would be ideal in the case of our experiment.

After consideration, the Oculus Rift was seen to be the best device to move ahead with the experiment. The Oculus is much lighter than the HTC Vive, therefore making it more comfortable for the user. Also, the initial setup requirements are easier on the Rift compared to the Vive. This is because the Vive requires fixed base stations to pick up real time movement of the user. This means that the Vive is only usable in areas that have the Lighthouse base stations. Another note to mention it that users who have never used the Vive may be prone to accidents, do to wiring. Also, currently having access to the Rift and experience made it the clear choice.

In order to create a 3D environment in some of tests the use of the Oculus Rift will be used in conjunction with Oculus Controllers to move and control within the environment. The use of the Oculus sensors will enable tracking of the participant.

For VR based experiments, the Oculus Rift Consumer Version 1 was used.

Hardware Specifications	
Graphics Card	*Titan X*
CPU	*Intel Core i7-6700K*
Memory	*16GB*
Video Output	*HMDI*
USB Ports	*3 x USB 3.0 ports (One for each sensor x2, one for the HMD)*
Operating System	*Windows 10*

Table 3.1: Hardware Specifications for Oculus Rift

The table below notes the exact specification used for the experiment: 3.1 page on 15.

Notes

To prevent any misheard or forgotten feedback given from the participants, notes were taken during the experiment

3.4 Setting up the experimental environment

The experiment process consisted of the author and the one participant at a time. The experiment took place in a room that provided an Oculus Rift, Touch controllers, a computer monitor, a computer able to handle the minimum requirements of the Oculus, a table and an office chair. For the experiment process, the participant was asked if they had any experience in using VR, to which they affirmed.

For each participant, they were told that for the experiment, there would be six tests that they would need to participate in. The last two phase requires the author to gather and analyse the data. Throughout the experiment, physical notes were made paper on the duration and reaction of the participant when participating in the investigation. The phases were as follows:

3.4.1 Phase 1: Setting up the experiment

For the first phase each participant would be shown an image of male. The image shown is pictured below. The image of the male was someone of no relation to the participant, they were then asked by the author if they knew the male shown, to which they confirmed that they didnt know. They were then told to look at the image for an unspecified amount of time. Whilst the participant studied the image, the author then looked at the time they looked at the image and removed the image from view after 1 minute and 30 seconds. For each of the tests, there was no time limit given.

3.4.2 Phase 2: Testing Phase

Test 1: Feature Based Design using FACES 4.0 and Physical Desktop

For the first test, the participant was shown the software FACES 4.0 was run on the computer and shown on the monitor screen. Participants were then asked to re-create and the same male that was shown in Phase 1. When the participant was satisfied, the image created was then saved to an appropriate folder. For each feature in the software, a number is assigned. All of the features that were used to create the facial composite were noted by the author.

Test 2: Game Character Design using Black Desert Online and Physical Desktop

For Test 2, the MMORPG Black Desert Online was launched. When the game started, the option of character customization was chosen. They were then asked to make the recreate the same male again. The image was then retrieved.

Test 3: Feature Based Design using FACES 4.0 and Virtual Desktop

In the third test, some setting up was required. The software Virtual Desktop in the Oculus Store is required to be run. This will allow the user to Oculus Desktop to use the PC Desktop applications. The participant was then asked to put on the Oculus Rift headset on and the Oculus Rift controllers. They were then asked to run the FACES 4.0 software again and whilst using the headset and controller, duplicate the image of the male. Again, the image created was then saved to an appropriate folder, along with the collection of ID numbers of the facial features.

Test 4: Game Character Design using Black Desert Online and Virtual Desktop

Test 4 also requires the use of the virtual desktop. Having the same participant use the same software on the virtual and physical desktop allows the author to see if there are any difference between each of the desktops and controls.

The same game software Black Desert Online was used and notes were taken by author along with the screenshots of the character created

Test 5: Creating an avatar using Oculus Avatars

For this test, the use of the Oculus headset and controllers will be required. The user is asked to recreate an avatar of their choice and when satisfied the test will move onto the next test.

Test 6: Creating a character using Virtually Naked

Lastly, this test requires the user to test the software using the Oculus Headset and controllers. After several minutes the author then asked if they satisfied with the software and if they wish to conclude. Participants are then asked several questions about the test that were conducted, which were

all noted. Key findings were summarised and can be found in the experimental results chapter.

3.4.3 Collection of Data

During this phase the author collected each of the images and compared the confidence level against the actual image of the male shown on the paper. These results are to be shown in a table. The responses noted when asking questions are then compared between each other so see if there were any distinct findings

Chapter 4

Results and Discussion

The total number of participants was two.

The image shown to the participants was the following:

Figure 4.1: Image of subject used to create a facial composite

In order to compare the results gained and to ascertain whether or not the hypothesis is correct, a method must be decided upon how to measure the results. In this instance, for this investigation, the use of Microsofts Face API will be used. More specifically, the verification model will be used to compare the composite to the image initially showed to the participants. The images that are generally used for this service compares two photographs against each other to give a score of how likely the faces belong to one person. Due to the fact the composites generated can never compare to an actual photo-

graph of a person, a range was made to determine how close the composite is to the photograph. When determining a range a composite was made with the FACES software. Whilst looking at the photograph throughout, the author generated two composites. One of the composites was made to as similar as possible to the photograph, whilst the other one was intended to have no similar facial characteristics traits at all. The highest confidence level that was achieved was 0.42001. When looking at the composites that will be produced the range should be from 0 to 0.42. Anything higher than 0.42 can be deemed better

The image shown to the participants was the following:

Figure 4.2: Lowest confidence level for facial composite

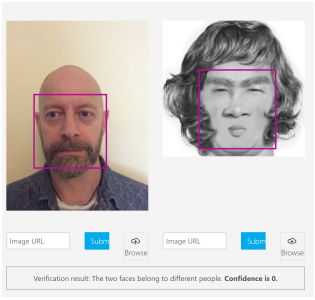
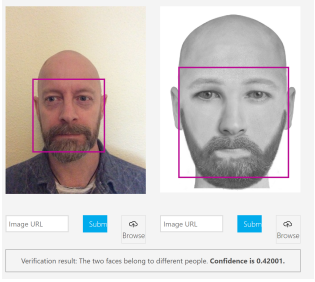


Figure 4.3: Highest confidence level for facial composite, when performed by looking at the image of subject whilst using the FACES software



4.1 FACES 4.0 Results

For each of the participants the composites created generated the following confidence levels when using the software with a regular computer display:

For test 3, the use of the Virtual Desktop and the Oculus Rift headset produced the following results: The outcome is noted below:
Confidence level of Participant 1 using Desktop on FACES: 0.33092
Confidence level of Participant 1 using VR on FACES:0.37624
Confidence level of Participant 2 using Desktop on FACES:0.35639
Confidence level of Participant 2 using VR on FACES:0.3857

Looking at the results, both participants faired better when using the virtual desktop. A reason for this may be due to the fact that they are more familiar with the software rather than the use of the virtual desktop. Another reason may be that the fact that they are replicating the same image that they initally created meaning they may know roughly where each of the features are located on the catalogue page.

All of the composites were higher than the median of 2.1.The confidence levels between each of the composites differ even though image of the person was to be recreated was the same. A potential reason for this may be down to the participants memory. Eyewitnesses memory of a subject can heavily impact the composite generated. The use of the VR headset was used only starting in the third test to allow there to be some time between the creation of the second facial composite. This is to eliminate the potential of the participants using their short-term memory and remembering which page the facial features were on. Looking at the results, it is evidence, specifically Participant A, there were some key differences in facial characteristics.

Looking at the results, it is still difficult to determine if there is a correlation in virtual reality headsets can aid in creating a realistic facial composite. Factors for this include the software used. The realism of the composite in this example is entirely dependant on the database used. Ideally, if there were more participants then merging all the desktop composites into one composite and merging all of the VR composites together to create another then comparing the results could be seen as beneficial.

4.2 Black Desert Online Results

For this test the same program verification model was used as in the first and third experiment. The outcome is noted below:

Confidence level of Participant 1 using Desktop on Black Desert: 0.20892

Confidence level of Participant 1 using VR on Black Desert:0.12529
Confidence level of Participant 2 using Desktop on Black Desert:0.08852
Confidence level of Participant 2 using VR on Black Desert:0.15816
Looking at the results, there is no clear answer as to which display produces a realistic composite. The best result was produced was by participant 1 on the desktop.

When comparing the results of the Black Desert Character creator it shows that there were issues when using the controllers in VR. When asking the participants, they felt that the controlling the controls on the program difficult to do. This is most likely due to the fact that the creator isnt used with virtual reality in mind.

Comparing the two results found when using the faces software and the Black Desert, the FACES software faired better. All of the composites created in FACES scored a higher than median value but many factors could have contributed to this. One factor may be down to the user interface being more more simple and that fact that is was specifically generated for the the purpose of creating a composite

4.3 Oculus Avatar Results

After each of the participants finished creating their avatar they were asked question regarding the software. Both had noted that it felt quite realistic due to the fact they were in a 3D environment. When asked about the facial features they felt that the amount of selection of accessories was good but there was a lack of choice because the avatar was a solid colour. Lack of colour could be seen unrealistic as humans are not just one solid colour.

4.4 Virtually Naked Results

When asked about the program, both participants noted that the graphic looked very realistic. The use of animation and following of the eyes was deemed as factors that contributed to the realism. When asked about the face one participant said that it looked very realistic because they able to see the eyelashes and skin texture. Other statements taken from the participants included the use of the Oculus controller is very cool and I like the fact you

can move around the model or move the model around you. Something to take note of is the amount of rendering that it takes to generate a model. This is a factor that can contribute to a realistic facial composite illustration.

4.5 Dicussion of potential modelling software than can help produce more realistic composites if using virtual reality

In regards to creating a 3D facial composites, there are multiples forms of software that have the potential to assist in creating a realistic facial composites. Several types of these are open sources tools that are available to use which are not only limited to creating faces. During the research process several of these programs were tested to find the most ideal tool that is most suited to the experiment. For each of the tools tested the advantages and disadvantages of each tool were noted below. Consideration into whether the user interfaces are ideal for the target stakeholders have also been taken into consideration.

MakeHuman [9]

The software MakeHuman allows users to create 3D human models. MakeHuman enables users to create fully rigged and textured human models that can be imported into other programs such as Unity. Having the possibility of importing the model into Unity allows the witnesses to view the composites of the suspect they described, visible in a virtual environment. This also makes it beneficial towards users that are looking to create models with animations. Animations of potential suspects could be seen as a potential advantage to finding suspects especially if they have a distinctive trait, such as a limp. However, creating animations of models can be seen as costly and redundant regarding a police environment. The user interface of the software is more suited towards model designers as many of options uses text over images. This would make it difficult for witness to be able to use it by themselves and would require assistance from a trained professional, which may alter facial composite results.

Character Creator [8]

Reallusions Character Creator is another online tool that allows for 3D models to be made, specifically for animation. A benefit of using Character Creator compared to current facial composite software used is that there is a far wider selection that can be chosen when creating a composite. Options such as nostril width can be adjusted to specific size through the use of a scroll button, which can be useful if some features are more exaggerated on a suspect. Yet, having too many possibilities can also be seen as disadvantageous when creating a facial composite. This is because for a witness that is looking to recreate an image of a suspect from memory, having too many options can be confusing and may make them second guess.

Figure 4.4: Confidence level of Participant 1 using Desktop on FACES

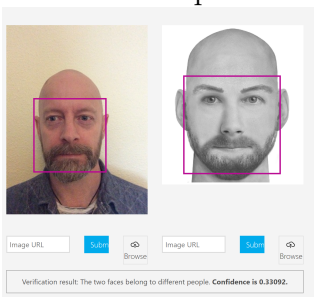


Figure 4.5: Confidence level of Participant 1 using Oculus Rift on FACES

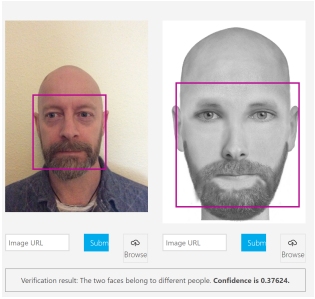


Figure 4.6: Confidence level of Participant 2 using Desktop on FACES

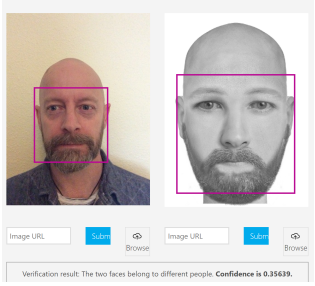


Figure 4.7: Confidence level of Participant 2 using Oculus Rift on FACES

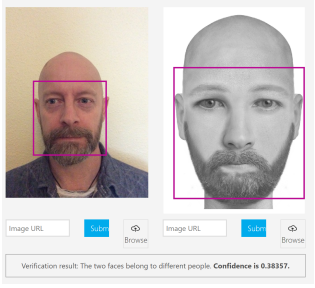


Figure 4.8: Confidence level of Participant 1 using Desktop on Black Desert

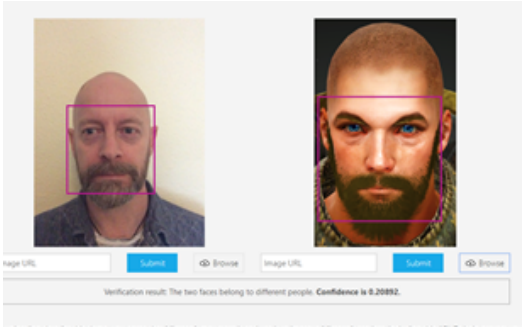


Figure 4.9: Confidence level of Participant 1 using Oculus Rift on Black Desert

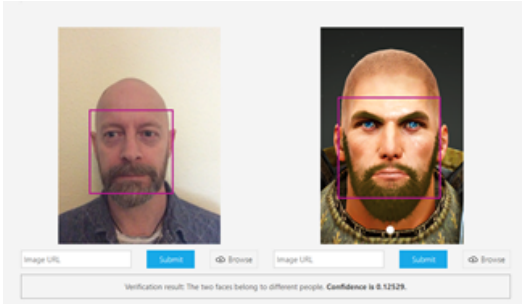


Figure 4.10: Confidence level of Participant 2 using Desktop on Black Desert

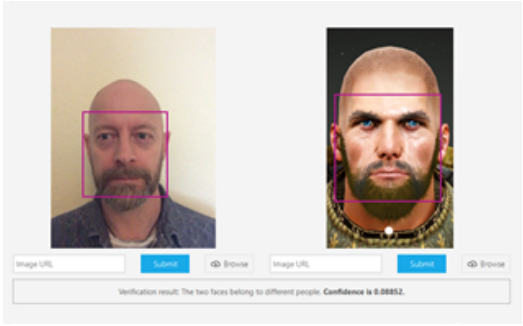
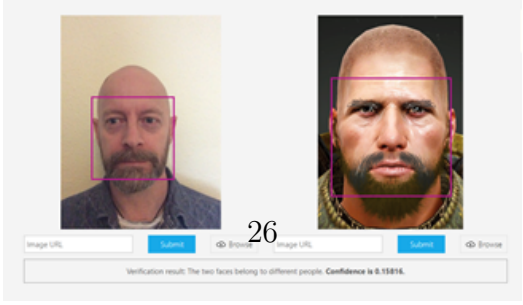


Figure 4.11: Confidence level of Participant 2 using Oculus Rift on Black Desert



Chapter 5

Conclusion and future work

Looking at the results given, further development and a lot more investigation would be needed about the subject of facial compositions within virtual reality. Based on the results, there seems to be a potential promise of virtual headsets providing the witness themselves to view the suspect that they remember, with the potential option of allowing them to make modifications themselves rather than having a forensic expert assist. This could be beneficial to witnesses who have difficulty in relay descriptive traits that the suspect has, as the witness could be self-sufficient. Replicating a scenario in which a crime had taken is difficult to replicate and may have a different impact on the participants Working together with law enforcement would have been more beneficial.Current modelling tools such as Blender are far too complex for a user with no experience to use.Also there is no current option for the 3D models designed in such modelling software to view and edit in 3D without rigging. Potential future work could just involve taking a standard rigged face and having pre-made features that can be added or manipulated. User interfaces within the virtual environment needs to be researched further, regarding customization of a character and not a avatar.

The use of the virtual reality headset proved more positive when used with the feature based system during our investigation, but other factors may have lead to this. If the investigation was to be done again, a bigger range of participants should be used and split into creating the composite in either virtual reality or just on a regular desktop.

A benefit of using virtual reality is that the facial composite could po-

tentially be seen in a 3D view and in 360 degrees. Seeing the model of the suspect virtually could help make a more realistic composites. The results based on the use of Virtually Naked shows that users are far more responsive when viewing a model in 3D rather than on a screen. This could be beneficial because it may trigger responses, such as the suspect being far taller than a number that a witness would initial provide.

An advantage of having 3D facial composites being viewed within a virtual world also means that the model of the suspect can be imported to the same environment of the crime scene virtually. This could possibly help aid in finding the suspect, but more evidence would be needed to prove this.

In regards to creating facial composites, having more realistic models doesnt necessarily mean that there will a higher chance of catching a suspect but using virtual reality and modelling software can allow for more features to be exaggerated or more realistic. Current facial composite systems dont allow for the option of having both options at the same time but based on current character creator systems that are used in games shows that there is potential.

Current controllers used for virtual reality are more centred around gaming and recreational fields, which make it more difficult for users to create an exact replication when compared to using a mouse. But evidence shows that if the right user interface (e.g. no use of sliders) is implemented then more realistic composites could be generated.

¿Future work Based on the research and results found, possible topics of interest could include the following:

-Could the use of computer-generated full body composites aid law enforcement?

-Could the use of augmented reality favour better than virtual reality?

-Would placing a witness in the same exact same scene physically along with a 3D representation of the suspect make a difference?

-Could creating a virtual environment along with a virtual composite provide different results?

-Could software such as Virtually Naked be adapted in other ways? Could people who are missing or have passed away be generated? Could it be used in other sector aside from recreational purposes?

-What existing modelling software could be useful in creating better composites? Specifically, regarding facial composites.

-Could the use of sound be incorporated with virtual reality to aid in making a better composite?

Bibliography

[1] EvoFIT, available at *h*ttp://www.evofit.co.uk/)

[2] FACES version 4.0, available at *h*ttp://www.resourcemanagement.net/faces.htm

[3] Black Desert Online, available at *h*ttps://www.blackdesertonline.com/lahn

[4] Oculus Avatar, available at *h*ttps://www.oculus.com/experiences/rift/911715622255585/

[5] Oculus Avatar, available at *h*ttps://developer.oculus.com/downloads/package/oculus-avatar-sdk/

[6] Virtually Naked, available at *h*ttps://github.com/virtuallynaked/virtually-naked/wiki

[7] K Taylor, *LaTeX: Forensic Art and Illustration*, 2000.

[8] Character creator, available at *h*ttps://www.reallusion.com/character-creator/

[9] Make Human, available at *h*ttp://www.makehumancommunity.org//

[10] Jayasekara et al, *LaTeX:Facial Index Based 2D Facial Composite Process for Forensic Investigation in Sri Lanka*, 2002.

[11] Gibson, *LaTeX:The Future of Facial Composite Systems.*

[12] Frowd et al, *LaTeX:A forensically valid comparison of facial composite systems*, 2002.

[13] Frowd et al, *LaTeX: Catching Even More Offenders with EvoFIT Facial Composites*, 2012.

Frowd, C.D. (2017). Facial composite systems: Production of an identifiable face. In M. Bindemann and A. Megreya (Eds.) Face Processing: Systems, Disorders and Cultural Differences (page. 55 86). Nova Science.

Frowd, C.D. (2015). Facial composite systems. In T. Valentine and J. Davis (Eds.) Forensic Facial Identification (page 43 70). Wiley-Blackwell.

Frowd, C.D., Skelton, F., Atherton, C., and Hancock, P.J.B. (2012a). Evolving an identifiable face of a criminal. The Psychologist, chapter 25, page 116 119.

Frowd, C.D. (2012). Facial Recall and Computer Composites. In C. Wilkinson and C. Rynn (Eds). Facial Identification. Cambridge University Press.

Frowd, C.D. (2011). Eyewitnesses and the use and application of cognitive theory. In G. Davey (Ed.) Introduction to Applied Psychology. BPS Wiley-Blackwell.

Frowd, C.D. (2010). Varieties of biometric facial techniques for detecting offenders. International Conference and Exhibition on Biometric Technology. India.

Frowd, C.D., Park., J., McIntyre, A., Bruce, V., Pitchford, M., Fields, S., Kenirons, M. and Hancock, P.J.B. (2009). Evolving facial composite systems.

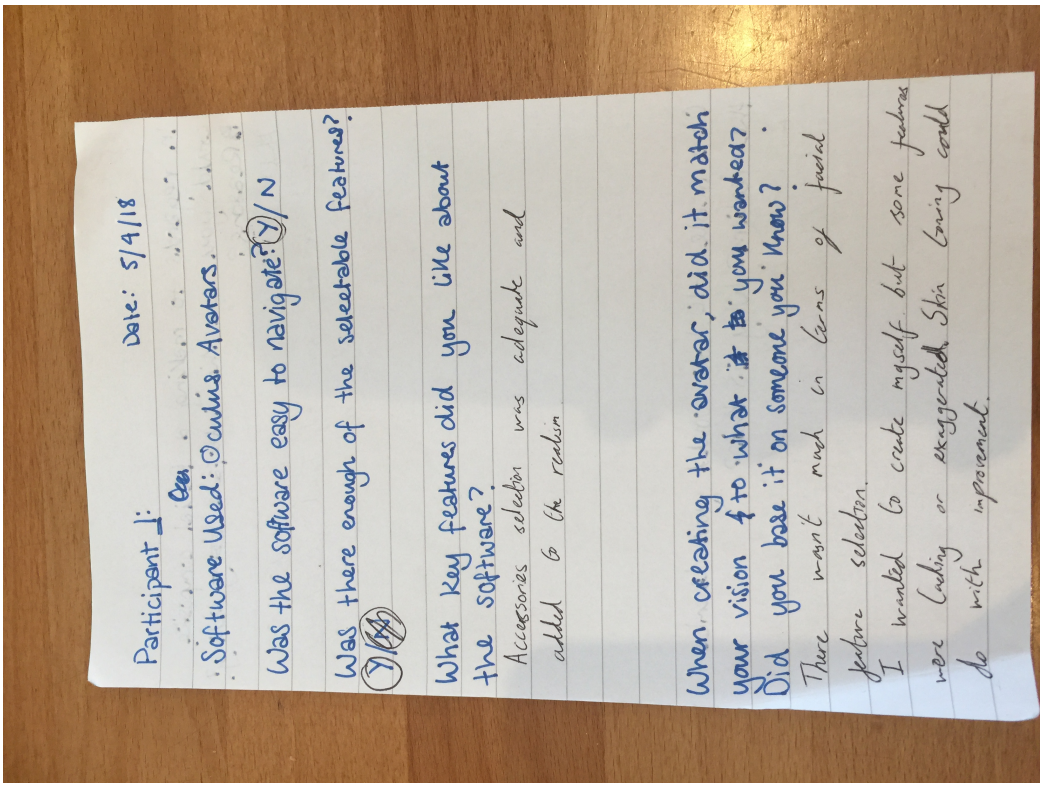
Frowd, C.D., Bruce, V. and Hancock, P.J.B. (2008a). Changing the face of criminal identification. The Psychologist, chapter 21, page 670-672.

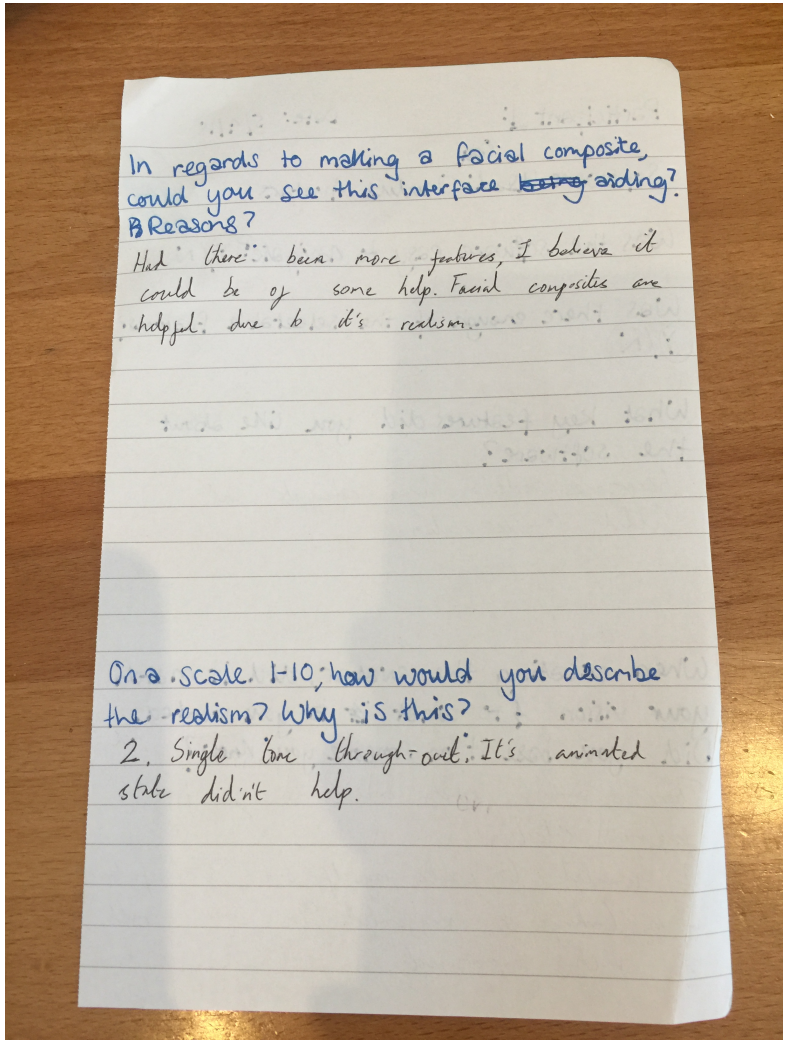
References

[14] K Taylor, *LaTeX: Forensic Art and Illustration*, 2000.

[15] Lange et al , *LaTeX:The Potential of Virtual Reality and Gaming to Assist Successful Aging with Disability*, 2010.

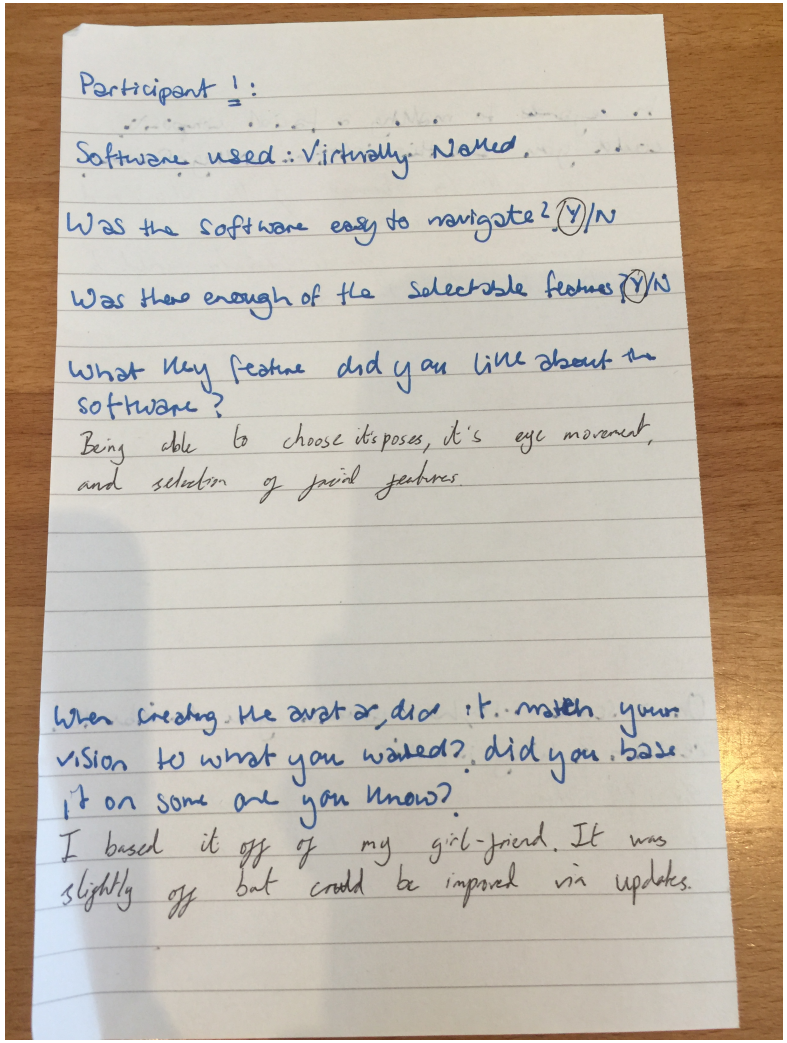
5.1 Appendix

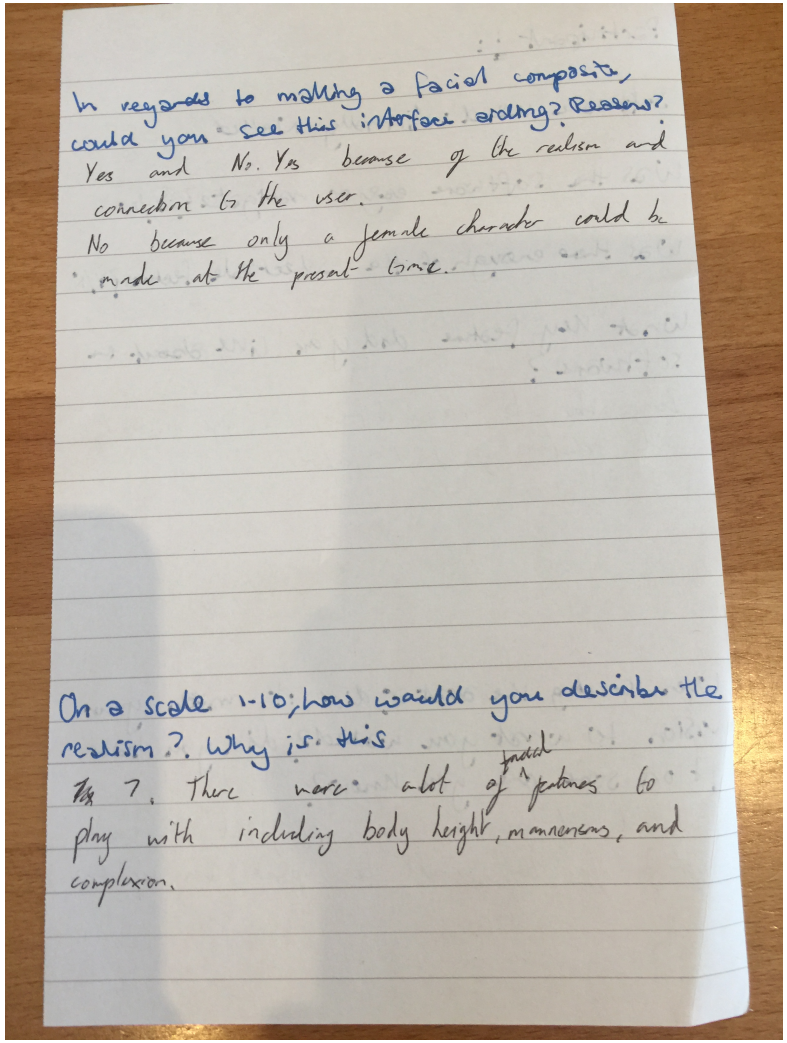


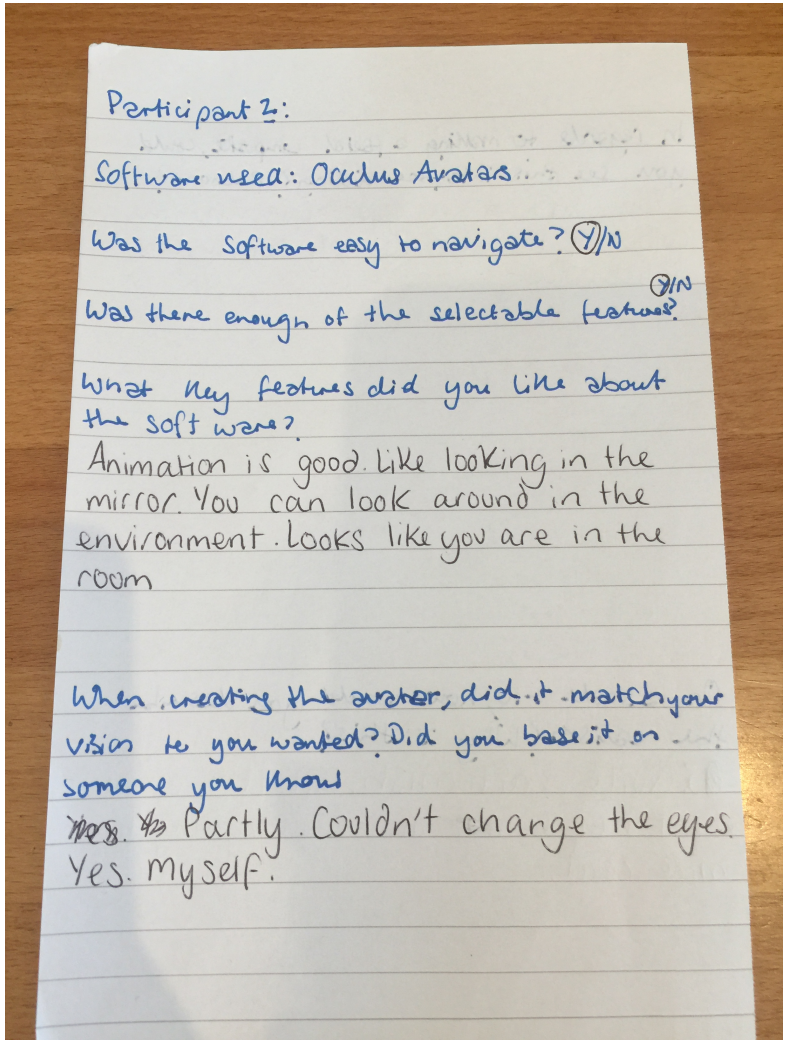


In regards to making a facial composite, could you see this interface ~~being~~ aiding?
B Reasons?
Had there been more features, I believe it could be of some help. Facial composites are helpful due to it's realism.

On a scale 1-10, how would you describe the realism? Why is this?
2. Single tone through-out. It's animated state didn't help.


Participant 1:
Software used: Virtually Naked.
Was the software easy to navigate? (Y)/N
Was there enough of the selectable features? (Y)/N
What key feature did you like about the software?
Being able to choose it's poses, it's eye movement, and selection of facial features
When creating the avatar, did it match your vision to what you wanted? did you base it on some one you know?
I based it off of my girl-friend. It was slightly off but could be improved via updates.


In regards to making a facial composite, could you see this interface aiding? Reasons?
Yes and No. Yes because of the realism and connection to the user.
No because only a female character could be made at the present time.
On a scale 1-10, how would you describe the realism?. Why is this
7. There were a lot of features to play with including body height, mannerisms, and complexion.



Participant 2:

Software used: Oculus Avatars

Was the software easy to navigate? (Y)/N

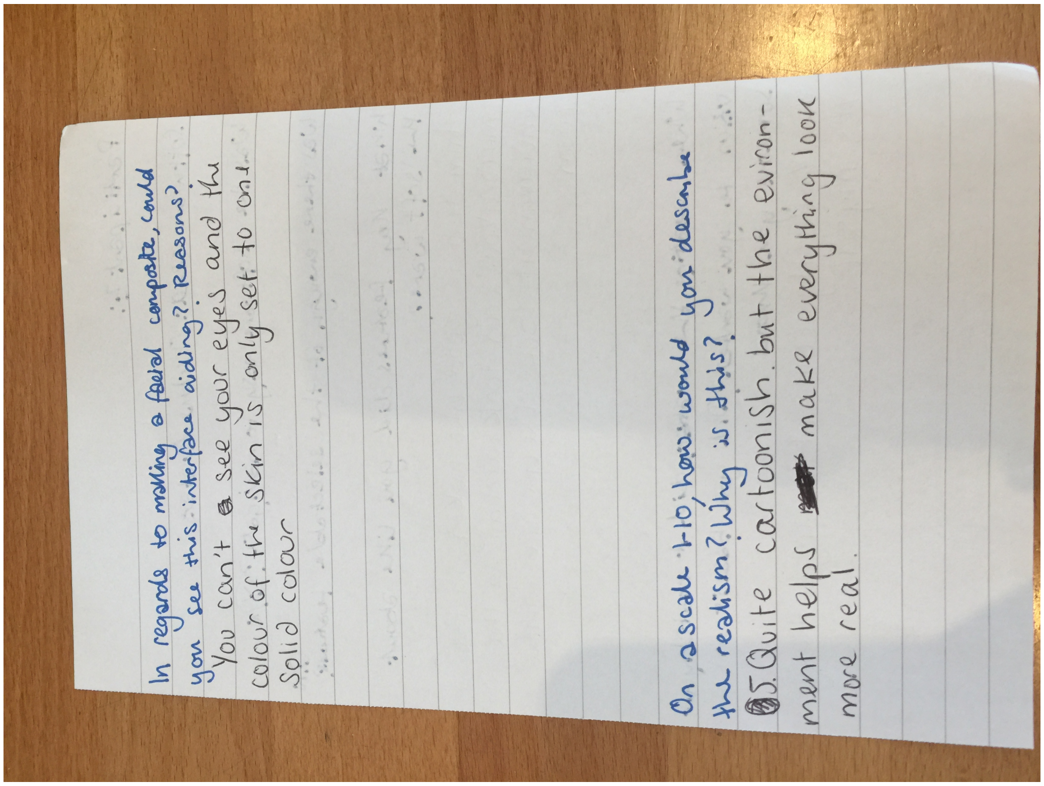
Was there enough of the selectable features? (Y)/N

What key features did you like about the soft ware?

Animation is good. Like looking in the mirror. You can look around in the environment. Looks like you are in the room

When creating the avatar, did it match your vision to you wanted? Did you base it on someone you know

~~Yes~~. Partly. Couldn't change the eyes. Yes. myself.

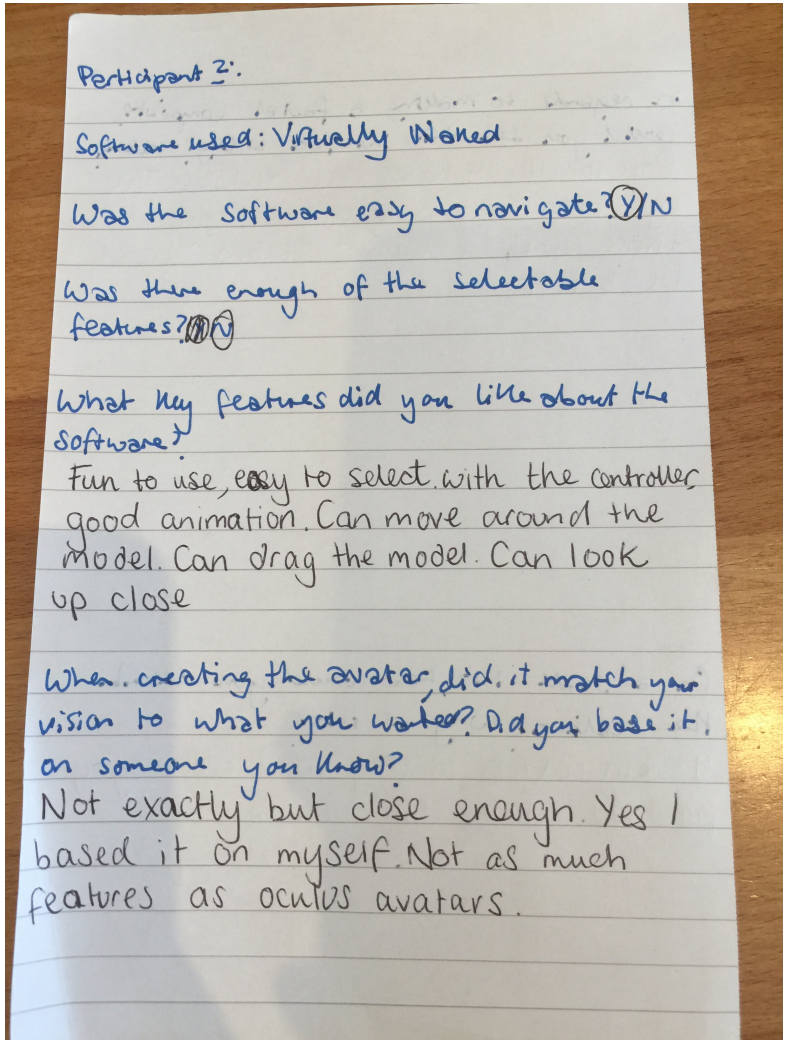


In regards to making a facial composite, could you see this interface aiding? Reasons?

You can't see your eyes and the colour of the skin is only set to one solid colour

On a scale 1-10, how would you describe the realism? Why is this?

5. Quite cartoonish, but the environment helps make everything look more real.



Participant 2:

Software used: Virtually Naked

Was the software easy to navigate? (Y)/N

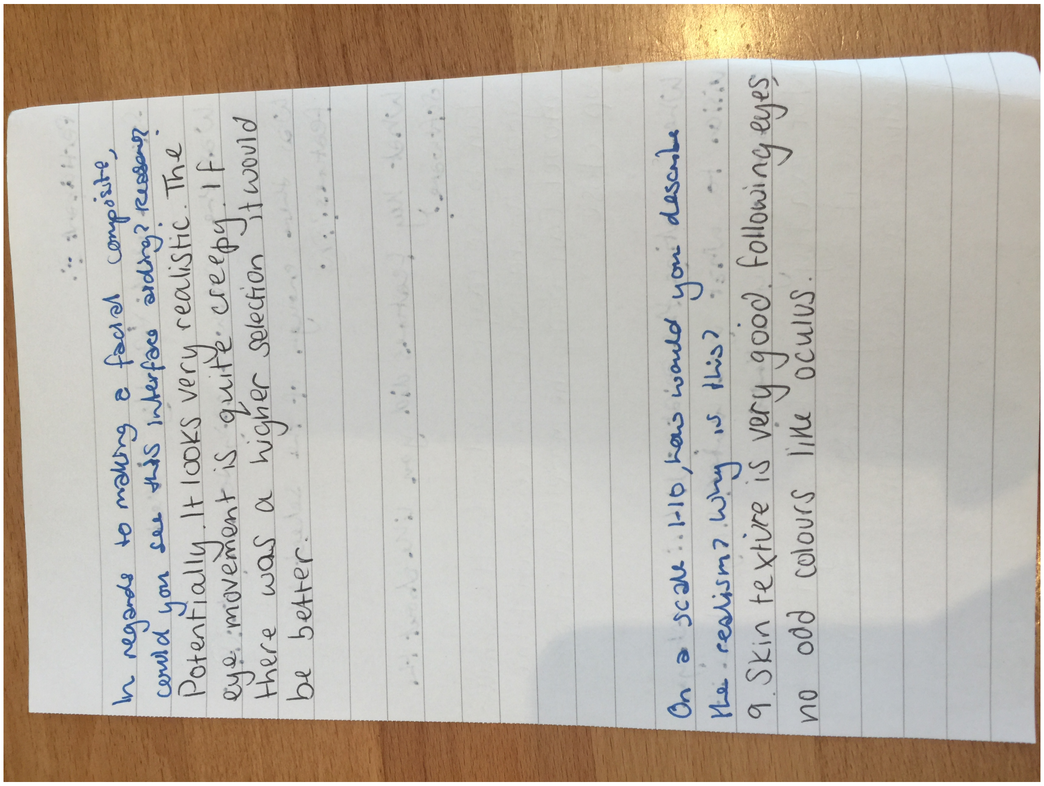
Was there enough of the selectable features? (Y)/N

What key features did you like about the software?

Fun to use, easy to select with the controller good animation. Can move around the model. Can drag the model. Can look up close

When creating the avatar, did it match your vision to what you wanted? Did you base it on someone you know?

Not exactly but close enough. Yes I based it on myself. Not as much features as oculus avatars.


In regards to making a facial composite, could you see this interface aiding? Reasons?
Potentially. It looks very realistic. The eye movement is quite creepy. If there was a higher selection it would be better.

On a scale 1-10, how would you describe the realism? Why is this?
9. Skin texture is very good, following eyes, no odd colours like oculus.