Enclothed Cognition in Virtual Worlds

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Thesis to obtain the Master of Science Degree in

Information Systems and Computer Engineering

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July 2017

Acknowledgements

I want to begin by thanking my supervisor professor Carlos Martinho for accepting my idea proposition and helping me develop this project in every step of the way.

Secondly, I want to thank my colleagues with which I have shared both knowledge and friendship. There is nothing like loving to work and you are the reason work is so much fun.

I would also like to thank my family for supporting me unconditionally and believing in my ability to achieve my dreams, difficult to achieve as they may be.

And at last but not least, I want to thank my girlfriend for all the care and support and especially for patiently waiting for me during this long year. Eager for our new life in London.

Mira, July 2017
André Filipe Cruz Fonseca

For all those who helped me
be the person I am today,

Abstract

Studies have shown that wearing different clothes have different effects on human psychological processes, an effect referred to as enclothed cognition. This work aims at verifying whether this influence is also present in a virtual space where a person is represented by an avatar he/she controls. Using Unreal Engine 4 and Nvidia's APEX clothing, we created three distinct virtual scenarios. In the first one, the player's character is dressed in casual clothes. In the other two, they dress in a lab coat. However, one is implied as belonging to a doctor and the other to a painter. In all scenarios users performed problem solving tasks. 51 participants were distributed and played through the different scenarios and the results suggest that the effects of enclothed cognition are not always observed in virtual environments.

Resumo

Estudos demonstraram que usar diferentes roupas pode ter diferentes efeitos no processo cognitivo humano, a este efeito dá-se o nome de Cognição ”Enroupada”. Este trabalho tem como objetivo verificar se esta influência também está presente num espaço virtual quando o jogador é representado por um avatar virtual controlado pelo mesmo. Através do *Unreal Engine 4* e da *Nvidia APEX clothing*, foram criados três cenários virtuais distintos. No primeiro a personagem está vestida com roupas casuais. Nos outros dois veste uma bata. No entanto, um dos casos é subentendido que a bata pertence a um médico e no outro a um pintor. Em todos os cenários os jogadores executaram tarefas de resolução de problemas. 51 participantes foram distribuídos e jogaram pelos vários cenários e os resultados sugerem que os efeitos de cognição ”enroupada” nem sempre se manifestam em ambientes virtuais.

Keywords
Palavras Chave

Keywords

Enclothed Cognition

Embodied Cognition

Virtual Avatars

Virtual Environments

Palavras Chave

Cognição ”Enroupada”

Cognição Incorporada

Avatares Virtuais

Ambientes Virtuais

Contents

List of Figures

List of Tables

List of Acronyms

UI User Interface

UE4 Unreal Engine 4

AI Artificial Intelligence

API Application Programming Interface

1 Introduction

1.1 Motivation

Progress in the field of computer technology has been in fast expansion since the middle of the twentieth century. This technological development allowed for new user experiences that were once impossible. One of these are the computer generated virtual worlds. In them, a user is represented by an avatar (a person's graphical representation or character) that lives in a virtual environment. A user can act through the avatar in the surrounding virtual environment and change its current state.

One common use of virtual worlds is in the context of video games. These worlds are generally studied in the discipline responsible for the creation of video games: game design. More specifically, they are studied in the subcategory of game design labelled as level design. There are multiple definitions of what is level design but, in this document, we will follow the definition of level design by Christoffer Totten: "Level design is the thoughtful execution of gameplay into gamespace for players to dwell in. Gamespaces are spaces that both embody gameplay and facilitate the player's journey through it, allowing him or her to better experience the game's mechanics" [23].

One of the most important objectives in level design is to try to make the user feel involved, as if he/she is a part of the world. Game designers call this state of intense absorption game "flow". Because game flow is an optimal and extreme state, researchers often employ the term immersion instead. Immersion is generally a term that is used to describe the degree of involvement, whereas flow is mainly used to delineate an optimal state where individuals are entirely involved and absorbed by the activity [8]. In order to achieve game immersion, the player should feel as being part of the world and as the character he plays. As such, both the avatar's clothes and the believability of the environment created are fundamental for game immersion.

Although designers have studied how to create both clothes and environment in order to guide the player and reward his actions, no study had been conducted in order to perceive just how these elements affect the player's cognition and decision making. To understand this connection between the avatar and the player's mind, the relation between human body and mind have first to be uncovered.

In the seventeenth century, Descartes theorized in his book, *The passion of the Soul* [11], that body and mind are separate entities and each is capable of working separate from each other. Although some of the flaws in this theory were analyzed by Kant [14], the separation between mind and body theory remained very influential in scientific and technological studies. When the first Artificial Intelligence (AI) programs were created they used Descartes' ideas as a baseline. However, progress in the field was starting to halt thanks to this narrow view. New ideas in AI such as those of Rodney Brooks [6], inspired the creation of a new paradigm.

Embodied cognition is the belief that our mind and thoughts are affected by our bodies. A person being more impatient when hungry or more open to share experiences when feeling warm are some

common examples of this idea. Due to the numerous ways the human body can affect the thought process, embodied cognition has multiple subcategories.

One of them, enclothed cognition, studies the effects of clothes in human cognition. This theory argues that wearing clothes leads us to adopt behaviours and perceptions associated with the clothes. Some studies have been performed in this field and demonstrated that wearing lab coats increases success in attention-related tasks [1] and others have proven that, when presented with a painter's coat, subjects increased their success in insight problem-solving [9].

Based on these studies and with the knowledge provided by previous work in level design, this thesis has as its objective to inquire if the effects of embodied cognition and, in particular, enclothed cognition is still present in a virtual world. If proven true, the results of this investigation could prove useful as a reference for future work in level design.

1.2 Problem

The existence of embodied cognition has been tested and its effects studied in real life situations. More particularly, wearing specific clothes proved to influence behaviour. However, it is not clear whether the underlying principles of enclothed cognition still hold true in a virtual world where the interaction is mediated through an avatar. The work presented in this thesis focus on this problem: *Are the effects of enclothed cognition preserved when interacting in a virtual world through an avatar embodiment?*

1.3 Hypothesis

This work specifically focus on the effects of clothes in the behaviour analyzed. Environment influence is also tested although only to understand how it can change someone's perception of clothes. Our hypothesis is then: *By manipulating the clothes dressing the user controlled virtual avatar, the impact on user behaviour in the virtual world is similar to the impact in the real world under similar conditions.*

This project answers if the effects of embodied cognition in the virtual world are maintained in the multiple scenarios of varying clothes (doctor or painter's coat) and environments (doctor's office, painter's atelier or neutral) using a sustained attention test. It also studies which of these scenarios has the strongest influence over the user.

1.4 Approach and Contributions

Multiple documents and reports have been written in both embodied and enclothed cognition. A thorough study was performed in both the genesis, discussion and scientific studies related with these topics.

With the acquired knowledge from the analysis of previous work, an experiment prototype was created. Problem solving tasks were designed for the users to complete. These were implemented in a virtual world by using a graphical engine. Virtual environments were created for the tasks to be solved in. The user's avatar was also dressed in different ways. Once finished, the experimental scenario was subject to usability tests and tweaked until ready.

Test subjects then played through one of the multiple experimental scenarios. Depending on the scenario, they also answered some questions about the clothes the avatar was wearing.

Both the user questions and results in the problem solving task were analyzed. Through statistical methods, we concluded if the results obtained are similar to those in real life and, therefore, confirmed the veracity of the proposed hypothesis.

1.5 Document Outline

This document is divided in 6 chapters.

After this introduction (chapter 1), chapter 2 discusses work important to this project. It starts with an introduction to the history of embodied cognition and its relation to this work, followed by a history of the term enclothed cognition as well as some studies in the area. The next parts discuss the state of the art in computer graphics on cloth modelling, game engines and level design. The second chapter of the document concludes by discussing how the information gathered from related work is applied to the project.

Chapter 3 describes how the project was created, starting with an explanation of the experimental scenario, followed by a description of the project development divided in five parts: introduction, characters animation and clothing, level design and level progression and UI. It then concludes with a description of the final obtained result.

The next chapter (4) explains the usability tests performed after the project was complete. After a small introduction, it details the population sample used for the tests. Then it describes the testing procedure followed by a description of the data collected. The chapter concludes with a discussion of the problems found with the project and the solutions applied to solve said problems.

Chapter 5 is very similar in structure to chapter 4 but in regard to the results that test the proposed hypothesis. Information such as the population sample, testing procedure and data collected is described. However, a discussion section is also present were the information obtained by the results is explained, examined and interpreted.

The document ends with chapter 6, a conclusion summarizing this paper and suggesting future work that might improve or complement what was achieved with this thesis.

2 Related Work

2.1 Embodied Cognition

The mind-body problem which studies how our physical body and our intellectual mind are connected has been a question of debate in both philosophy, psychology and even religion for multiple centuries. The first recorded contributions to this problem come from Buddha in the fifth century BCE where the mind and body are described as dependent of each other just as two sheaves of reeds stand leaning against one another [4]. Some Greek philosophers such as Plato in his theory of forms [7] and Aristotle's idea that mind is a faculty of the soul [21] also contributed to the mind-body problem discussion. However, no relevant contributions were added to this question during the following millennium.

It wasn't until the seventeenth century that a new philosophy appeared to try and answer the link between mind and body, or better yet, lack there of. Descartes believed in a mind-body dualism. He reached this conclusion by arguing that the nature of the mind (that is, a thinking, non-extended thing) is completely different from that of the body (that is, an extended, non-thinking thing), and therefore it is possible for one to exist without the other [20]. Despite this separation, Descartes believed that our bodies are influenced and, in fact, controlled by the mind through the pineal gland. In his book, Passion of the Soul he describes the process: "[The] mechanism of our body is so constructed that simply by this gland's being moved in any way by the soul or by any other cause, it drives the surrounding spirits towards the pores of the brain, which direct them through the nerves to the muscles; and in this way the gland makes the spirits move the limbs." In contrast, his option was that the mind is not influenced by the human body and therefore can be represented in its complete form without it. These ideas created the foundation for the cognitivism theory.

Cognitivism is the hypothesis that the central functions of thinking can be accounted for in terms of the manipulation of symbols according to explicit rules [2]. During the 60's and 70's most of the progress in AI was inspired by cognitivism ideals. However, this paradigm had some limitations that were impossible to overcome.

The embodied movement in AI was a response to the stale progress of cognitivism based agents [13]. This new idea in turn caused its resurgence in psychology studies. There is no clear answer as to who introduced the term embodied cognition but much can be attributed to Rodney Brooks and his work on an alternative AI, a highly reactive model that would bypass the representational model all together and act based on sensory perceptions[2]. This AI is, therefore, capable of body-based cognition.

This new perspective inspired philosophers and psychologists to further explore the idea. **Embodied cognition is generally defined as the idea that human cognition is altered by aspects of the human body**. However, a concrete definition as to what extent the body affects cognition and, subsequently, behaviour is yet to be defined. There are six distinct claims about the characteristics of embodied cognition that were presented, discussed and defined by Margaret Wilson: [26]:

Cognition is situated - Cognitive activity takes place in the context of a real-world environment, and it

inherently involves perception and action.

Cognition is time-pressured - Cognition must be understood in terms of how it functions under the pressures of real-time interaction with the environment.

We off-load cognitive work onto the environment - Because of limits on our information-processing abilities, we exploit the environment to reduce the cognitive workload.

The environment is part of the cognitive system - The information flow between mind and world is so dense and continuous that, for scientists studying the nature of cognitive activity, the mind alone is not a meaningful unit of analysis.

Cognition is for action - The function of the mind is to guide action, and cognitive mechanisms such as perception and memory must be understood in terms of their ultimate contribution to situation-appropriate behaviour.

Offline cognition is body based - Even when decoupled from the environment, the activity of the mind is grounded in mechanisms that evolved for interaction with the environment, that is, mechanisms of sensory processing and motor control.

There is no consent among those who study embodied cognition as to which of these claims are true. In her work, Margaret Wilson argued "the first three and the fifth claim appear to be at least partially true, and their usefulness is best evaluated in terms of the range of their applicability. The fourth claim (...) is deeply problematic. The sixth claim has received the least attention, but it may in fact be the best documented and most powerful of the six claims."

2.2 Enclothed Cognition

In 2012, Hajo Adam and Adam D. Galinsky [1] compiled multiple experiments related with clothes and behaviours they provoke. Some of these studies are:

1. Wearing large hoods and capes makes people more likely to administer electric shocks to others [27];
2. Professional sports teams wearing black uniforms are more aggressive than sports teams wearing non-black uniforms [22];
3. Wearing a bikini makes women feel ashamed, eat less, and perform worse at math [12].

They proposed an unifying theory that could explain these multiple studies. Based on embodied cognition, they introduced the term "enclothed cognition". This idea is defined as the influence clothes have on those who wear them. Moreover, they proposed that in order to produce an effect there are two requirements. The user must wear the clothes and there needs to be a symbolic meaning for the clothes. To prove their concept, they conducted three experiments to test performance in attention-related tasks using a lab coat which is generally associated with attentiveness and focused attention.

In the first experiment, the objective was to prove that wearing clothes affects performance. To do so, they tested selective attention which is the ability to focus on relevant stimuli and ignore irrelevant ones. The test subjects were divided in two groups of people: those who wore the lab coats and

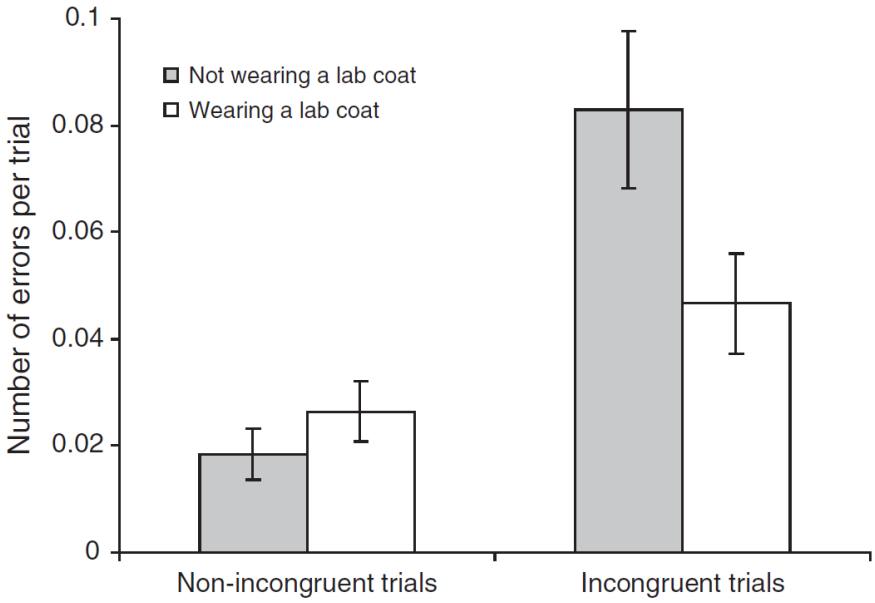


Figure 2.1: Results of the first experiment by Hajo Adam and Adam D. Galinsky in Enclothed Cognition.

those who did not. This allowed to also test the effects of physically wearing the lab coat. Each test consisted in a Stroop task were each participant had to indicate as quickly and accurately as possible whether a series of letter strings was presented in red or blue on a computer screen. There were 50 challenges, 20 incongruent (with cases where the word RED was in blue or vice versa) and all other 30 were non-incongruent. The results, shown in figure 2.1, demonstrated that, as predicted, wearing the lab coat increases selective attention. Even though symbolic meaning was not attributed to the coat in this experiment, it can be assumed that test subjects recognized it as belonging to a doctor, which is the most common association for this object. In their work, Adam and Galinsky argue: "the role of the symbolic meaning of the lab coat was assumed rather than explicitly examined."

While the first experiment proved that wearing the coat does have an effect, the importance of the symbolic meaning behind the coat was proven in experiment 2. To do so, they divided participants in three different groups: those that saw a coat described as being from a doctor but did not wear it, those with a coat described as belonging to a doctor and those with a coat described as belonging to a painter. Instead of selective attention, the second experiment tested sustained attention which is the ability to maintain focus on a continuous activity. As such, the activity was comprised of four exercises where the four differences between two similar pictures had to be found. Sustained attention was assessed by adding the number of differences participants found across the four tasks. As we can see in figure 2.2, the results showed yet again that wearing the coat is required to increase attention, seeing it is not enough. They also show that the symbolic meaning of the coat is crucial, with the painter's coat performing worse than the doctor's coat. The third and last experiment was very similar to the second and had similar results, corroborating the previous results.

Further studies have supported the enclothed cognition theory. A second study was performed with lab coats but this time, tested the individuals capabilities in insight problem-solving: tasks that rely on associative, "out of the box" processes. The results proved that wearing a coat decreases this capability. This conclusion corroborates with Hajo Adam and Adam D. Galinsky previous work (wearing the lab coat increases individual attention).

These studies in enclothed cognition are the basis for this thesis and their results will be compared

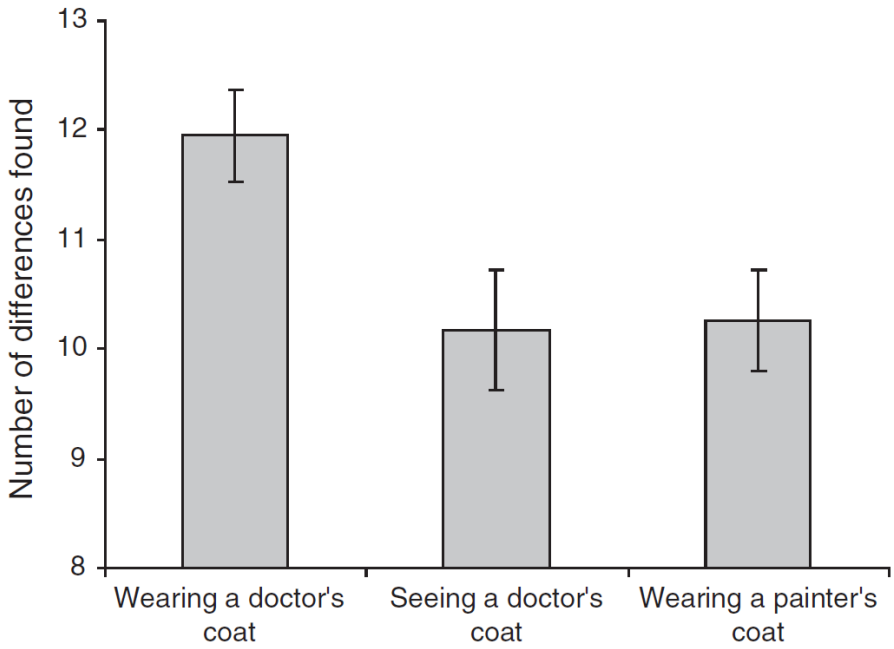


Figure 2.2: Results of the second experiment by Hajo Adam and Adam D. Galinsky in Enclothed Cognition.

with the ones obtained in this project.

2.3 Cloth Modelling in Computer Graphics

One of the objectives of this work is to identify a correlation between clothes used by an avatar and the player's cognitive decision making process. This connection has been proven to exist in the real world. To test this idea in a virtual world, it is important to minimize the differences between real and virtual world as much as possible. As such, the clothes presented in the avatar must be as realistic as the current technology in computer graphics allows it. One of the most well known problems when creating realistic clothes in a real time graphic environment is cloth modelling, that is the simulation of the appearance and movement of clothes in computer graphics. As such, this section will discuss how this problem is solved.

During the last decade of the twentieth century, most research in cloth simulation focused on using techniques from the mechanical engineering and finite element communities to solve the problem of deformable surfaces. These techniques, while providing the first results in the field were not capable of real-time results [3].

After the turn of the century, multiple researchers investigated techniques fast enough to be capable of real-time cloth modelling. These techniques were mostly presented in four different groups [15]:

Subdivision - Subdivision surfaces are the most common way to create cloth simulation. First applied in 1998 by DeRose et al. [10]. However these methods do not have into account forces or material properties.

Procedural wrinkle synthesis - To provide increased detail to the cloth, some methods procedurally

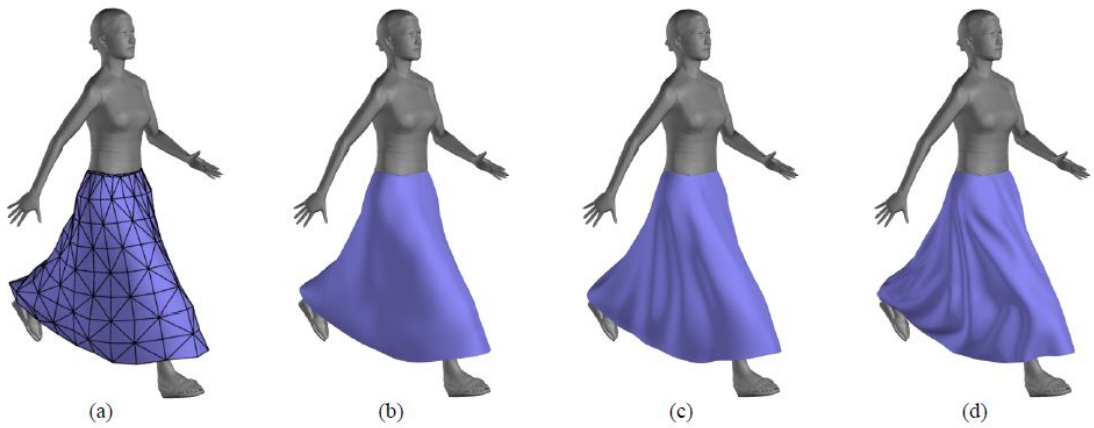


Figure 2.3: Example of multiple techniques in cloth simulation [15]:
(a) Coarse simulation, (b) subdivision, (c) physics-inspired upsampling and (d) fine-scale simulation

create wrinkles in the cloths. One of the most recent contributions being that of Rohmer et al. [18]. The technique is capable of realistic wrinkles with small computation trade-off.

Data driven methods - Other methods utilise data examples to create the simulation. The results depend highly on the quality of data provided.

Regularisation - Regularization is a method for solving ill-posed inverse problems by injecting additional assumptions (priors). The most popular method was developed by Pighin et al. [17].

With the ability to apply all these techniques and their advantages in a simple to use interface, most modern game engines provide users with some form of cloth simulation. However, one of the most important aspects that influence the quality of cloth modelling is if the solution uses GPU acceleration. This technology is able to use the power of the GPU to create more realistic cloth modelling than those possible with only the main processor. One of the most utilized examples of this technology is the Nvidia's APEX[1] which provides high quality cloth simulation for dedicated Nvidia graphic cards. Unfortunately, it was not possible to obtain further information about this technique's specifications.

2.4 Graphics Engine

The creation of virtual worlds in the area of computer science became more streamlined in the past decade thanks to the development of game engines. These are software frameworks that support the creation of video games and, as such, virtual environments. A game engines is, therefore, an important tool for game designers in order to ease the process of creating a virtual experience.

There are three popular and high quality game engines that do not require a professional license to use. They are Unity, Unreal Engine 4 (UE4) and CryEngine[2]. Each engine has some advantages and disadvantages associated with it. After some research on these frameworks, the following conclusion was reached:

[1] https://developer.nvidia.com/clothing (as consulted in July 2017)
[2] www.worldofleveldesign.com/categories/level_design_tutorials/recommended-game-engines.php (as consulted in July 2017)

Figure 2.4: Example of results with APEX Clothing from an Nvidia Demo[3].

Unity is the most versatile and easy to use of all these engines. Also, it was the first of these to be free to use and, as such, is the most utilized and best documented engine. However, Unity is the less powerful of the graphics engines and presents the less realistic results of all three.

CryEngine is the polar opposite of Unity. It has created some of the most impressive looking games since the debut of its second iteration with the release of the video game Crysis in 2007. However, the ability to use this engine without a license is very recent and as such there is still very little documentation and examples of other professionals working on the engine. Besides, this engine is the most complex of all, with a steep learning curve that requires a big time investment in order to start obtaining results.

The last option is the UE4. While more complex to work with than Unity, many systems of the engine's current iteration have been simplified. The creation process is now very similar to that offered by Unity. The visual fidelity, however, has significantly increased from the third to the fourth edition of the engine, and is almost on par with that of the CryEngine.

While Unity and CryEngine use their own built-in cloth simulation, UE4 integrates the more advanced APEX Cloth, a technology from Nvidia capable of realistic cloth simulation (example on figure 2.4). Although it was not possible to obtain information about the specifications of this technology, by observing cloth simulation demonstrations it was possible to conclude that the results obtained with APEX are visibly better than the built in cloth simulation in both CryEngine and Unity.

2.5 Level Design in Computer Graphics

From the inception of the first video games in the 1970's to the multi-billion dollar gaming projects of the last decade, level design has always been a main focus for creating these projects. Super Mario Brother's 1-1 or Duke Nukem 3D's Hollywood Holocaust are examples of levels that had a profound impact in both those who played them and the gaming industry's future.

Level design theory is a recent subject that appeared with the first video games. Inspiring level

designers such as Hironobu Sakaguchi *(Final Fantasy)* and Shigeru Miyamoto *(Super Mario Brothers)* created some of the first examples of virtual levels. Without even knowing it, they were starting to establish the rules of level design. Their work, as well as that of others as been analyzed and the level design process is now a documented and studied subject. Richard Rouse III describes in his work [19] that a level is divided in five components:

Action - Conflict between the player's avatar and the world or other avatars;

Exploration - Observation of the level through character movement;

Puzzle Solving - Answer problems in order to progress;

Story Telling - Unfolding of the game's plot;

Aesthetics - How the level looks and sounds.

All of these components should be balanced in a level in order to achieve maximum level flow. Level flow is defined as "A reward-response system that challenges the gamer and then provides a *treat* for completing tasks." [5]. It is therefore, divided in two parts: first, the designer must construct challenges for the player to overcome. These must neither be impossible nor too easy. Their difficulty must feel like a hard but possible to overcome challenge for the player. Secondly, a reward should be presented to the player after completing a task. It should be of value similar to the difficulty of the challenge. The greater the risks, the higher the reward.

Level design theory has helped designers create levels capable of rewarding and immerse those who play them. Its principles were taken in consideration when creating the experimental scenarios. However, even though designers study how level design affects player cognition in order to guide player action, no scientific studies have been done in this subject in order to understand how player cognition may be affected in other ways. In real life scenarios such studies have already been performed:

1. A world-renown musician was completely ignored when performing incognito in a metro during rush hour [25];
2. A study of the relation between ceiling height and thought process revealed that a high versus low ceiling can prime the concepts of freedom versus confinement, respectively [16].

It is therefore important to identify if similar situations can occur in virtual levels just as they already occur in the real world. Plus, as these studies show, environment is important to establish symbolic meaning to both objects and people. This is crucial in this work because the environment is important to create the connection between the lab coat and its symbolic meaning.

2.6 Discussion

This section discusses how the previously presented works in embodied cognition, enclothed cognition, cloth modelling, game engines and level design are relevant to this study.

Embodied cognition is the theory in which this project is based. As such, it is of utmost importance to study the principles and ideas of this topic in order to verify if they can be observed in a virtual world.

The studies in enclothed cognition, especially those by Hajo Adam and Adam D. Galinsky [1] are the most relevant for this work. In fact, this project is partially a continuation of these studies. This experiment is, as much as possible, a recreation of their second experiment but in a virtual world. Just as in it, the avatar wears either a lab coat or casual clothes. Also, the pictures with differences are the same in their test and this one. There is, however, a difference between both experiments. In their test, subjects kept their clothes but in computer graphics there is no possibility of mimicking the clothes of every subject. As such, the avatar is dressed in a way perceived as casual clothing for the player. In order to follow their experiments as closely as possible, in the scenarios where the avatar is dressed with a lab coat, the character starts with casual clothes and then dresses himself or herself with the lab coat during gameplay. Also, just as in these studies, user performance was tested in attention-related tasks. The obtained results were compared with those recorded by Adam and Galinsky and were expected to be similar.

To successfully recreate Adam and Galinsky's experiment in a virtual world, the clothes should be as realistic as possible. In order to do that, the advanced graphics technique of cloth simulation must be utilized. It was therefore important to study the multiple alternatives of this technique in order to choose the one that best adapts to the experimental requirements. Even though it was not possible to obtain detailed information about this technique, APEX cloth by Nvidia is capable of producing good results in efficient time. Furthermore, this technology is supported by some graphics engines, making it easy to use and implement. It is, therefore, the chosen solution for this project.

UE4 engine is the only of the studied graphics engines capable of using the aforementioned APEX cloth from Nvidia. Paired with the fact that it supports better graphics quality than Unity and superior usability when compared with the CryEngine there was no doubt that UE4 was the best option for this project.

Enclothed cognition is not the only parameter studied in this project. How the environment surrounding the virtual avatar affects the user interpretation of the clothes, and henceforth, user cognition is also being studied. Even though it was not possible to find experiments in this field similar to those created for clothes, some works in both architecture and real life events suggest that the results do exist. It is also important to understand the fundamentals of level design since it is the area of study that mostly dwells into the question of how a virtual space affects the player. The techniques employed to increase level flow and improve user experience, practised in the context of level design , are also taken into consideration when creating the virtual environments.

3 Implementation

3.1 Experiment

As explained previously, the objective of this experiment is to identify if the principles of enclothed cognition can be verified in a virtual world. As a side objective, it is also important to keep as much experimental variables similar to those of the original experiment as possible. As such, with these elements in mind, the experiment detailed in this section was devised.

Since this scientific test occurs in a virtual world, all scenarios were computer generated. Three different levels were created: a doctor's level, a painter's level and a casual level. Also, two types of clothing were designed for the avatar to dress: a lab coat and casual clothes. In the casual level, avatars are dressed with casual clothes. In the other two the avatars start with casual clothes but later dress in the lab coat. As such there are a total of three possible scenarios. Also, an exercise that tests problem solving skills was coded into the scenarios. The problem solving test consists in a sustained attention test using the same images as the ones used in Hajo Adam and Adam D. Galinsky's enclothed cognition second experiment [1].

Each scenario consists on the following steps (represented in figure 3.1):

1. The user starts in a neutral room dressed with casual clothes. The camera is zoomed-in on the main character on the right side of the screen. On the left side of the screen, a character creator UI allows the user to change the eye color, hair color, skin tone and the avatar's gender (figures 3.2a and 3.3a). After pressing *start the game*, the camera will zoom out to show the entire room and the player will be able to control the character using *point-and-click* style controls. They are then free to move to the next room (figures 3.2b and 3.3b).

2. The next room is different depending on the level. The casual level skips to 3, the doctor's level goes to (a) and the painter's level goes to (b).

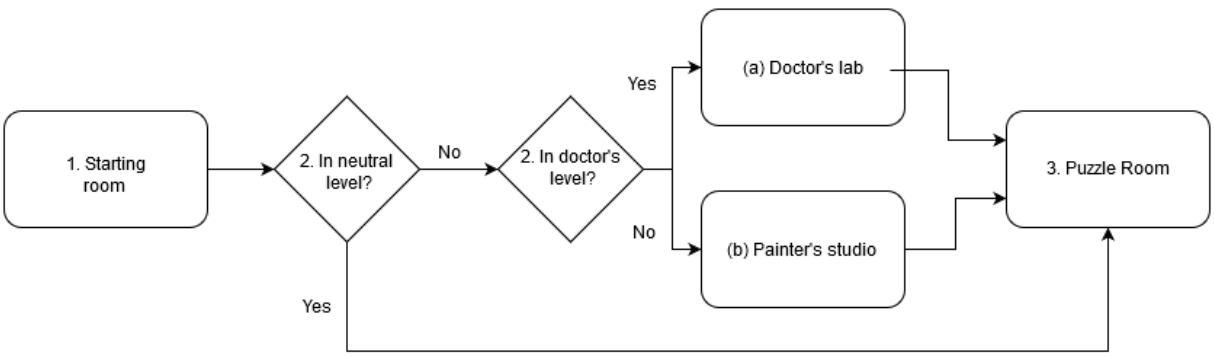


Figure 3.1: Flowchart of the experimental scenarios.

(a) The user is in a room that can clearly be associated with a doctor's lab full of medical apparatus such as an operating table, monitors, x-rays and even a skeleton (figures 3.2c).

(b) The user is in a room that can clearly be associated with a painter's studio with multiple paintings, blank canvas and paint (figure 3.3c).

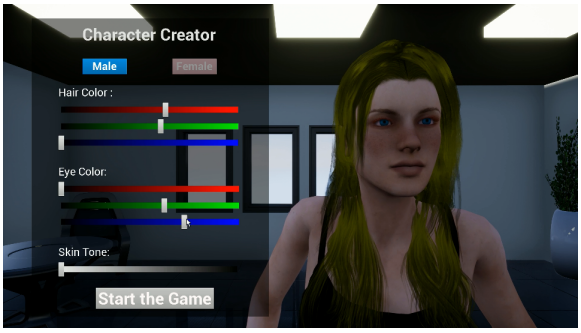
Even though cases (a) and (b) are different when it comes to the aesthetics, the gameplay sequences are similar in both. There is a locked door in both scenarios that cannot be opened. If the avatar goes near the door, it replies that he left the keys in his/her *doctor's coat* (in the doctor's level) or in his/her *painter's coat* (in the painter's level), as shown in figures 3.2c and 3.3c. The player must then dress the avatar in a lab coat in the middle of the room (same mesh model in both cases) (figures 3.2d and 3.3d). After a small animation showing the avatar getting dressed the user is asked if the coat looks like a doctor/painter's coat (figures 3.2e and 3.3e). After answering, a new animation shows the door being unlocked followed by a confirmation expressed by the avatar. Finally, the player may proceed to the last room.

3. The avatar enters in a new neutral room. In it, there is a table with a pile of images. The avatar replies that he/she has work left to do at that table (figures 3.2f and 3.3f). If the user interacts with table or the chair next to it, he will play a game of spotting the differences between different pictures (figures 3.2g and 3.3g). There are four exercises with four differences each (Same images and differences as in the original experiment). The player can try to find as many differences as he/she can before submitting the final answer. They can view how many differences they have marked in each picture and in total as well as how much time they spent in the game (figures 3.2h and 3.3h). After submitting the answers, the experiment ends.

As such, the only difference between the experimental scenarios is the existence of a middle room, both with the same coat to dress but different environments. One room is a doctor's lab and the other is a painter's studio. This small difference is important to imply the meaning of the coat as belonging to a certain profession. It is crucial to verify if the participants understand this connection between the room's design and the corresponding profession. This problem was thoroughly examined during the usability tests. Even still, to help the player make this connection the avatar implies in multiple moments that the coat belongs to him/her and is also a painter's or doctor's lab coat. Also, in order to confirm that the user associates the coat with the correct profession, the following question is asked to the user after dressing the coat:

- Regarding my coat... Do you think it looks like a doctor's coat (in the doctor's level) / painter's coat (in the painter's level).

The fact that the association between the lab coat and its profession is done through environment hints instead of telling a story is the single detail where this project diverges from the original Adam and Galinsky's experiment [1]. However, through careful testing and by using in-game hints, this difference was controlled in this experiment.

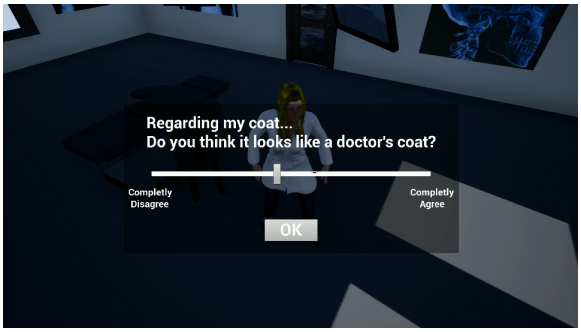


(a) Character creation.

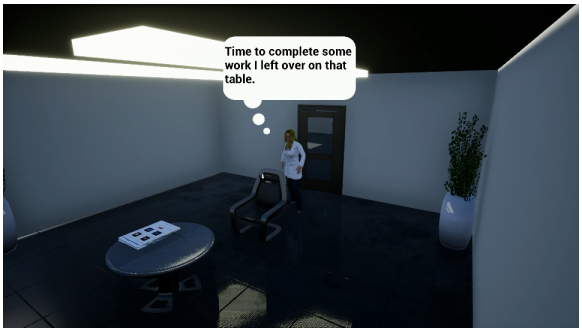
(b) Starting room.

(c) Doctor's room.

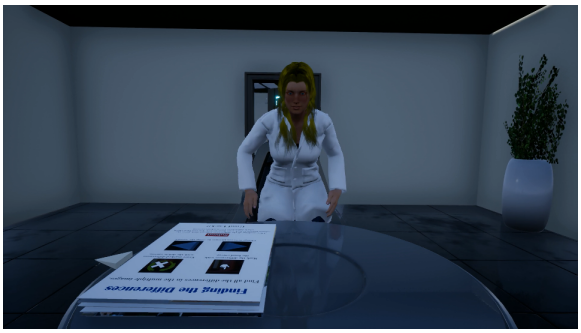
(d) Dressing the doctor's coat.



(e) Rating the doctor's coat.



(f) Puzzle room.

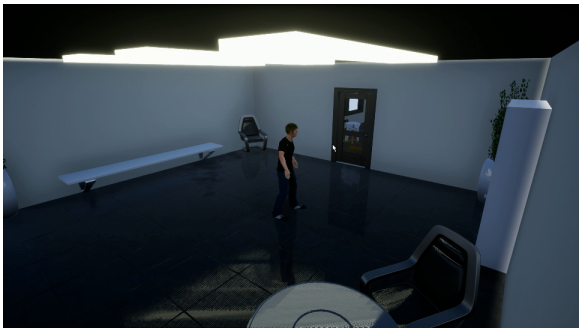


(g) Sitting to find the differences.

(h) Finding the differences.

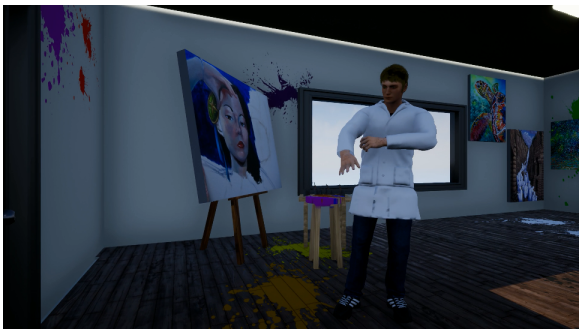
Figure 3.2: Implemented doctor scenario using a female character.

(a) Character creation.

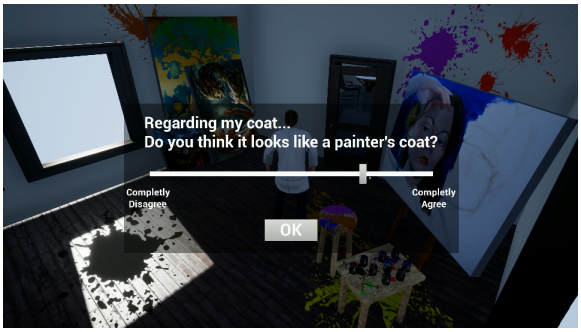


(b) Starting room.

(c) Painter's room.

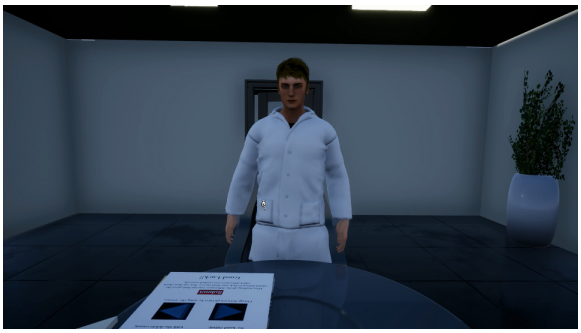


(d) Dressing the painter's coat.

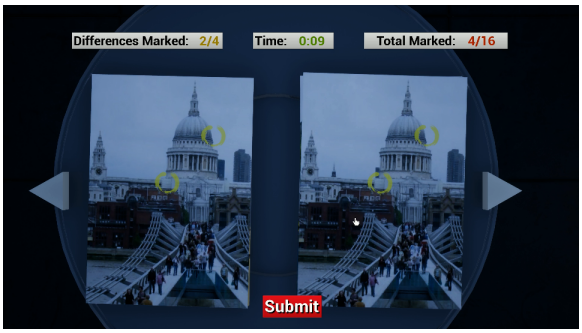


(e) Rating the painter's coat.

(f) Puzzle room.



(g) Sitting to find the differences.



(h) Finding the differences.

Figure 3.3: Implemented painter scenario using a male character.

3.2 Project Development

3.2.1 Development Introduction

This project was mostly developed in a period of two months and half (from 14 of February to 5 of May), followed by two weeks of usability tests which helped change some final details before establishing a final version. The last version of the project was deployed on the 5th of May.

The project development was carefully divided in the four main phases detailed bellow:

1. Characters, Animations and Clothing
2. Level Design
3. Point and Click Control System
4. Level Progression and UI

A more detailed list of the tasks required to complete the project can be found in annex A.1.

In the following sections, I will explain each of the phases in more detail. I will also describe the tools used to complete each phase as well as what they were used for. It is important to note that the project was created with UE4 and, as such, the use of this program is recurrent in all phases.

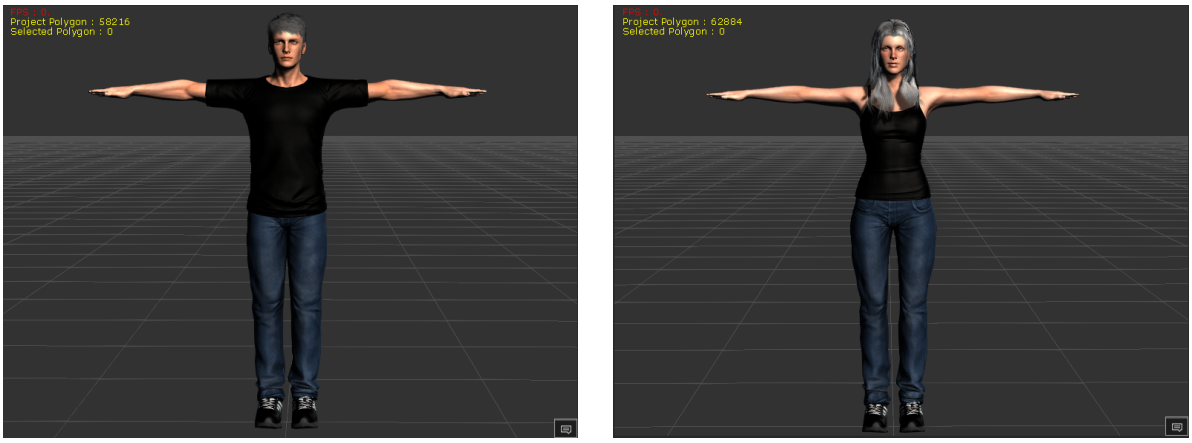
3.2.2 Characters, Animations and Clothing

Unreal Engine allows those who start a new project to choose between some example projects with some features already implemented. One of those is the third person project that already has a 3D model of a robot with animations (idle, walk, run, jump), a working third person camera (from behind the playable character) and controls. This simple yet versatile template was the basis from which this project was created.

The first change to the template was changing the 3D model of the robot for an human model. This was accomplished using iClone[1], or more specifically iClone Character Creator. As the name implies, this program can be used to create human characters to be used in video games. It allows to change multiple body and facial features in order to create the characters as desired. After creating the character it can be exported to a FBX file (the file type for 3D models used by UE4). In this project, we exported two models, a male and a female, both already wearing casual clothes (as seen in figure 3.4. The exported characters include a skeleton, that is, a set of joints organized hierarchically which allows to easily create and share complex animations between models. This made it possible to easily re-target the human-like animations from the UE4 robot to the new models. And since both model have the same skeleton, they can share the animations between them without any restrictions.

After successfully importing the characters into the new project, there were some animations that needed to be changed. First, the characters would need to open doors. To do so, using the built-in physics system of UE4, a blueprint (game object composed of multiple components and related code) of a physics based door that opens when pushed by the character model was created. Also, using iClone,

[1] https://www.reallusion.com/iclone/ (as consulted in July 2017)



(a) Male model.

(b) Female model.

Figure 3.4: Character models exported from iClone.

a small animation where the right hand extends to touch a door was created. This animation was added to the main character's animation graph and is triggered when the front side of the model is close to a door. The jump animation was also removed from the graph (since it is not required for this project).

More animations were added later (after phase 2 was complete) for the transition from the character creator to the to main game, for dressing the lab coat and for sitting in the chair. These are different from the previous animations since they aren't only related with changes in the character's skeleton but also with the game's camera, sound effects and other effects. These types of animations are generally referred to as cinematics and were accomplished in this project by using UE4's level sequencer.

The last detail added to the characters ended up being the most difficult to implement: the lab coat. Each character needed a lab coat for them to dress over their casual clothes. Although it seems simple, since the coat was created from scratch, needed to move exactly the same way as the characters without clipping below them and also needed to include NVidia PhysX for more realist movement, this was a very long process that took about two weeks to complete. First of, the lab coat was created using Marvelous Designer[2]. This program uses a paradigm of 2D cloth cut and stitching to create 3D clothes for a character model. It also uses a simulation system that allows for folds to form naturally in the clothes. After creating the lab coat, two different versions of it were exported (in order to better fit the different anatomy of the male and female model) into Maya[3], a program for creation and manipulation of 3D models. In this program, each lab coat was separated into three components: arms, torso and bottom. Then all three parts were bound to the skeleton of their corresponding character models. Afterwards, the skin weights from the human were copied to the lab coat. Every component copied weights from different parts of the model to more correctly represent the necessary movement and avoid clipping. Lastly, the bottom part of the model was converted to a Nvidia Cloth. Nvidia Rigid Bodies were added around the legs and pelvis in order to stop the cloth from penetrating the character's pants. The final models were then imported to the game. The lab coat was added as an element of the character and shares the same skeleton in game execution (always plays the same animations).

[2] https://www.marvelousdesigner.com/ (as consulted in July 2017)
[3] https://www.autodesk.com/products/maya/ (as consulted in July 2017)

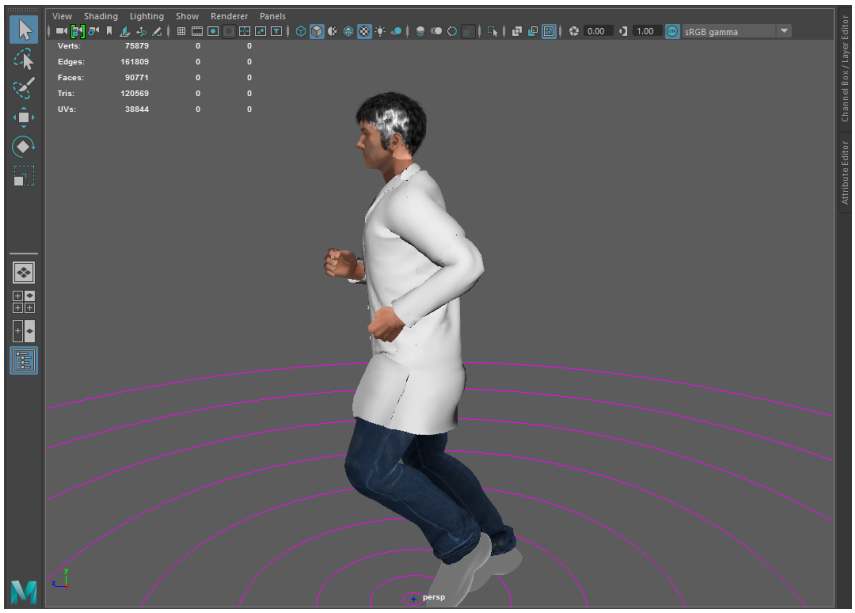


Figure 3.5: Running Nvidia Cloth Simulation on Maya.

3.2.3 Level Design

With the characters ready for the final version of the project, the next step was creating the levels. There were only four rooms to have in consideration: the starting room, the doctor's room, the painter's room and the final room.

Every room was created in the same way. Each one is represented by a blueprint that contains all the objects of that room. This modular design allows for the rooms to be reused by simply placing them in the world wherever they are required. This is important for this project since each room is reused various times through the multiple versions of the experiment.

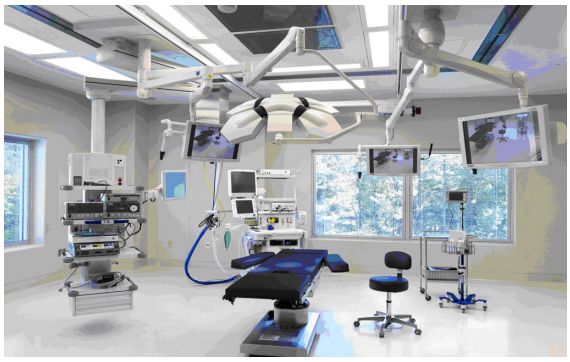
As for the objects themselves, they were created in one of two ways: either they are free assets from UE4 (or other outside source) or were manually created using UE4's geometry brush actors.

The first room was created to be as simple and neutral as possible. Its decoration is very simple: some chairs, a table, a plant and some windows, all created using models provided by UE4. Only the room itself was manually created with the brush actors and then converted to a static mesh. Multiple bounding boxes were also added to the room in order for it to collide with the character.

The final room is very similar to the first room. Many of the objects are similar. The greatest difference is the chair and table in the center of the room for the avatar to sit in.

The doctor's room was created to look as much as possible as an operating room. In fact, the design was inspired by the room in figure 3.6. The room has multiple objects one could find in such a place such as complex machines, monitors, syringes and their vials and even an operating table. All these objects were created using the geometry brush actors. Also, after some usability testers showed difficulty in associating this room as one where a doctor would work, less subtle hints such as decals (images that are imprinted on 3D models) of x-rays and a skeleton model were added to the room.

As in the doctor's room, almost every object in the painter's room was manually created. These include a painter's brush, painting bottle, a small wooden table, wooden chair, an easel and a blank canvas (where the blank texture was replaced with a multitude of different paintings that were spread



(a) Inspiration.

(b) Final model.

Figure 3.6: Comparison between the inspiration for the doctor's room and the final room.

through the room). Decals are also used on the walls and floor to show splatters of paint (common in such a place). This room is also smaller than the doctor's room since a painter's atelier is generally a small and crowded space which is the opposite of the polished and organized appearance of an operating room. These conclusions were also supported by the first wave of usability testing.

3.2.4 Point and Click Control System

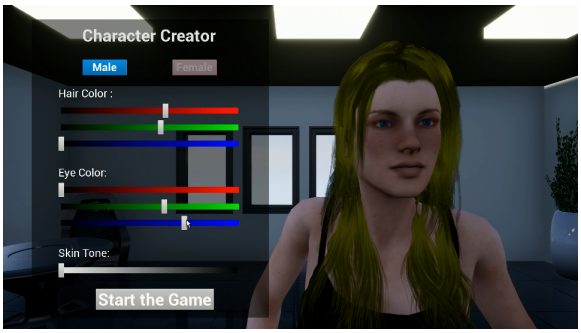
Up until this point, the game was controlled using the WASD[4] movement system from the UE4's third person template. Even though this control scheme allows to freely move the character and the camera as desired and, as such, is the control method of choice for most avid video game players, it also requires some dexterity and experience in the medium in order to be able to control both systems at the same time. Since this experiment is aimed at the general public and not only those with expertise in video games, a different control scheme was required.

Point and click games have a very simple method of control. As the name implies, they are controlled with the mouse and only require clicking to move the character or interact with the environment. In a general case, if an object is clicked, the character moves to the object's location and then interacts with said object. This type of games are generally 2D but also exist in 3D using fixed position cameras that follow the character.

This fixed camera was the first feature of this control scheme that was implemented into the game. In each room, a trigger box (bounding box that triggers an event) and a camera were added. When the main character begins overlapping with the trigger box, the camera is automatically swapped to that room's camera. Also, the cameras were programmed to rotate in such a way that they are always looking at the main character. Both at the start of the game (with the character creator) and after the character starts the mini-game also required a change of the current camera and, as such, the initial and final rooms of the game have two cameras instead of only one. All camera positions used in the game are shown on figure 3.7.

Now that the camera was controlled by the game and not the player, only the character movement remained. In order for the character to move to a position when a button was clicked meant that the character is not being directly controlled by the player and instead is only following determined behaviors.

[4]WASD is a movement system for video games that uses the corresponding keys in the keyboard to move the character: W- move forward; A - move left; S - Move back; D - Move right.

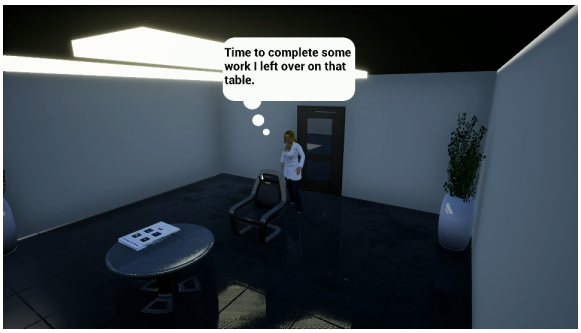


(a) Character Creator.

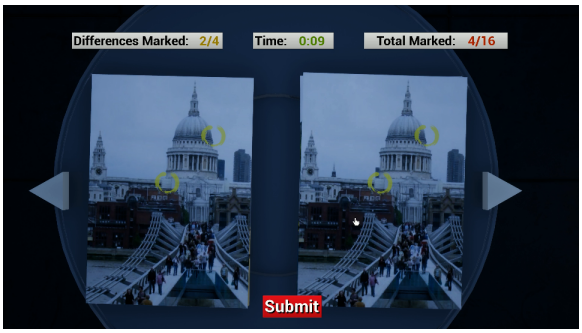
(b) Starting room.

(c) Doctor's room.

(d) Painter's room.



(e) Puzzle room.



(f) Finding differences.

Figure 3.7: Camera locations in the project.

It is, therefore, an AI. Artificial Intelligence in UE4 can be constructed using a behavior tree. Depending on the current state and how the tree is constructed, AI may be able to execute complex sequences of actions. It is in this manner that it was possible to program the character to move to certain locations and only then execute other actions such as playing the dressing animation or sitting down. The move action, in particular, requires the AI to find a path to the location (always moving forward may not work if an object is in the way). Thankfully, UE4 has a built-in navigation mesh volume that automatically calculates the traversable space and can be used in conjunction with the *move to* action to correctly move the character to the desired location.

There was still a problem with this approach. UE4 doesn't allow for a character to be both controlled by the player and be an AI. This not only meant creating a new point and click character (omniscient and invisible) that controls the AI, but more complicated still, being able to change user control between this new character and the old one in order for the character to still be movable with the old control scheme (for more advanced players who wish to do so). Figure 3.8 shows this system at work.

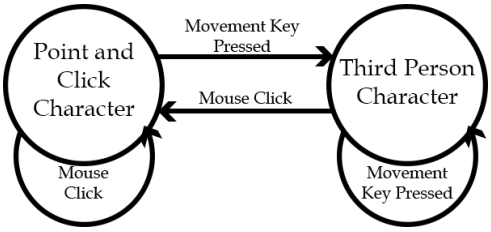


Figure 3.8: Automaton showing how player control is transferred between characters.

Finally, there needs to be a way for the AI to know what action to process and where that action takes place (where to move to). This processes is done in the mouse cursor blueprint. Every frame, the mouse cursor casts a ray from its current position to the scene and stores the information about the hit location. Objects that can be clicked show a specific mouse cursor if hit with the ray. This method visually helps the player to recognizing the different actions possible. If a mouse click occurs, the point and click character controller asks the mouse cursor for the current hit information and then commands the AI character to execute the action located at the hit position (if there is any). Figure 3.9 shows this system's architecture.

3.2.5 Level Progression and UI

With the core elements of characters, level design and game controls correctly working, there were only a few features that required development in order to complete the project. The two most important of these are the character creator and the mini-game.

In order to change the appearance of a character in the character creator, dynamic materials were created. These allow, through a variable input parameter, to change how the material (and therefore, the mesh it is attached to) looks. By combining a black and white texture with a color parameter (a vector 3D) for both the eyes and the hair of the characters it was possible to dynamically change the eye color at run-time. In the eye, only the iris part of the texture was blended with the input color thanks to a mask texture used to isolate that region. However, the materials that change the skin tone work differently. In the same program where the characters were designed (iClone Character Creator), textures for both tone extremes were exported as shown in figure 3.10. All the material does is blend those two textures based on a scalar input between 0 and 1. The UI for the character simply allows the users to change

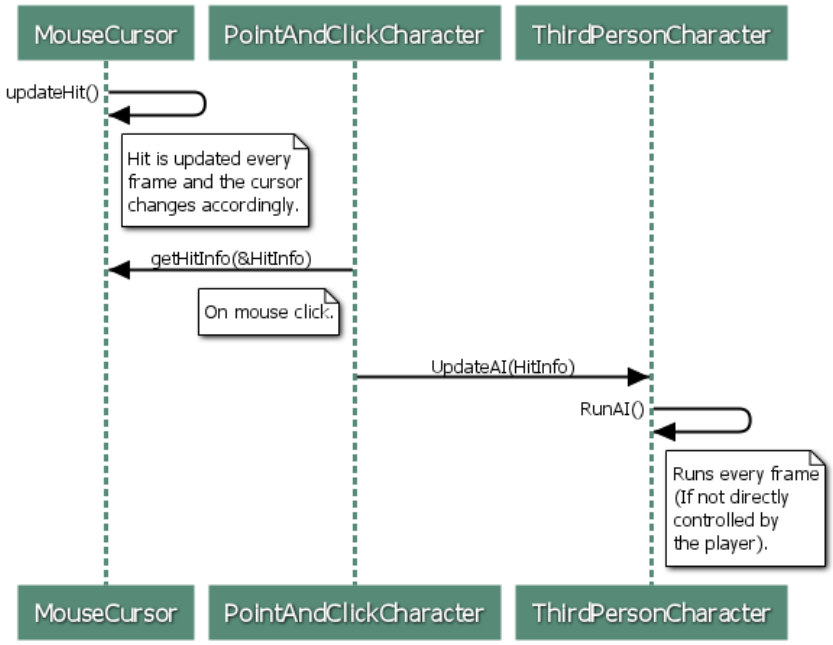


Figure 3.9: A sequence diagram of the point and click controller logic.

the parameters for the materials described. The functionality of the character creator can be observed in figure 3.11.

(a) Light Texture.

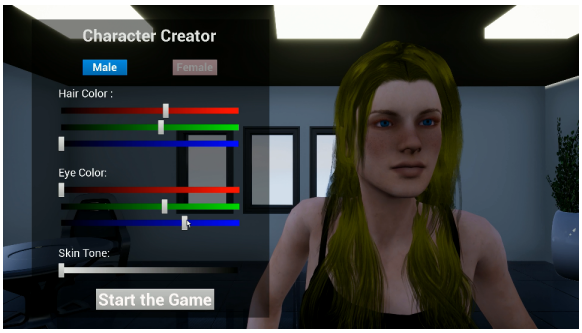
(b) Dark Texture.

Figure 3.10: Comparison between the light and dark diffuse textures for the face of the male model.

The finding the differences mini-game was a more complex system that involves the connection of multiple interconnected blueprints:

The *paper heaps actor* is a blueprint for an in-game object divided in two heaps that contains all the papers for the mini-game. When creating a *paper heaps actor*, an array of *paper actors* has to be received as a parameter. These are the papers that define the heaps. At the start they will all be placed in the right heap in the reverse order they are in the array (the first array element stays on top). This blueprint is responsible for positioning the papers it contains in their correct heaps as well as transition

(a) Creating a male character.



(b) Creating a female character.

Figure 3.11: Examples of the character creator in action.

the top paper between heaps. To do so, it includes two arrows (a left and right one) that, when pressed, change the corresponding top paper to the other heap with an animation (figure 3.12).

Figure 3.12: Paper heaps animation.

The *paper actor* is an in-game object that contains a right and left side[5] and each one may be used for a different difference finding exercise. Each side is also subdivided in two groups of components. The first one is the differences: these components have the final locations of all the differences and are invisible until the game is complete. The second one is the marks: they are temporary components created by the player at run-time when they click in the image. The differences and marks are compared after submitting the game to confirm which differences were found by the player.

Since each *paper actor* contains part of a different difference exercise in each side, that means that the pair image for each exercise is in another paper. As such, another blueprint is needed to keep information and manage the connection between corresponding papers. That is the responsibility of the *finding differences manager* blueprint. Each one is responsible for a single exercise and thus connects two paper together. Each manager is only active if both papers are on top of each heap (both facing the player). With this blueprint, once a mark is placed/removed in one image, the same can be done in its pair. Also information such as number of total differences or current marks is stored and handled by the *finding differences manager* to avoid different results in both papers. Once the solution is submitted,

[5]Right and left is used instead of top and bottom since left and right directly correlates the visible side with the heap the paper is currently on.

each manager confirms if the center point of each mark is inside the bounding box of the difference for both papers. If so, that difference is considered found and is not cross-referenced with the marks again (to avoid counting the same difference twice if other marks are nearby). This technique is the same as the one used in the online game from where the pictures for the original Adam and Galinsky's experiment [1] were obtained.

Figure 3.13: Example of the bounding boxes for the differences between pictures.

With every exercise now working correctly and independently, the only other necessary system is one capable of storing all the information about all the managers at the same time. That is the function of the *finding differences game* blueprint. This collects and stores information about all the exercises to show the user through the UI and also print to a file when the game is complete. The blueprints for the finding differences mini-game and how they relate to each other can be observed in figure 3.14.

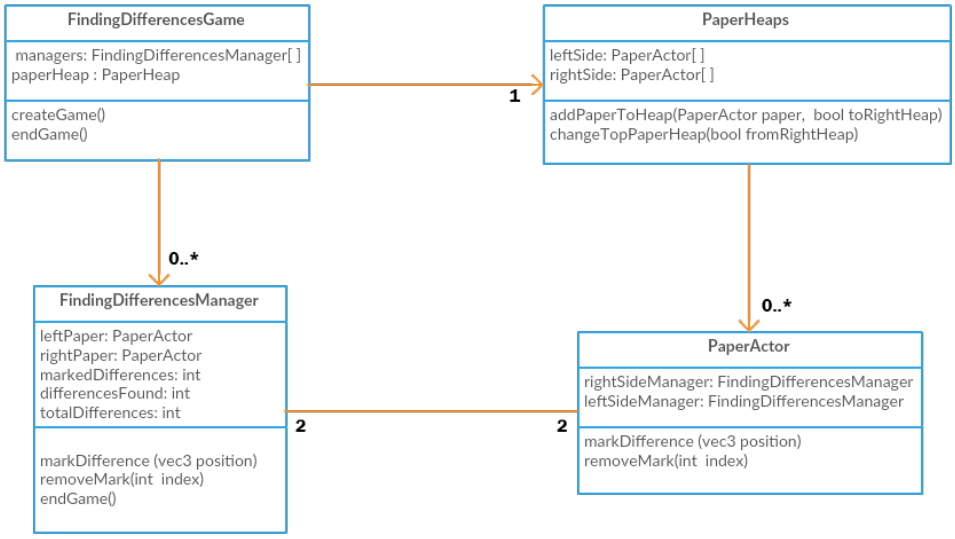


Figure 3.14: Finding Differences Blueprints Class Diagram.

With the game's progression complete, the last required feature was a tool-tip system to help the players understand how to progress. In this game, the system is very simple. An UI component of a thinking bubble was added to the main character in order to make it look as if the character is thinking.

Most of the time, this component is invisible. However, when required, a message can be displayed thought the bubble using a 4 second animation before it disappears again. This system is used to show hints when the player tries to enter the locked door (as shown in figure 3.15), after dressing the lab coat and when the avatar enters the final room.

Figure 3.15: Example of the thinking bubble.

3.3 Final Remarks

The final project was very similar to the initial concept. However, there were still some overlooked details and problems that were found during the usability tests.

Probably the most difficult milestone of this work, creating the lab coat from scratch, involved many programs and processes in order for it to work. Marvelous designer was where the mesh was created and it used a paradigm similar to how real life clothes are created. Unfortunately, since I had no experience in this area I had to dedicate some time to learn how to sew to create the coat. Afterwards, the cloth was rigged and skinned to the character's skeleton. This process was a trial and error experiment of applying different techniques in the mesh for the skinning to be correct. Even the last step, cloth modelling, had its problems. The process itself was more straightforward than the previous two parts but both Maya and Unreal only worked with specific versions of the Nvidia APEX Application Programming Interface (API) and it also had to be the same version between both programs. The final solution was to use the most recent version of all three parts involved so that all the correct versions could align.

Another unexpected feature was the point and click control system. When the project development plan was designed, this phase wasn't accounted for. However, it later became apparent than in order for non-gamers to be able to test, a normal third person control system would not suffice and a simpler input method had to be created. Having said that, the implementation was straightforward. The only complex system was setting up the character in a way that it could change between being controlled by the player or the AI.

With the exception of the situations described above, the project was developed without many problems. All the possible experimental scenarios were created, both the lab coat and casual clothes were designed and even the original colored pictures used in Adam and Galisky's tests were located. Thanks to a well organized list of tasks and work log, whose details can be found in annex A, the project developed smoothly and rapidly being finished in only two months and a half.

4 Usability Testing Results

4.1 Introduction

As with most projects, usability tests are important for this game in order to ensure it can be correctly used by the public. As such, after completing the UE4 project, the next step was testing if there were usability problems with it. The game can be divided in the following interaction steps:

1. A player creates a character as they desire;
2. He/she walks through a painter or doctor's room using a point and click navigation system;
3. The player then dresses a lab coat;
4. Finally, he/she plays a mini-game of finding differences.

4.2 Population Sample

Usability tests usually require around 6 participants in order to find most of the usability problems of a project [24]. It is also important to test different demographics. This test was executed by 8 participants between the ages of 23 and 35 ($M = 29.75, \sigma = 5.18$), divided in 2 groups (4 for the painter's room and 4 for the doctor's room). Of the 4 participants in each group, 2 were female and the other 2 male. Also, for each gender, 1 had above average experience with video games and virtual environments while the other did not. The usability tests occurred in two testing waves (3 participants in the first, 5 in the second).

4.3 Procedure

The procedure for the usability test was individual for each tester. The test started by confirming some demographic data such as age, sex and experience with video games with the tester. These questions are displayed in appendix B.1.

Then, the user was left alone in the testing room to play the game with no indication of what they should do besides the fact that the game is controlled with the mouse. The gameplay, as well as their reactions (both verbally and physically) were recorded in video through a web cam.

Once the tester was done with the game, some questions about their usability experiment were asked. There were four important game systems that needed to be tested. If either of them was compromised in their ease of use, that could affect the experimental results. These game systems are explained in more detail in remaining of this section.

4.3.1 Character Creator

Players have to create a character when starting the game. There are 4 possible variables: Sex, hair color, eye color and skin tone. Testers were asked if these systems were intuitive or needed modifications.

4.3.2 Point and Click Navigation

The control system is similar to those of point and click games. It does not require knowledge of complex controls since the computer mouse is the only input system used. The experiment was performed with both gamers and non-gamers alike. If non-gamers showed difficulties using this system, then there were still problems that need addressing in its complexity.

4.3.3 The lab Coat

The final experiment tested if the players acted differently by using an avatar with a painter's lab coat or a doctor's lab coat. To do so, it is first necessary for them to correctly identify it as belonging to the corresponding profession. Usability testers were asked who owns the lab coat and/or what does the avatar do.

4.3.4 Finding the differences

The game ends with an exercise where users have to find the multiple differences between pairs of images. Once again controlled only with the mouse, it was important to verify if users were able to correctly understand how to play, how to finish the exercise and how to check their score.

The list of usability questions can be consulted on appendix B.2.

4.4 Data Collection

The data was collected in two waves of tests.

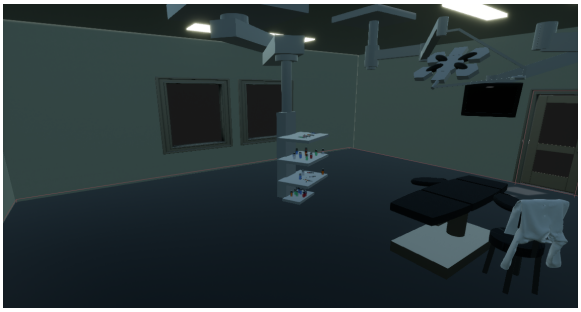
The first wave consisted of three testers. Tester 1 played the doctor's level while tester 2 and 3 played the painter's level. The results from this testing wave are displayed in tables B.1 and B.2.

The second test wave was made with five testers. From these, testers 1, 2 and 3 played the doctor's level while tester 4 and 5 played the painter's level. The results from this testing wave are displayed in tables B.3 and B.4.

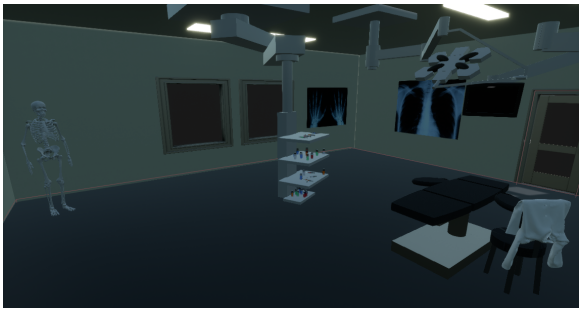
4.5 Results and Findings

The first wave of tests showed four main problems with the game:

Firstly, the player who experimented the doctor's level could not interpret the avatar as a doctor or even the room as a medical room of any kind. As such, more decorations needed to be added to the room so that it could be correctly perceived as belonging to a doctor. The decorations of choice were multiple x-ray decals on the walls of the room and a skeleton in the back corner.



(a) Before the usability tests.



(b) After the usability tests.

Figure 4.1: Comparison of the doctor room before and after the usability tests.

Another problem was the fact that one tester did not understand how to correctly play the finding the differences mini-game. He assumed that the game would signal a correct or incorrect response when marking a difference (which was not the way the game was designed). As such, the tester ended up randomly marking all the differences and submitting the final answer with zero correct differences. This problem was easily solved by creating an image with instructions for the game and setting it as the texture for the first page of the paper heaps (before starting the mini-game).

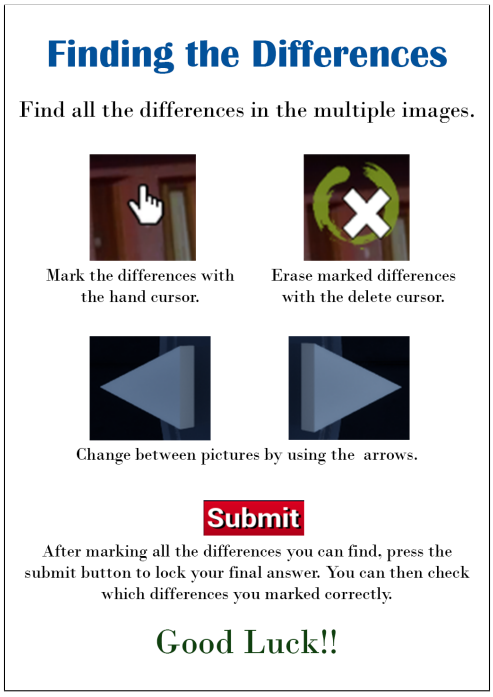


Figure 4.2: Finding the differences instructions.

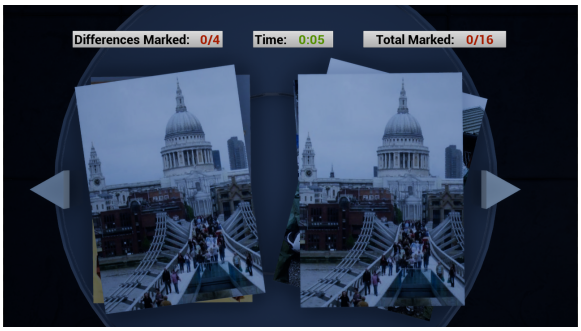
Two of the testers tried multiples times to click on the table (instead of the chair) to sit down and play the mini-game. That was mostly due to the fact that a hint pops up when entering the final room referring to the *"work left on the table"*. The solution was simple. To allow the player to sit on the chair by clicking the table as well.

Lastly, a tester was confused as to what to do after dressing the lab coat. He still thought the door was locked and that more actions were required to unlock it. This was solved by showing the door is unlocked with an animation after the avatar dresses the lab coat. Also, the character shows an hint saying *"I found the keys in my pocket."* after the door unlock animation.

There was also a question that arose suspicion as to if it was a problem that needed solving or not. Two users agreed that the picture quality was not sufficient. However, one complained about the image of the city (the only picture where he missed a difference) and the other tester was the one that did not understand how to play the mini-game and, as such, cannot correctly evaluate picture quality. Besides, since the pictures were the same as the one's used by Adam and Galinsky, it was important to keep them in the experiment.

Although the second wave of tests involved a larger number of testers, only two problems that needed to be fixed were found.

The first one was the fact that 3 of the testers had visual difficulties finding the differences with the pages rotated in the XZ axis as they were. Even though the rotation was not completely removed, attenuating it from a -15 to 15 range into a -2.5 to 2.5 range was enough to remove the visual discomfort. This was confirmed with the testers after the alteration was complete.



(a) Before the usability tests.

(b) After the usability tests.

Figure 4.3: Comparison of the page rotation before and after the usability tests.

The final problem was that one tester correctly understood what the room was but did not associate it with the player's lab coat. Since only one tester had this problem, we believe it is an outlier and should not occur frequently in the experimental tests. However, just to be sure, a question was added in the game asking if the lab coat looks like a doctor's/painter's coat.

Some others complaints were considered not relevant enough to justify changes. Two users did not like the RGB system used to choose the hair and eye color but eventually were capable of choosing colors of their preference in just a few seconds. Two other testers felt the controllers lacked a particular mechanic: one felt the character should move by interacting with the walls and the other thought the camera should be able to rotate. Since these problems were specific to a tester and not a problem to everyone else, they were ignored. Finally, some people incorrectly interpreted the doctor as being either a dentist or a medical scientist. However, these two professions are so similar to a doctor that they should not affect the results.

Test Wave	Problems Found	Solutions Applied
1	Users who played the doctor test were not able to associate the middle room as being a doctor's room and therefore didn't think the character was a doctor.	Four x-ray images as well as a skeleton model were added to the room so it looks more like a doctor's room.
	One of the testers expected to receive feedback when marking a difference (whatever it was correct or incorrect) and so didn't correctly complete the mini-game.	Instructions for the mini-game were added and can be read before starting to play it. The concept of marking the differences and submitting a final answer is also explained.
	Thanks to the hint that describes the character has "left over work on the table", almost all of the users tried to click on the table instead of the chair to start the mini-game.	Clicking on the table now does the same action as clicking on the chair (the character moves to the table, sits and the starts the mini-game).
	After dressing the lab coat (and especially if they dressed it before trying to walk through the locked door) it was difficult to know what to do next.	Added a small section after the cinematic of dressing the lab coat where the camera zooms on the door to show it unlocks. Also the avatar comments finding the keys in the coat.
2	Most users had problems with the rotation of the images in the finding the differences mini-game.	The paper rotation used to be a random value between -5 and 5 degrees. The minimum and maximum values were changed to -5 and 5 in order to solve this issue.
	A tester was not able to make a connection between the room and the symbolic meaning of the lab coat	A question to rate if the coat looks like a doctor's/painter's coat was added to the game.

Table 4.1: Summary of the problems found in the usability tests and solutions applied.

5 Experimental Results

5.1 Introduction

Having solved the problems found with the usability tests, the final details for the game were completed on the 11th of May. This was the version used in the test which started on the 20th of May.

This chapter describes the details of the experimental procedure as well as the results obtained.

5.2 Population Sample

This experiment was comprised of 51 samples provided by participants with ages between 18 and 72 years of age ($M = 24.49, \sigma = 8.45$) from which 54.9% were male and 45.1% female. Also 23.5% claimed to not play video games, 43.1% say that they play video games occasionally when the opportunity presents itself and the remaining 33.3% answered that they make some time in their schedule to play video games. The 51 participants were evenly distributed in groups of 17 elements. Each group experimented one of the scenarios: the doctor's level, the painter's level or the neutral level (control group).

5.3 Procedure

The experiments took place in 3 distinct events. The first was a gaming showcase event entitled MOJO that occurred in the 30th of May in IST's Alameda campus in Lisbon. In this event 21 individual results were collected. Afterwards, on the 1st of June, tests were executed at the faculty of Medicine (Pólo 3) of the university of Coimbra where 18 tests were collected. Finally, in the following day (2nd of June) 8 results were obtained in the department of informatics engineering of the university of Coimbra. Also, four tests were executed outside of the aforementioned events. These added for a total of 51 executed tests.

In every event, participants were motivated to participate by receiving chocolate or caramel candies by playing. A giveaway between all participants of two video games and a movie ticket for two people was another measure used to encourage user participation. This strategy proved to be successful as the down time between tests was usually lower than 10 minutes.

Even more so than the usability tests, it was crucial for the veracity of the experimental results that players did not know what was being tested. It was also imperative that the test could not be influenced by my presence or the presence of others. As such, individuals were left alone to perform the experiment with only the information that the game controls with the mouse and that a small survey would automatically open upon completion.

Name	Description
Test ID	A unique ID shared with the form in order to merge entries in both tables.
Scenario	The scenario played. Possible values are: Doctor, Painter, Neutral.
Time in Character Creator	Time in seconds the player spent creating the character.
Time to Find the Lab Coat	Time in seconds the player spent since starting to move the character until dressing it in the lab coat (ignored for players in the neutral scenario).
Time to Sit on Chair	Time in seconds the player spent after dressing the character until sitting to play the mini-game (for players in the neutral scenario the time is measured since the player is able to move the character until sitting).
Time Finding Differences	Time in seconds the player spent playing the mini-game (can be seen in-game by the player).
Lab Coat Score	A score from 0 to 1 for how much the player agrees the lab coat looks like a doctor/painter's coat (0 for players in the neutral scenario).
Picture x - Marked Differences	The number of differences marked by the player in picture x (data Parameter repeated 4 times, once for each picture).
Picture x - Differences Found	The number of differences found by the player in picture x (data Parameter repeated 4 times, once for each picture).
Picture x - Max Differences	The number of differences picture x has (data Parameter repeated 4 times, once for each picture).
Left Arrow Clicks	The number of times the player pressed the left arrow button in the finding differences mini-game (0 clicks are required to finish the game).
Right Arrow Clicks	The number of times the player pressed the right arrow button in the finding differences mini-game (to finish the game at least 4 clicks are required).

Table 5.1: Data collected in the experiment by the game.

5.4 Data Collection

Data from the experiment was collected in two different ways. Gameplay information was saved by the game itself in a file while both demographic information (table 5.1) and some long text answers were collected within the google form presented after playing (table 5.2).

5.5 Results

Using SPSS Statistics, the data from the participants was analyzed.

Participants took between 117 seconds (1 minute, 57 seconds) and 1170 seconds (19 minutes, 30 seconds) to complete the test ($M = 454.75, \sigma = 30.22$). Of that time, they spent between 6 and 124 seconds (2 minutes, 4 seconds) in the character creator ($M = 43.20, \sigma = 3.57$) and between 58 seconds and 1083 seconds (18 minutes, 3 seconds) looking for differences ($M = 351.14, \sigma = 29.28$). Those who played trough the doctor or painter scenario took between 13 and 116 seconds (1 minute, 54 seconds) to find the lab coat ($M = 34.09, \sigma = 3.53$) and between 22 and 159 seconds (2 minutes, 39 seconds) to sit in the chair ($M = 43.91, \sigma = 4.17$). Also, those who played the neutral scenario spent between 12 and 60 seconds moving until sitting on the chair ($M = 25.24, \sigma = 3.44$).

Name	Description
Test ID	A unique ID shared with the game in order to merge entries in both tables.
Gender	The gender of the player.
Age	The age of the player.
Video game usage	Information about how often the participant plays video games. Possible options are: I don't play video games, I play video games occasionally when the opportunity presents itself or I make some time in my schedule to play video games.
Video game genre familiarity	Whatever the user is well acquainted with the game genres of the project. Options are: I don't play video games, I play video games that are neither 3D or point and click, I am familiar with 3D video games, I am familiar with point and click video games or I am familiar with both 3D and point and click video games.
Lab Coat Score Justification	A long answer for the player to explain the score given to the lab coat in the game (participants in the neutral group did not answer this question).
Suggestions	Optional long answer were the users were given the opportunity to suggest improvements for the game.

Table 5.2: Data collected in the experiment through the questionnaire.

	Shapiro-Wilk		
Scenario	Statistic	df	Sig.
doctor	.840	17	.008
painter	.869	17	.021
neutral	.885	17	.039

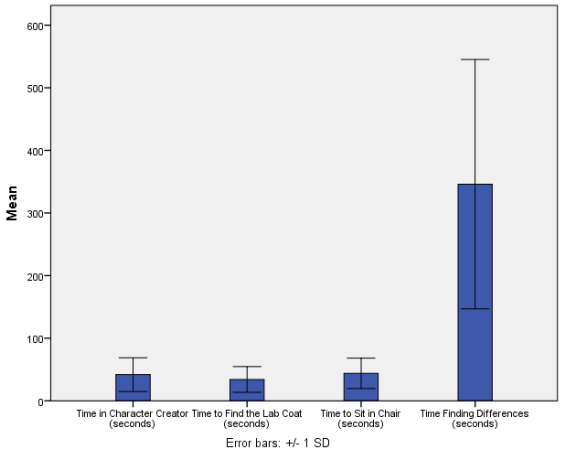
Table 5.3: Tests of normality with **Total Differences Found** as dependent variable and **Scenario** as factor.

Since the main purpose of this work was to study if using a lab coat affected the number of differences found, for most of the tests, **Scenario** was used as the grouping variable and **Total Differences Found** (a sum of the differences found for all the pictures) was used as the dependent variable.

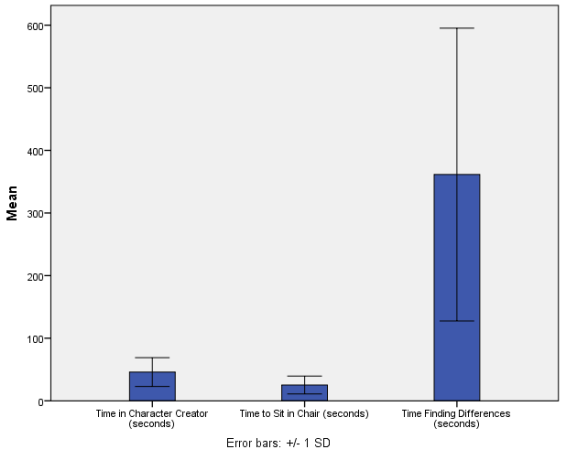
The first step in the analysis process was to execute tests of normality using the two variables described above. Using a confidence interval of 95% for the mean, we obtained the results on table 5.3. Since we have fewer than 60 data points, it is preferable to use the Shapiro-Wilk test. Its significance value was below 0.05 for every scenario (0.08 for the doctor, 0.02 for the painter and 0.04 for the neutral) and we can conclude that the data deviates from a normal distribution. As such, non-parametric tests had to be used to evaluate the data.

Since there are three distinct scenarios (the grouping variable), methods for K-Independent samples were applied. The first test used all the data available without filtering. The Kruskal-Wallis test showed that there was no significant difference in the number of differences found between the multiple scenarios, $\chi^2(2)$ = 0.409, p = 0.815, with a mean rank score of 27.06 for the doctor, 24.15 for painter and 26.79 for the neutral scenario. Table 5.4 shows the test in more detail. The mean and standard deviation for each group were as follows: $M = 11.53, \sigma = 3.1$ for the doctor, $M = 10.88, \sigma = 3.44$ for the painter and $M = 11.53, \sigma = 3.16$ for the neutral case[1].

[1] Although the average and standard deviation are presented in this section, it is important to recall that the data does not pass the normality test.



(a) Scenarios with the lab coat (painter and doctor).



(b) Neutral scenario.

Figure 5.1: Bar chart with the mean and standard deviation of the time player took to complete the various sections of the game.

Ranks		
Scenario	N	Mean Rank
doctor	17	27.06
painter	17	24.15
neutral	17	26.79

Test Statistics	
	Total Diff. Found
Kruskal-Wallis H	0.409
df	2
Asymp. Sig.	0.815

Table 5.4: Kruskal-Wallis test with **Total Differences Found** as test variable and **Scenario** as grouping variable and with no data filtered.

After filtering data to analyze only those whose **Lab Coat Score** was higher than 0.5 and deleting the neutral cases (there is no lab coat score for the neutral cases and, as such, their results are irrelevant), better results were achieved. Since only two independent variables are analyzed this time, instead of the Kruskal-Wallis test, the Mann-Whitney test was applied. The Mann-Whitney test still did not show any correlation, U = 119.5, p = 0.216, although the results were better as show on table 5.5. With this filter, we obtained the following values for mean and standard deviation: $M = 12.3, \sigma = 2.71$ for the doctor, $M = 11.33, \sigma = 2.27$ for the painter and $M = 11.77, \sigma = 2.47$ for the neutral case.

Ranks			
Scenario	N	Mean Rank	Sum of Ranks
doctor	10	13.35	133.5
painter	12	9.96	119.5

Test Statistics	
	Total Diff. Found
Mann-Whitney U	41.5
Wilcoxon W	119.5
Z	-1.238
Asymp. Sig. (2-tailed)	0.216
Asymp. Sig. (2 $\times$ [1-tailed])	0.228

Table 5.5: Mann-Whitney test with **Total Differences Found** as test variable and **Scenario** as grouping variable and with filtering: (Lab Coat Score $>$ 0.5).

Another result was obtained by filtering only those who had experience with both genres of videogames (point and click and 3D). Once again, the Kruskal-Wallis test showed that there was no significant difference, $\chi^2(2)$ = 4.091, p = 0.129. Detailed results on table 5.6. Mean and standard deviation for each

Ranks		
Scenario	N	Mean Rank
doctor	10	14.35
painter	8	9.75
neutral	9	17.39

Test Statistics	
	Total Diff. Found
Kruskal-Wallis H	4.091
df	2
Asymp. Sig.	0.129

Table 5.6: Kruskal-Wallis test with **Total Differences Found** as test variable and **Scenario** as grouping variable and with filtering: (genre familiarity $=$ 3D and point and click).

Ranks			
Scenario	N	Mean Rank	Sum of Ranks
doctor	8	10.19	81.5
painter	8	6.81	54.5

Test Statistics	
	Total Diff. Found
Mann-Whitney U	18.5
Wilcoxon W	54.5
Z	-1.437
Asymp. Sig. (2-tailed)	0.151
Asymp. Sig. (2 $\times$ [1-tailed])	0.161

Table 5.7: Mann-Whitney test with **Total Differences Found** as test variable and **Scenario** as grouping variable and with filtering: (Lab Coat Score $>$ 0.5 & (genre familiarity $=$ 3D and point and click).

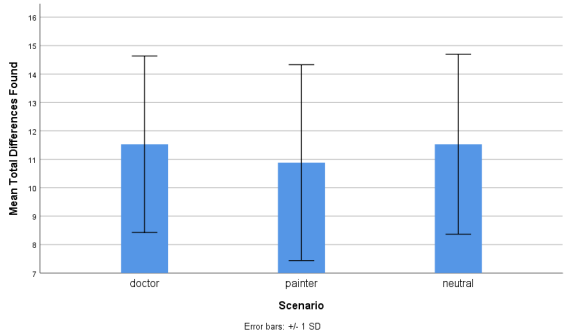
group were: $M = 11.9, \sigma = 2.6$ for the doctor, $M = 10.75, \sigma = 2.31$ for the painter and $M = 13.0, \sigma = 1.73$ for the neutral case.

Even by using the **Lab Coat Score** and **Video game genre familiarity** filters at the same time, it was not possible to show a significant difference. In fact, the Mann-Whitney test with both filters, U = 18.5, p = 0.15, showed slightly worse results than before. Table 5.7 show the results of the test. For this last filtered test the means and standard deviations are as follows: $M = 12.13, \sigma = 2.85$ for the doctor, $M = 10.75, \sigma = 2.31$ for the painter and $M = 11.44, \sigma = 2.6$ for the neutral case.

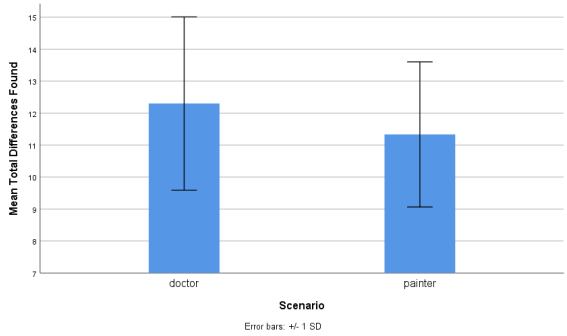
The mean and standard deviation values for the four test cases described is represented in figure 5.2.

To confirm these results were consistent across all pictures (shown on figure 5.3), each **Picture** x **differences** (where x is picture number) were also tested for their difference when grouped by **Scenario**. For the first three cases, the Shapiro-Wilk test shows that the the data deviates from a normal distribution. In **Picture 4 differences** however, the test shows that the doctor's scenario to be significative (p = 0.142). Still, since the other two scenarios do seem to deviate from a normal distribution (p = 0.045 in painter and p = 0.033 in neutral) it is also deduced that **Picture 4 differences** also deviates from a normal distribution.

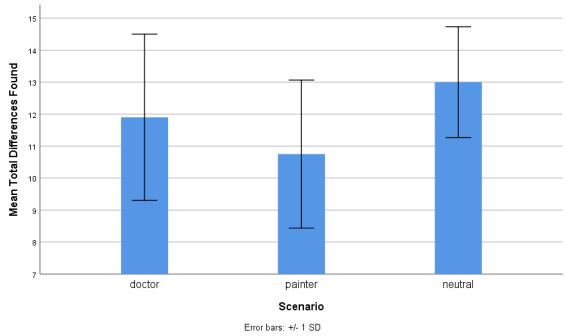
For **Picture 1 differences** the Kruskal-Wallis test showed no significant difference between the scenarios, $\chi^2(2)$ = 0.153, p = 0.926. The same occurred for **Picture 2 differences** and **Picture 3 differences** with the results $\chi^2(2)$ = 0.920, p = 0.631 and $\chi^2(2)$ = 1.747, p = 0.417, accordingly. Finally, **Picture 4 differences** also showed no significant differences between all three scenarios, $\chi^2(2)$ = 0.258, p = 0.879.



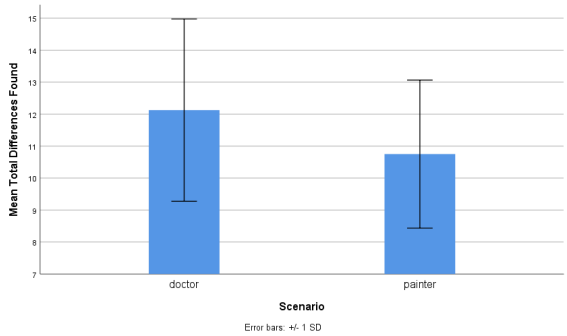
(a) No filter.



(b) Lab Coat Score $>$ 0.5 filter.



(c) genre familiarity $=$ 3D and point and click.



(d) Both filters from 5.2b and 5.2c.

Figure 5.2: Mean and standard deviation graphics of the data using **Total Differences Found** as the dependent variable and **Scenario** as an independent variable with different data filters.

5.6 Discussion

According to the results obtained, it was not possible to verify the proposed hypothesis: *are the effects of enclothed cognition preserved when interacting in a virtual world through an avatar embodiment?* This means, according to these studies, that enclothed cognition is not effective when applied indirectly through a virtual avatar. Not only was no significant difference between scenarios found in the sum of all differences, but also testing every picture individually did not show the expected results. Even by filtering data so that is only applies to those who felt the lab coat belong to the corresponding profession and who already are familiar with both point and click and 3D video games, the differences between scenario were not significant enough to support the proposed hypothesis.

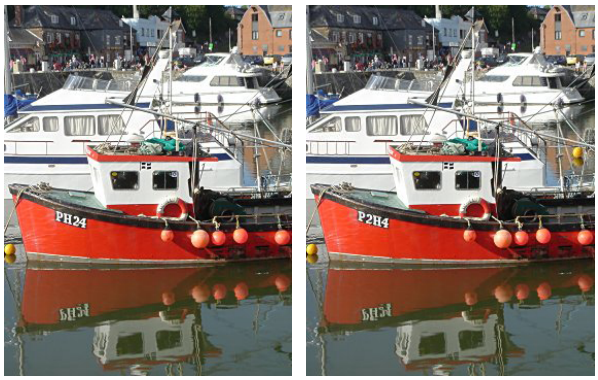
However, this does not necessarily mean that enclothed cognition cannot be observed within a virtual environment. While it is true that this work could not support this connection, it is also a fact that the average differences found from participants in this study within each scenario are very similar to those accomplished in the original Adam and Galinsky's [1] study. The average results obtained when the data is filtered by both **Video game genre familiarity** and **Lab Coat Score** are very similar to the original for the scenarios of both doctor and painter. Figure 5.4 shows this comparison in detail. The difference relies on the very high standard deviation of this study when compared with the original. This fact suggests that there could be unanticipated factors influencing the results beyond the scenario of choice.

One of those factors may be how much the lab coat looks like a doctor/painter's coat. Some testers didn't feel the lab coat the avatar was wearing belonged to a doctor/painter. In fact, of the 34 testers who played with the lab coat (17 as doctor and 17 as painter) only 22 (10 as doctor and 12 as painter) gave

(a) Exercise 1.

(b) Exercise 2.

(c) Exercise 3.



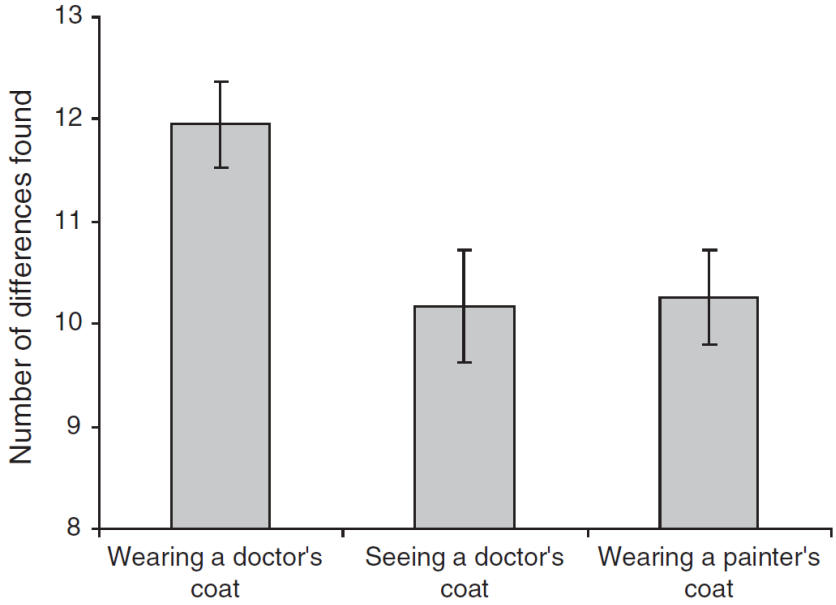
(d) Exercise 4.

Figure 5.3: Pictures used for the finding differences mini-game.

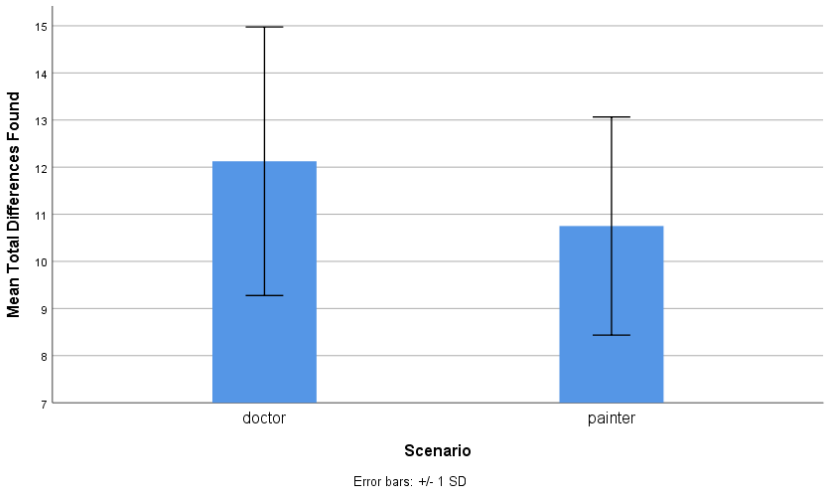
the **Lab Coat Score** an above average value (above 0.5). As explained in Adam and Galinsky's work [1] this infringes one of the necessary requirements for the enclothed cognition effect to occur: a symbolic meaning must be associated to the clothes. Filtering the data obtained to cases where the testers felt the lab coat looked like the associated profession proved indeed to increase the tests significance from 0.815 to 0.493.

Another factor influencing the tests is the familiarity of the tester with the game genres of the experimental game. Even though we deliberately chose a control scheme that non-gamers should easily adapt to, there is no doubt that prior knowledge of how to play affected results. When the data is filtered by video game genre familiarity, the significance of the Kruska-Wallis test changes drastically from 0.815 to 0.129. We theorize that those unfamiliar with 3D environments or the point and click control system are too focused in learning how to navigate the world to let themselves feel immersed with the character.

Still, filtering out the two factors described above is not enough to verify enclothed cognition in the game(as proved by the filtered results) and other, not evaluated factors, need to be taken into consideration. One of the most common comments given by participants in both usability and experimental tests after they complete the test and are explained its objective, is that it was not possible to feel empathy, and therefore a connection, with the avatar by just dressing the lab coat. As such, an extra step were testers execute an additional activity like drawing with the painter or performing an operation with the doctor could make a big difference in the results. We speculate that this factor is of extreme importance and is the main reason results could not be achieved. The character creator was implemented with this problem in mind but was not enough to solve it. The data shows that the time spent in the character creator does not affect the number of differences found.



(a) Adam and Galinsky's experiment results.



(b) This experiment's results.

Figure 5.4: Comparison between Adam and Galinsky's experimental results in the real world and this experiment's results when filtered by **Video game genre familiarity** = 3D & point and click and **Lab Coat Score** $>$ 0.5.

6 Conclusions

This document presents a study in enclothed cognition in virtual environments, the idea that by dressing a game avatar in different clothes leads players to adopt behaviours and perceptions associated with such clothes. Although enclothed cognition was already verified in the real world, this theory had never been tested in a virtual environment. As such, this work presented the following hypothesis: *Are the effects of enclothed cognition preserved when interacting in a virtual world through an avatar embodiment?*

To correctly answer this question, both psychology and the state of the art in computer graphics technology was researched. Defined as the idea that human cognition is altered by aspects of the human body, embodied cognition has been studied in both AI and psychology. One such study was performed by Hajo Adam and Adam D. Galinsky [1] when they introduced the term enclothed cognition or the idea that clothes affect the wearer's cognition. They also argued that two requirements were necessary to produce the result: the affected must wear the clothes and there needs to be a symbolic meaning associated with the clothes. Through various experiments involving a lab coat that was announced to participants as either belonging to a doctor or a painter, they were capable of not only observe the effects of enclothed cognition but also prove that both requirements were indeed necessary for it to occur. Research was also performed about the state of the art in cloth modelling, a way to represent clothes in virtual environments, as well as what graphics engine would be most suited for this project. The chosen solution was to use UE4 with Nvidia APEX cloth. This combination provided both realistic graphics and high quality cloth simulation. Finally, an analysis on the principles of level design is described. Following level design philosophy was important to assure the virtual environments were as immerse as possible.

The project experiment was devised to be similar to that of Adam and Galinsky's [1] second experiment. Divided in three different scenarios, players would either go through a doctor's lab to dress a lab coat, through a painter's studio to the the same or neither (control group) before entering a room with a mini-game of finding differences (the same pictures as the ones used in the real world test). The project was developed in about two months and a half.

Once the first version was complete, the project was subject to usability tests. Thanks to the results obtained the project was fine-tuned and a final version was deployed soon after.

Finally, 51 test subjects played through the game (17 people for each scenario) and the results were analyzed and compared with the original experiment. Unfortunately, the results suggest that the effects of enclothed cognition are not preserved in a virtual environment. However, they also show there is still a high possibility of proving this hypothesis in future work.

Future Work

Although the effects of enclothed cognition in virtual environments could not be observed in this work due to a high disparity on the number of differences found, when using the correct subset of data

not only did the results show a more significative difference between scenarios, but they also approached the values obtained in Adam and Galinsky's test [1].

The variables that improved results when filtered were the lab coat score and the game genre familiarity. In both cases the problem was the same: a disconnection with the lab coat and difficulty controlling the character disrupted player immersion and stopped users from feeling "in-character". We present two possible fixes for this issue. The first is to have a higher number of participants and then filter those who show affinity towards the lab coat and are accustomed to the controls used for the experiment. The other is to improve the mesh of the lab coat so it better resembles a lab coat for both doctor and medic and to improve the control system to be more intuitive for non-gamers. However, since this work already associated realistic graphics and cloth modelling to provide the best representation of clothes possible, improving the mesh may be difficult. It is possible that a virtual environment is simply not enough to satisfy the first condition for enclothed cognition (wearing the clothes).

Another problem was the lack of empathy towards the avatar, as commented by participants. This could be solved by having the avatar perform more actions related with his/her profession before finding the differences or by adding a story to the game.

As such, future work should focus in removing the factors filtered in this work as well as search for other possible influences that may affect the results. More importantly, we speculate that the lack of empathy towards the avatar could be the main reason results could not be achieved and encourage future work to improve the experiment in this direction.

Bibliography

[1] Adam, H., Galinsky, A.D.: Enclothed cognition. Journal of Experimental Social Psychology 48(4), 918–925 (2012)

[2] Anderson, M.L.: Embodied cognition: A field guide. Artificial intelligence 149(1), 91–130 (2003)

[3] Baraff, D., Witkin, A.: Large steps in cloth simulation. In: Proceedings of the 25th annual conference on Computer graphics and interactive techniques. pp. 43–54. ACM (1998)

[4] Bhikkhu, T.: Nalakalapiyo sutta: Sheaves of reeds (sn 12.67). Translated from the Pali by Thanissaro Bhikkhu (November 2008), http://www.accesstoinsight.org/tipitaka/sn/sn12/sn12.067.than.html

[5] Bleszinski, C., Games, E.: The art and science of level design. In: 2000 Game Developers Conference Proceedings (2000)

[6] Brooks, R.A.: Intelligence without representation. Artificial intelligence 47(1), 139–159 (1991)

[7] Bruce, I.: Plato's theory of forms. No pages. Online: http://www. ccs. neu. edu/course/com3118/Plato. html (1998)

[8] Cheng, M.T., She, H.C., Annetta, L.A.: Game immersion experience: its hierarchical structure and impact on game-based science learning. Journal of Computer Assisted Learning 31(3), 232–253 (2015)

[9] DeCaro, M.S., et al.: Enclothed cognition and controlled attention during insight problem-solving. The Journal of Problem Solving 7(1), 8 (2014)

[10] DeRose, T., Kass, M., Truong, T.: Subdivision surfaces in character animation. In: Proceedings of the 25th annual conference on Computer graphics and interactive techniques. pp. 85–94. ACM (1998)

[11] Descartes, R.: The passions of the soul. Hackett Publishing (1989)

[12] Fredrickson, B.L., Roberts, T.A., Noll, S.M., Quinn, D.M., Twenge, J.M.: That swimsuit becomes you: sex differences in self-objectification, restrained eating, and math performance. Journal of personality and social psychology 75(1), 269 (1998)

[13] Hendriks-Jansen, H.: Catching ourselves in the act: Situated activity, interactive emergence, evolution, and human thought. MIT Press (1996)

[14] Kant, I., Munitz, M.K.: Universal natural history and theory of the heavens (1970)

[15] Kavan, L., Gerszewski, D., Bargteil, A., Sloan, P.P.: Physics-inspired upsampling for cloth simulation in games. ACM Trans. Graph. 30(4), 93:1–93:9 (2011)

[16] Meyers-Levy, J., Zhu, R.: The influence of ceiling height: The effect of priming on the type of processing that people use. Journal of Consumer Research 34(2), 174–186 (2007)

[17] Pighin, F., Lewis, J.P.: Practical least-squares for computer graphics. In: ACM SIGGRAPH 2007 courses. pp. 1–57. ACM (2007)

[18] Rohmer, D., Popa, T., Cani, M.P., Hahmann, S., Sheffer, A.: Animation wrinkling: augmenting coarse cloth simulations with realistic-looking wrinkles. In: ACM Transactions on Graphics (TOG). vol. 29, p. 157. ACM (2010)

[19] Rouse III, R.: Game design: Theory and practice. Jones & Bartlett Learning (2010)

[20] Skirry, J.: Descartes: The mind-body distinction. Internet Encyclopedia of Philosophy (2006)

[21] Sorabji, R.: Body and soul in aristotle. Philosophy 49(187), 63–89 (1974)

[22] Spears, R., et al.: Deindividuation. Blackwell (1995)

[23] Totten, C.W.: An architectural approach to level design. CRC Press (2014)

[24] Turner, C.W., Lewis, J.R., Nielsen, J.: Determining usability test sample size. International Encyclopedia of Ergonomics and Human Factors (2015)

[25] Weingarten, G.: Pearls before breakfast: Can one of the nation's great musicians cut through the fog of a dc rush hour? let's find out. Washington Post 8 (2007)

[26] Wilson, M.: Six views of embodied cognition. Psychonomic bulletin & review 9(4), 625–636 (2002)

[27] Zimbardo, P.G.: The human choice: Individuation, reason, and order versus deindividuation, impulse, and chaos. In: Nebraska symposium on motivation. University of Nebraska Press (1969)

A Project Log

A.1 Tasks

1. Characters, Animation and clothing
   (a) Animation
      i. Start game animation
      ii. Open door system
      iii. Open door animation
      iv. Dress coat system
      v. Dress coat animation
      vi. Sit down to play animation
      vii. End of game animation
   (b) Male Character
      i. Created
      ii. Rigged for animation
      iii. Lab coat crated
      iv. Lab coat rigged
      v. Lab coat as APEX cloth
   (c) Female Character
      i. Created
      ii. Rigged for animation
      iii. Lab coat crated
      iv. Lab coat rigged
      v. Lab coat as APEX cloth
2. Level Design
   (a) Common
      i. Common assets list defined
      ii. Common Assets creation
      iii. All scenarios maps created
   (b) First Room
      i. Room floor plan
      ii. Asset list defined
      iii. Asset positioning

iv. Asset creation

(c) Doctor's Room

i. Room floor plan

ii. Asset list defined

iii. Asset positioning

iv. Asset creation

(d) Painter's Room

i. Room floor plan

ii. Asset list defined

iii. Asset positioning

iv. Asset creation

(e) Final Room

i. Room floor plan

ii. Asset list defined

iii. Asset positioning

iv. Asset creation

3. Point and click control system

(a) Camera system

i. Camera placement

ii. Camera switching

(b) Interaction system

i. Mouse shown with ray casting

ii. Mouse indicators for interaction

iii. Movement with path-finding

iv. Interactions

4. Level progression and UI

(a) Character Start Screen

i. Changing from male to female model

ii. Materials for changing eye, hair and skin color

iii. UI System

(b) Dressing the lab coat

i. Door locking and unlocking system

ii. Coat rating UI

iii. UI System

(c) Spot the differences mini-game

i. Camera work

ii. Control system

iii. Scoring system and UI

iv. Saving data for analysis

(d) Tool tips

i. Create hint system

ii. Place hints

iii. Finding the differences instructions

A.2 Work Log

February

14 (Tuesday) - Started my work on the project by watching a couple of tutorial and creating a new 3rd person project on unreal engine.

15 (Wednesday) - Using iClone Character Creator, I created a male avatar. I added him to the scene and rigged the unreal mannequin animations to this character.

16 (Thursday) - No work (Travelled to Mira).

17 (Friday) - Created a physics based door capable of opening when colliding with the player character.

18 (Saturday) - Created an open door animation set (open, loop, reverse open) for the male character using iClone.

19 (Sunday) - Added the open door animation set to the character's animation state machine and blended it with the main animation using blend by bone. Added a trigger that correctly plays the animations when near a door.

20 (Monday) - No work (Travelled to Lisbon).

21 (Tuesday) - No work (Went to SINFO).

22 (Wednesday) - Started creating a lab coat using Marvelous Designer. Could not finish it until the end of the day.

23 (Thursday) - No work (Went to SINFO).

24 (Friday) - No work. (Travelled to Mira).

25 (Saturday) - Finished the lab coat. Exported it to Maya. Learned how to work with Maya and how to rig a character to a skeleton.

26 (Sunday) - Rigged lab coat to the male skeleton. Learned about mesh skinning and Nvidia PhysX for Maya.

27 (Monday) - Skinned lab coat mesh to fit character. Failed to create Nvidia cloth for the lab coat (mesh too complex). Imported lab coat to unreal while sharing the same skeleton as the character.

28 (Tuesday) - No work (Worked on 3D Programming [3DP] course).

March

1 (Wednesday) - No work (Worked on 3DP).

2 (Thursday) - No work (Worked on 3DP).

3 (Friday) - Created a new male character dressed with casual clothes, created a new lab coat for it and rigged it too.

4 (Saturday) - Spent the entire day trying to implement PhysX cloth on the lab coat. Couldn't obtain good results.

5 (Sunday) - Finished the PhysX cloth incorporation in the male character. Fine-tuned some details of the cloth properties.

6 (Monday) - Created material for the eyes, hair and skin to allow their change in color.

7 (Tuesday) - No work (Worked on 3DP).

8 (Wednesday) - Created the start game animation.

9 (Thursday) - Created the first room or at least a sketch of it.

10 (Friday) - No work (Travelled to Mira).

11 (Saturday) - Recreated the first room architecture with geometry brush actors and converted it to mesh for better performance. Started work on the doctor's room. Created room and operating table using geometry brush actors.

12 (Sunday) - No work (Took the day off).

13 (Monday) - Continued work on the doctor's room. Created a monitor machine.

14 (Tuesday) - Continued work on the doctor's room. Created a cabinet machine.

15 (Wednesday) - Finished the doctor's room, or at least the main part. Missing some objects to put on the table.

16 (Thursday) - Created the last objects for the doctor's room (syringes and vials). Started the painter's room by creating some paintings and floor.

17 (Friday) - Continued work on the painter's room. Created some paint stains decals. Added a chair, table and easel. Started work on a painter brush and bottle of paint.

18 (Saturday) - Finished the last details in the painter's room. Created the final room. Tested with fixed camera switching and character movement following.

19 (Sunday) - Finished the camera switching and positioning for point and click controls.

20 (Monday) - Point and Click ray-casting working for mouse browsing. Missing interactions and path-finding.

21 (Tuesday) - Camera capture texture for the monitors and project organizing.

22 (Wednesday) - Tried to create character movement just to find I had a lot of code that needed to change in order for it to work.

23 (Thursday) - Worked on creating an abstract controller that can control the character as an AI. Now able to move character inside the same room.

24 (Friday) - Finally finished the controls in order to work as both a third person and point and click controls. Completed interaction with floor and doors.

25 (Saturday) - Created the lab coat animation and the code related to it. Missing unlocking door, make the coat mesh disappear and creating the correct coat mesh.

26 (Sunday) - Finished the dressing lab coat animation and started the sitting on chair animation.

27 (Monday) - Finished the sitting and leaving chair animation and interactions.

28 (Tuesday) - (Travelled to Lisbon in the morning and classes in the afternoon) I only had time to put the project as a private Github repository.

29 (Wednesday) - No work (Worked on 3DP)

30 (Thursday) - Worked on a camera for the mini-game. Started working on a paper heap class that handles the multiple images.

31 (Friday) - Finished the paper heaps system. The gimbal lock in the Y rotation made this much more complicated than it needed to be. Thankfully I was able to solve the problem.

April

1 (Saturday) - Mini-game pretty much working. Now it only needs a way to keep score and end the game. Also needs some sounds and UI.

2 (Sunday) - Added some UI and sounds to the mini-game and created an end game animation.

3 (Monday) - Created the game start UI of character creator.

4 (Tuesday) - No work. (Worked on 3DP).

5 (Wednesday) - No work (Meeting with my supervisor and travelled to Mira).

6 (Thursday) - No work (Worked on Portfolio 2 and 3DP).

7 (Friday) - No work (Worked on Portfolio 2 and 3DP).

8 (Saturday) - Created the female character and added it to the game. Also fixed some problems with the male character textures and materials.

9 (Sunday) - Created the female character's lab coat. Female character now complete.

10 (Monday) - Changed the mini-game images to one's similar to the used in Adam and Galinsky's tests.

11 (Tuesday) - Changed the way the mini-game is played to be similar to Adam and Galinsky's experiment.

12 (Wednesday) - Changed the painter room's size; Added a song for low scoring players in the mini-game. Changed the game's resolution and activated fullscreen mode. Increased light intensity and direction.

13 (Thursday) - No work (Worked on Portfolio 2 and 3DP).

14 (Friday) - No work (Worked on Portfolio 2 and 3DP).

15 (Saturday) - Added the game hint system that uses thinking bubbles.

16 (Sunday) - Executed the first 3 usability tests.

17 (Monday) - No work (Studied for a 3DP test).

18 (Tuesday) - No work (Studied and executed the 3DP test).

19 (Wednesday) - Changed the required elements from the first usability tests. Added X-Ray decals and a skeleton to the doctor's room. Mini-game can now start by clicking on the table. Added door unlocking to dressing animation and created instructions for the mini-game.

20 (Thursday) - No work (Waiting for the results of the usability tests of the following day).

21 (Friday) - Executed the last 5 usability tests.

22 (Saturday) - Worked on the usability test report.

23 (Sunday) - No work (Travelled to Lisbon).

24 (Monday) - Created the neutral room and tests now save information. Final objectives completed.

25 (Tuesday) - No work (worked on 3DP).

26 (Wednesday) - Had an extra meeting. Found some extra work to do before releasing the final version.

27 (Thursday) - Corrected some bugs and added more data to the game output. Created the forms. Now waiting for professor's approval in order to start the experiments.

28 (Friday) - Added an ID to the saved data. Forgot about that.

29 (Saturday) - Added different messages after dressing the lab coat. Changed some details in the form.

30 (Sunday) - No work (Waiting for the professor's feedback).

May

1 (Monday) - No work (Waiting for the professor's feedback).

2 (Tuesday) - Changed the game so that players can submit results without finishing the game. They only need to get to the last exercise. Also added some extra info in the information printed to file.

3 (Wednesday) - Added a question after the dressing animation about the lab coat. Added a menu to confirm submitting the final answer and quitting the game. Added some more info to the printed file.

4 (Thursday) - Separated the dressing animation from the door unlocking animation to show the latter after answering the lab coat question. Rewrote some text so that it make more sense.

5 (Friday) - Last official day working on the project. Added a start screen and fixed an animation that was bugged in the packaged version. Packaged all 3 scenarios of the game. The project is finally finished.

6 days later: 11 (Thursday) - Following a friend's suggestion, I added a functionality in the game to automatically open a link to the online form after closing. Repacked all versions of the game again.

B Usability Test Questions and Answers

B.1 Demographic Questions

1. Are you male or female?
2. What is your age?
3. How often do you play videogames?
   (a) I don't play videogames;
   (b) I play videogames occasionally when the opportunity presents itself;
   (c) I make some time in my schedule to play videogames.
4. Are you familiar with 3D or point and click games?
   (a) I don't play videogames;
   (b) I play videogames that are neither 3D or point and click;
   (c) I am familiar with 3D videogames;
   (d) I am familiar with point and click videogames;
   (e) I am familiar with both 3D and point and click videogames.

B.2 Usability Questions

1. Within the given interface, it was possible to control the character appearance as desired. Do you agree with this statement?
   (a) Strongly agree;
   (b) Agree;
   (c) Neither agree nor disagree;
   (d) Disagree;
   (e) Strongly disagree.
2. *(If answered (c), (d) or (e) in question 1.)* Explain why the appearance was difficult to control.
3. It was possible to make the character move and act as desired. Do you agree with this statement?
   (a) Strongly agree;
   (b) Agree;
   (c) Neither agree nor disagree;

(d) Disagree;

(e) Strongly disagree.

4. *(If answered (c), (d) or (e) in question 3.)* Explain why the controls were not intuitive.

5. Was there any interaction icon that seemed incorrect for the action is represented? If so, why?

6. What does the main character do for a living?

7. *(If unable to correctly answer questions 6.)* What kind of room is the middle room?

8. The controls for the finding differences mini-game easy to understand. Do you agree with this statement?

   (a) Strongly agree;

   (b) Agree;

   (c) Neither agree nor disagree;

   (d) Disagree;

   (e) Strongly disagree.

9. *(If answered (c), (d) or (e) in question 8.)* Explain what made it difficult to understand.

10. Was the quality of the images good enough to find the differences? If not, are there any differences/pictures in particular that were difficult to see?

11. Did you easily understand how to finish the mini-game? If no, why?

12. Did you ever had any problems understanding what to do next? If so when?

13. What do you think we are measuring with this experiment?

B.3 Answers

questions	1	2	3
1	male	female	male
2	23	34	34
3	(b)	(a)	(c)
4	(c)	(a)	(e)

Table B.1: Answers to the demographic questions in the first wave of usability testing.

In table B.2 and B.4 red cells indicate problems that needed to be fixed and yellow cells represent possible problems. If preeminent in future tests they would need to be fixed.

[1] **N.A.** stands for **N**ot **A**pplicable.
[2] **N.A.** stands for **N**ot **A**pplicable.

Questions	1	2	3
1	N.A. [1]	(a)	(b)
2	N.A.	N.A.	N.A.
3	(b)	(b)	(a)
4	N.A.	N.A.	N.A.
5	No	No	No
6	Investigator	Painter	Painter
7	Shop	N.A.	N.A.
8	(a)	(a)	(a)
9	N.A.	N.A.	N.A.
10	City image	Yes	All images
11	Yes	Yes	No instructions
12	Clicked on table	Clicked on table	Door unlocking
13	No idea	Wrong idea	No idea

Table B.2: Answers to the usability questions in the first wave of usability testing.

questions	1	2	3	4	5
1	male	female	female	female	male
2	24	24	33	31	35
3	(c)	(b)	(a)	(b)	(b)
4	(e)	(e)	(a)	(e)	(e)

Table B.3: Answers to the demographic questions in the second wave of usability testing.

Questions	1	2	3
1	(c)	(a)	(c)
2	Dynamic sliders	N.A. [2]	Preset colors
3	(a)	(b)	(d)
4	N.A.	N.A.	Always move on click
5	No	No	No
6	Dentist	Scientist	Doctor
7	Dentist office	Medical scientist	N.A.
8	(a)	(a)	(b)
9	N.A.	N.A.	N.A.
10	Yes	Yes	Paper rotation
11	Yes	Yes	Yes
12	No	No	No
13	No idea	No idea	No idea

Questions	4	5
1	(a)	(a)
2	N.A.	N.A.
3	(b)	(e)
4	N.A.	Manually rotate camera
5	No	No
6	Painter	Scientist
7	N.A.	Painting room
8	(a)	(a)
9	N.A.	N.A.
10	Paper rotation	Paper rotation
11	Yes	Yes
12	No	No
13	No idea	Wrong idea

Table B.4: Answers to the usability questions in the second wave of usability testing.