# *Use of Philips Hue Lights to Make Game Design More Immersive*

**Candidate Number:** 149111

**Supervisor:** Prof Sriram Subramanian

Informatics - Computer Science

2019

## Statement of Originality

This report is submitted as part requirement for the degree of Computer Science at the University of Sussex. It is the product of my own labour except where indicated in the text. The report may be freely copied and distributed provided the source is acknowledged.

……

## Acknowledgments

I would like to thank Sriram Subramanian for his valuable and constructive suggestions throughout the development of this research.

I would like to express my very great appreciate to the staff of Philips for enabling me the resources and help needed to complete this research. Most particularly, I am grateful to Dzmitry Aliakseyeu for the time and effort he has put into all our meetings and his endeavours in helping me achieve the quality of work that has been produced.

## Summary

This report is focused on the creation and use of external lighting effects in making more immersive game design for the player. The tradition gaming setup is a desk, with a monitor and speakers. It has not had much innovation over the past few years. With external lighting it is hoped that a more immersive experience can be created for user, where the whole environment is part of the game.

The aim of this project was to see if immersion can be increased with the use of coloured smart lighting. Drawing on work by Michel Chion about how sound and visuals work together, this same theory was hoped to be applied to external lighting in game design in hope create similar immersive effects.

A demo of how the lights would be used in this way was created for Minecraft. This demo was user tested by 6 participants, where each would play the demo for 2 lots of 20 minutes, once with the lights and once without. There were two main types of effects used in this demo, ones that re-enacted objects such as fire and ones to invoke emotion responses within the player. The users played the game in a dimly light room with 5 lights, 4 placed in a square around the user and the 5th behind the screen.

After each playthrough the user completed a questionnaire that has been adapted from a standardized Game Experience Questionnaire. This questionnaire contains question that will help in finding out how immersed the user felt. After the study the users also gave feedback on what they thought about the lights and how they felt they affected their immersion. This feedback was used to suggest future refinements that could've been made to the code to improve it.

The results of the question showed that the lights did improve immersion but needs further study for this to be conclusive. For all users their experience felt richer due to the lights and thought that it made the game more aesthetically pleasing. Almost all users said they wanted to play more games with these lighting effects again. However, a low sample size, a non-optimum test environment and a non-optimum questionnaire has not yielded the best data to fully conclude this. For this to be more conclusive it has been said these lights needs to be tested over longer gaming sessions and with a multitude of games on a bigger user group.

# 1.0 Introduction

This project is about the investigation of making game design more immersive using coloured smart lighting. Immersion in gaming is measured by how engaged a game makes a user feel [12]. This project will investigate how these lights can be used to achieve more immersive features, discussing different ideas that can be used to achieve this. Then a game will be used where code will be added to, or software will be created to make demonstrations of some of the discussed ideas. These can then be tested by users and evaluated to see how immersive people find them.

There are many options of lights that can be used such as Razer, Logitech light speakers, Ambilight TVs, etc. but in this project the Philips Hue lights will be used. They will be used to create more engagement by using similar effects to that of sound, ultimately making use of hue lighting to add more immersion and tell a greater story. Lighting is one of the most essential elements in creating an atmosphere [13] and only making use of the monitor means a lot of opportunity is forgone. Bringing light into the whole environment will add more life to a game, make better composition, as well as aid the gamer.

## 1.1 Philips Hue

Philips Hue is a series of different kind of smart lights. They are lights that connect to a bridge through a local network which can then be controlled remotely. They can produce 16 million different colours that can be controlled through use of apps and other software, allowing users to interact and setup whatever atmosphere they wish for. These lights are programmable through use of the hue development kit allowing them to be used in all different types of software.

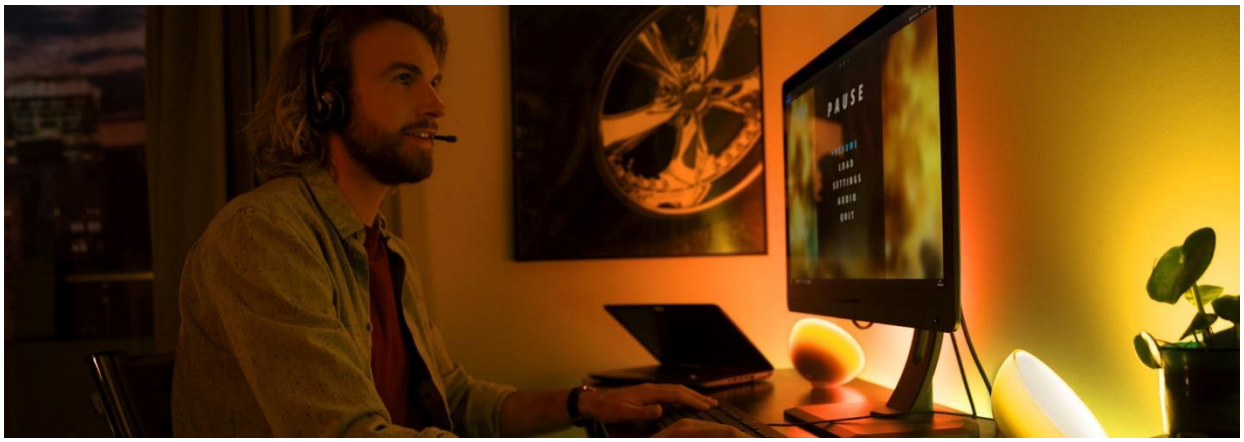



Fig. 1.1.1 Philips Hue lights [6]

Currently, Philips Hue already has features where the lights will interact with movies, games and music. This is done using the HueSync app. For the game feature of this app, it is very limited and only replicates the colours on screen. These lights can be utilized better and this is what will be investigated with plans to make some demos and examples of how this can be done.

Philips are an industry contact in this project who will be there to assist in and discuss any ideas, problems or advice that may be needed. There will be progress checks and they're available to give any assistance. They are very interested in the software made with their lights and so are keen in aiding with this problem and giving any information necessary.

## 1.2 Gaming and Setups

The gaming market is set to grow from $137.9 billion in 2018 to an estimated $180.1 billion by the end of 2020. It is a big market with a lot of opportunity, with an audience between 2.2 and 2.6 billion people [8]. As it grows this increases the demand for there to be things like Philips Hue by specific audiences. As the market demand grows the opportunities to make advancements present themselves.

Up to now the typical gaming setup is a monitor for display and sound. This setup can be improved. Currently there are a lot of advances in moving games into virtual reality and augmented reality, the traditional setup has not had any advances. With the Philips Hue lights these advances can be made. They are not a huge change, but they can add a lot more dimension to gaming.

## 1.3 Minecraft

For this project Minecraft [2] will be used as the game for making demonstrations of the lights. Minecraft is a game for exploration and interaction on a terrain made of blocks. The environment contains plants, mobs and items. The aim of the game is to go around and survive, by building and crafting items. To do this you have to collect resources, fight of enemies and craft tools.

It is a game that is allowed to be modified and changed, but these modifications cannot be distributed. Adding straight the game code will mean a lot more information will be available when making these lighting demos. Its code base is written in Java.

Fig 1.5.1 Image to show Minecraft [7]

## 1.4 Coding

The Philips lights use the RESTful interface over HTTP, this is because they are connected through a bridge that acts as a local network and all lights will connect to this. They have an SDK that is used to program them, and these have been produced for a few different languages. For this project the Java SDK will be used as that's what Minecraft is coded in.

## 1.5 Problem Area

Gamers are always striving for the most immersive experience. To improve immersion, engagement with the user needs to be increased. Games are currently only making use of image and sound and so immersion isn't being achieved to the highest of capacity. New innovations, as of late, are virtual reality and augmented reality. These are putting the gamer into the game, unlike the traditional setup. For example, with virtual reality you wear a headset and so everywhere you look you are in the game. However, it has been said that VR is not where the industry is heading because it doesn't add much value to a lot of game genres [14]. Therefore, there is still need for the traditional setup to be advanced and improved.

# 2.0 Objectives

## 2.1 Primary Objectives

The most prevalent objective of this project is to investigate how Philips lights can be used in game design and to test if they can be used to make a more immersive experience for the user. Once this has been researched and discussed some of these ideas will be produced as examples that can then be tested and evaluated.

What is hoped to be achieved by the end of the project, given the time and experience levels, is a good analysis of the use of the lights along with some examples of how the lights could work. But, it will not be possible to produce all the ideas that will be researched therefore only some basic uses will be made.

An example of a lighting effect to be produced is when close to fire, the lights should mimic and flicker in an equivalent manner. These types of scenarios should be implementable; however, this is all dependent on how much the game allows its code to be changed and information that can be accessed.

Investigating the science behind colours in the peripheral vision will be a big advantage when discussing and creating the lighting effects. Using the best colours for certain situations will help to build atmosphere. Researching and implementing lighting that is influenced by this research could add a lot of value to the lights and the project. In a paper by Alvin Raj and Ruth Rosenholtz [10] they discuss how knowing what is in the peripheral vision will help make better user interfaces, this paper can be adapted to help with creating the lighting effects.

## 2.2 Secondary Objectives

In addition to the primary objectives, looking into and potentially producing some of the secondary objectives below is desirable. These are dependent on how difficult and the time it takes to implement the primary objectives.

One of these is a model that will read in an image and predict its light sources. These light sources can then be translated to the lights. There is an algorithm from another project by Naoki Kimura and Jun Rekimoto [9] that can take images and then extend them. That project took images and would then make peripheral projections and project them behind the screen. To do this they needed to train a network that was able to extend images and project that extension in a lower resolution. Projectors are not used in this project and so this idea needs to be adapted for the Philips lights.

Something that could be explored further too is the use of biometrics. Biometrics can be used for both affecting light patterns as well as to analysis how users are reacting to the lights. With biometrics they can be used to exaggerate lighting effects based on the state of the user, for example making the lights flash quicker as heart beat increases. The use of biometrics could make for a very immersive experience. Also, the opportunity to collect data that is not subjective would

be of immense value. Seeing how the lights effect someone through their heartbeat or brain activity will allow for some good in-depth analysis that isn’t affected by users' subjective views.

# 3.0 Requirements Analysis and Research

## 3.1 Requirements for the Project.

For this project the main requirement is the Philips Hue lights. The number of lights to be used needs to be explored. In another project [3] that has been looked at they have used a 5 light setup and after speaking to a professional contact at Philips, they suggested a 5-light setup for me. This is because with 5 lights it should be enough to light up each direction of the room and allow enough variety in the lights to reflect in-game features. The suggested setup will be a strip light behind the screen and then two lights either side of the screen and another two either side of the user. The lights are all connected through a bridge supplied by Philips. This bridge needs to be connected to a router so that they can be controlled.

Minecraft [2] is an open-source game that will be required to fulfil this project. Eclipse will be used for developing, this is because this is the IDE originally used to develop Minecraft in Java. The project, when downloaded, is already setup to be open in Eclipse and so this is the easiest IDE to use.

GitHub will be used as version control for this project. GitHub will allow the code to be kept secure from accidental deletion and will also record the progress that is made. It will also allow the code to be rolled back if any mistakes are made and make branches to test any risky code.

## 3.2 Requirement of the Users

When using media such as games, users want the most immersive experience. The requirements of the user are to feel as if they are inside the game and experiencing what is happening on screen. Games are currently, as standard, only making use of image and sound and so immersion isn't being achieved to the highest of capacity. With this project it's hoped to make use of the Philips lights to help make advances towards the immersive experience users want.

In Michel Chion's book [1] he talks a lot about how sound and the image interact with one another; this book will be used a lot in this project. It describes how our perception of what we're seeing is changed because of the use of sound. There are a lot of parallels between how sound effects gaming and how external light would affect gaming. Therefore, the theory from here will be adapted and used to create a different way for the user to perceive the game, one which invokes more emotion and creates more engagement.

When watching a movie, you do not just watch what is on screen you experience an audio-visual whole [1], where you experience both image and sound as one. The image is the focus with sound contributing to it. Sounds will alter our impression of what is on screen, adding to the effect of making something more immersive and feel as if we are experiencing what we are viewing. One doesn't experience the image or sound the same as they do when they're put together. They merge together to allows us to better interact and empathise with what is happening on screen. Michel Chion talks about how this is done through different methods like use of empathetic and anempathetic sound and temporalisation. These will be discussed more later on.

## 3.3 Use of the Lights

The use of the lights can vary and be used to add value in different ways. This is similar to the way sound works. Movies make use of different types of sounds: diegetic sound – anything that both audience and the characters can hear; non-diegetic sound – sound only heard by the audience; empathetic sound - sound to reflect overall mood of the scene; anempathetic sound – sound indifferent to the mood [4].

The use of lights can be used in the same capacity as this. For diegetic sound you can use the lights to replicate the light sources on screen (e.g. fire or car headlights) and have the lights shine in their respective places. This is extending the screen into the real world and putting you into that environment. For empathetic sound where music might be used you could use colour psychology to invoke emotions that are desired for the particular scene. For example, using red to make feelings of anger or yellow for happiness.

Different films have different genres and depending on the genre will depend on how sound is used. This will be the same for games. Games and movies differ. This is especially prominent in fast past first-person shooters like Call of Duty. In these types of games, you are paying more attention to your surroundings and visual cues, as they want to detect enemies as fast as possible. Here a lot of diegetic sound is used such as footsteps and gunshots, playing music in the background will be of no value to the user. Therefore, in these types of games/situations in games, the hue lights should be used to improve performance.

## 3.4 Philips Hue Lights for Doom 3

A project by Erik Dahlström [3] was to use the Philips lights to make visual cues for the user. In this project he used the lights to aid in a game called Doom 3 where he used the lights as a way of pointing out where enemies were and to give cues as to whether enemies were close or not. The purpose of the project was to use the lights to improve performance.

In the conclusion of this project it was noted that the light effects didn't help in player's performance, based on the statics. However, participants in this project said that lights helped them perform. This shows that participant's recognised that the lights were of use and drawing from this I think that they could be well used in the making of a more immersive experience.

Learning from that project, visual cues from the lights were not performance increasing, but they were thought to be helpful. It was said in this report that some people found them diverting their attention away from the screen which is not what you want in a game. Diverting attention away from the screen will break an immersive experience. This is a factor that needs to be kept in mind when analysing features for immersion. There were features in that project that could be implemented into the immersive features of this project, like the kill confirmed feature where the lights flashed to confirm the death of an enemy as participants said 'this gave them extra motivation' [3].

The use of the lights, like that of sound, will need to be adapted to the type of game you are playing. In horror games, more tension needs to be built, whereas open world games you want more diegetic projections of the lights.

## 3.5 Requirements of an Ideal System

In an ideal system the lights will have a perfect balance of invoking the best emotions at specific times in a game, but also used in a way to extend the screen to make it feel as though they are inside the game. This needs to be done in a way so that the user doesn't get distracted, if their attention is taken away from the screen it will disrupt the immersion. The sound, screen and lights all need to work with each other. This would contribute to creating the Immersive experience that gamers are always looking for.

Within the given time, it won't be possible to produce all of this. Getting all three components to perfectly align with each other is something that is not possible with the experience levels. However, in the given time, as stated above, a few simple but well executed examples will be attempted. As well as this an in-depth analysis of other potential immersive features will be made. Depending on how fast and how easily the code is picked up, more complex examples could be developed.

In this project a big down fall is that the demonstrations are to be coded straight into the game. This means the code made will not be able to be applied to multiple games, it will only be applicable for Minecraft. It would not necessarily be possible to make a general software to apply to multiple games as the ideas thought up make use of a game's mechanics.

## 3.6 Requirements of the Game

The game for demonstration needs to be a game that will be explored, and time will be taken when playing through; there also needs to be scenes where different emotional states are created. Open world games are games that users are more likely to explore and take time interacting with different things. This is because they are not always being pursued by enemies unlike first-person shooters. They have a multitude of different missions that don't involve fighting, but puzzles and exploration. A good narrative is also needed where immersion is involved. Where the user is using more mental capacity to notice what is going on and following along will mean they are deeper involved with the game [11].

Minecraft fulfils some of these requirements for an immersive game but lacks in others. It is a simple game that needs to be explored. It has enemies however, these are a small part of the game and can easily be avoid. So, use of these haptics encounters can be used. It has a lot of natural elements and weather that can be used in extending the game from the screen into the room.

On the other hand, Minecraft doesn't have a full narrative that you can get lost in. First person shooters and horror games are ones where more intense emotions are built like panic and rage,

due to the narrative of them. This brings a lot of adrenaline and makes you more receptive to what's going on. Therefore, users may be better affected by lights in these cases.

Some other games that would be better to use because of their immersion levels are Red Dead Redemption, Assassins Creed and Destiny. These games are immersive because of their attention to detail, their open world environments that can be explored and engrossing narratives. These games are not able to be used for demonstrations in this project because of the complexity and access to their code bases.

## 3.7 Requirements of the Lighting Setup

A consideration that needs to be made when setting up these lights is making sure that the lights are set up well. The lighting setup that is currently being considered is shown in figure 3.7.1.

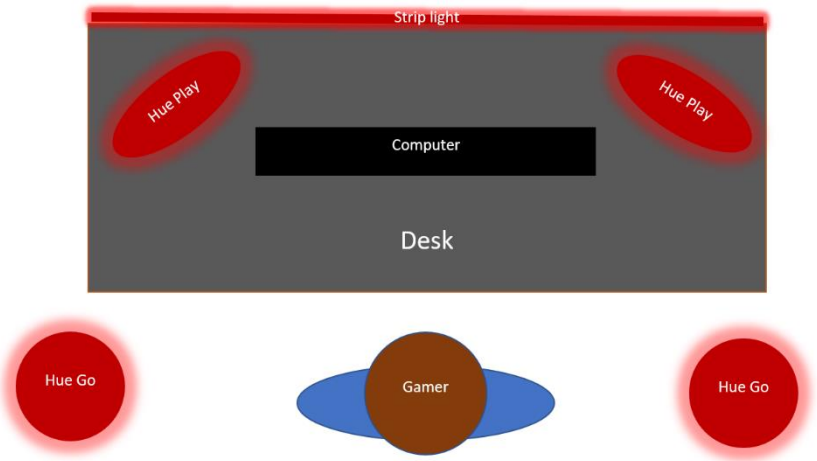



Figure 3.7.1 Planned setup of Hue lights

When setting up, the lights need to have a good amount of distance between them. This is because different colours of the lights may end up mixing together and creating different colours. This will have effects on the immersion aspect of the lights. In games there are colour conventions, these are things such as red and amber indicating a bad situation [5] and green meaning something good is happening. If a red light is shining because a bad situation is happening, but then another light starts shining blue for some reason then they may merge into a purple light; this will then clash with the effects that is supposed to be produced.

## 3.8 Colour Theory

When creating the lighting effects, the colours used need to be considered. In gaming there is colour theory where certain colours are used to indicate certain events and invoke certain emotions. For example, green for good and red for bad. So, when damage is inflicted red is flashed and when an enemy is defeated green is flashed, these are non-diegetic effects. They are to inform the player of events that are not in their immediate focus.

Light having physiological effects has been proven, as can be seen in the paper by TCP [19]. Brightness, saturation and hue will all have effects on the emotional state of a player. A brighter light will cause more intense emotions, a more saturated light will also amplify effects and the hue will change the type of emotion inflicted.

It has been shown that blue light reduces melatonin levels and therefore makes us more energetic. Changing the saturation and brightness of the light will then change the strength of this effect [19]. This means when coding events for interactions, where we want users to be more alert and energetic, more blue toned light needs to be used and for events that are more dangerous the lights need to be bright and saturated.

Diegetic effects will be used to make it seem as if the screen is being extended into the room. For these events, colours that are the same to the actual objects on screen will be used. The colours used here are to mimic the screen and not to invoke emotional responses necessarily.

Mixing together the two different types of lighting effects will be difficult. This is because when making diegetic effects, we don't want to cause an unintended emotional response. An example is for when going near fire, these lights flicker and are very reddish in colour. From this effect we didn't want to make it so that they feel tired or even think that something dangerous or bad is about to happen. To reduce this from happening the diegetic effects need to be made as similar to what is on screen as possible, so that they aren't as noticeable. Most diegetic effects will be made as close to that what is on screen, whereas non-diegetic effects will be more structured and precise.

### 3.9 In-game Interactions

Interactions that happen in-game need to be distributed between those that represented good things happening for the player versus those that were bad. A Thayer's arousal-valence emotion plane was used.

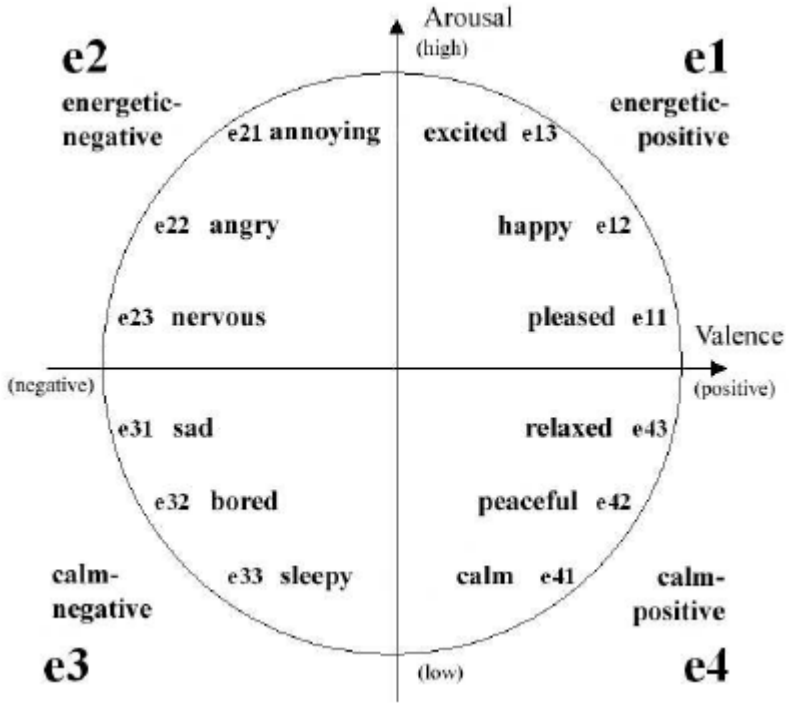



Figure 3.9.1 Thayer's arousal-valence emotion plane [16]

By designing effects for a range of these of these emotions, the lights will make the user feel immersed through the range of emotions they feel during a playthrough. The more emotions they would feel the more they would find themselves getting involved and engaged by the game, making it feel more like a real-life experience. Figure 3.9.2 shows the table of interactions to try cover as big a range of these emotions as possible.

| Minecraft Interaction | Emotional Response | Effect to Use |
|---|---|---|
| Damage taken | Panic | Flash red |
| Poisoned | Panic | Flash green, only on front light |
| Drink potion | Excitement / Annoyed | Ping the colour of the potion when first taken, only on front light |
| Go near fire | Calm but aware | Flicker like fire |
| Go near lava | Calm but aware | Slow and subtle flicker like fire but softer |
| Go near torch | Relaxed | Bright and constant as supposed to be an aid to the player |
| Stand in nether portal | Disorientated | Purple light pattern |
| Go underwater | Nervous | Pulse and get darker |
| Explosions | Scared | Sudden and big |

| | | |
|---|---|---|
| Mine an ore e.g. gold ore | Pleased | Ping with colour of ore, only on front light |
| Lightning | Nervous | Flash blue on back lights |
| Killing an enemy | Happy | Flash green (needs to be quick as could be multiple enemies) |

Figure 3.9.2 table of interactions and desired effect and how it's implemented

A flash will be one second long, the lights will take 500ms to get to the desired brightness and then 500ms to go back to dim. Interactions that flash are ones that we want to bring to the user's attention quickly. By making them flash it will invoke more arousal in the player and so make them feel more emotions like excitement or panic. To differentiate between which is felt different colours will be the colour used. So, a red flash will be more panic, and a green flash will be more excitement.

Flickering is when the lights will transition between different shades of a given colour, the amount of time it takes to change between colours will also be different for different interactions. Interactions that involve flickering or light patterns are ones that are trying to represent more diegetic events like fire. However, these can still be made so they invoke some emotions. With fire and water, you want to make the user feel calm, but aware as these things are not going to cause any damage to a player unless they go too close. A dim flicker will be used, so arousal isn't too high, and they match what is on screen.

To get higher arousal the changing of the lights needs to be more dynamic, so making them sudden and fast. To reduce arousal slow and smooth transitions need to be used. To change the valence this will be more focused on the colours and brightness's that are used. Mixing these together was hoped to produce most the emotions that we wanted for our interactions. What will also be used to affect the emotional response is which lights are light up. There are 5 lights so less important events will use just one light and more important will use all.

The spread of interaction in figure 3.9.2 is more towards those that are negative. This is due to the nature of most Minecraft events and it being difficult to reflect more positive effects without them becoming distracting and meaningless. An example is that eating could be deemed as positive as it regenerates health, however if every time the player ate food the lights reacted it would soon be becoming very repetitive as you eat a lot in the game. Also, being informed of conscious tasks like eating, that you invoke yourself, isn't of much benefit to the player. Whereas, when a player takes damage and it flashes red, informing the player of this is helpful as they may not be aware of the damage as they may not be inflicting it themselves, for example if a mob attacked from behind.

## 3.10 Light Predicting Model

For a light predicting model the lights will illuminate around the room where they think the light source would be in relation to the player. For each different light source, it will have to

react differently depending on what is producing the light and accurately imitate the object with the right brightness. By doing this it will be a good extension of the screen.

From the project 'Augmentation of Visual Experiences' [9] this was done with a deep neural network where it is trained on context-images. However, it takes a long time to prepare context image and their system doesn't appear like it will be able to handle game play at the level needed for this project. Another way to do this would be through computer vision, analysing single images to find the brightest parts of it and then predicting where about the light source is based on saturation and brightness.

### 3.11 Biometrics

To make the lights react to a player, a heartbeat sensor would be the easiest to use. This will make the lights react to the speed of a player's heart and intensify the emotions they are feeling. With the heart rate monitor, when there is any noticeable change in the heart rate then the lights will react to this. For example, as you encounter an enemy and they start to attack, it is expected to startle a player and increase their heart rate. As the heart rate starts to increase the lights will start to flash quicker.

However, in Minecraft there aren't many situations that there is going to cause a significant increase in heart rate. Due to the game being open world and not having a story mode, this kind of feature would be better suited to other games.

There could be use of heart rate monitors not to affect the game, but to record the state of the player when they're user testing. By doing this more data is then collect and can be analysed to find out the true effect of the lights on them. Doing this will give us more data and of a different kind. This type of data is physiological data whereas, usual methods like questionnaires are subjective measures.

### 3.12 GEQ (Game Evaluation Questionnaire)

The demo created will be put to user testing and so a questionnaire that collects good data is needed, so that it can be well evaluated, and a good conclusion about its effects on immersion can be made. There are already validated questionnaires made, that are used for measuring a user's experience of a game. One example is the GEQ [17]. This is the same one that was used in the project discussed above about the game Doom 3.

This questionnaire has an area on immersion and so these are the questions that will be used to get feedback from the user. Some of these questions are not particular relevant to the demo, however to keep the integrity of the questionnaire all the questions from this section will be used.

# 4.0 Professional Consideration

## 4.1 Public Interest

This project will not have any negative effect on public health, privacy, security and wellbeing of others and the environment. Much of this project will evolve around the research of introducing external lighting into immersive game design and so there will not be much area where this can have these negative effects, but there will also be a user testing part, where they will play the game along with the lights. There will be no discriminatory actions taken against any type of people who take part in the testing, however as this project uses external lighting there could be negative effects against people with epilepsy if they were to participate and so people who suffer with this will not be allowed to take part in any sort of user testing due to the risks involved. All others will be allowed to take part in the user testing, but at their own risk of using lights that will be bright and contain flashing.

Users will be asked to give consent to take part in the user testing, legally under the age of 16 they can't give consent, so permission from guardians would be needed and for this reason participants under 18 will not be used. Being clear about what you want from the person is vital, making sure they know what they're doing and what is expect, however not in a way to affect the results. Safety concerns will also be explained. For this project to be of full effect the room will need to be dimly lit and so safety measures need to be put into place so that no risks such as tripping occur.

No personal data will be collected. Participates will be number for comparison of their data later. Nothing that can identify the user will be collected.

Care will be taken to be within the legitimate rights of third parties. Wherever material of third parties is used it will be referenced and credited, especially as third-party products and games are used.

## 4.2 Professional Competence and Integrity

This project will focus on the research for using Philips lights in game design to create a more immersive experience. This will be done through background reading and research on relevant topics so that ideas can be created and discussed with enough detail and reputable sources to back any ideas.

Through this research it will allow me to develop my professional knowledge within the field. As research will be continuous throughout this project it will mean that I will continuously stay up to date with the technological developments and procedures.

# 5.0 Building the System

## 5.1 Design

Minecraft is a simple game that needs to be explored. In the game it has a lot of natural elements such as fire, weather and mobs. These are good interactions that can be used as triggers for lighting effects. On the other hand, Minecraft doesn't have a full narrative that you can get lost in. So, it is important to try to use what is available to the best of its ability to get the users to engage as much with the game as possible.

To do this the lighting effects had to be made so that they were adding good value to the scene. Interactions that were going to be very repetitive and not add much value were avoided. The interactions were discussed above, and these will be the ones that are implemented. They are a mixture that will invoke a wide range of emotions and bring as much immersion to the game as possible.

The layout of the lights was a factor discussed before too. Having the lights laid out all around the user meant that many different effects could be made. Lighting up different areas of the room or using more or less lights gave more significance to certain effects and helped create different atmospheres.

## 5.2 GitHub

A GitHub repository was created before any code was written, this is because it allowed all iterations of the code to be tracked and has allowed for rollbacks and branching. Doing this removed a lot of worry about losing code and removed any risk when being experimental with the code. An example of this is when attempting to make the lights directional (discussed in more detail later) it involved a lot of the code to be moved and changed where there was potential risk of breaking the build.

## 5.3 Minecraft Code

Learning how Minecraft code worked took a big chunk of time in the coding phase. A lot of tutorials were watched [15] and forums read to get answers. The way the code works, is through event handlers, most things that happen in game cause events to fire. To then make the lights react to these events they needed to be caught using a method like so:

```
@SubscribeEvent
    public static void onHurt(LivingHurtEvent event) {
```

These event holds certain information, this information can then be interpreted and used to affect the lights. This specific event above, is when something living gets hurt. From the event given you can find out how it got hurt and then this is what is used to cause the different lighting effects. An example is being hurt by a mob (moving entity), which would call a method to make the lights flash red.

## 5.4 Philips Hue Code

Philips Hue has both an SDK (software development kit) and an EDK (entertainment development kit). The EDK streams the request between the lights and the bridge and therefore is much faster at sending out requests and is used for game developments.

The EDK is written in C++ and so must be wrapped up into a Java equivalent. This makes it difficult to use as you no longer have any comments or method descriptions in the Java version. You therefore need to keep referring to the C++ version and finding the coinciding method to check how to use them and what their parameters are.

In the documentation an explanation of how to connect to the bridge is provided along with some examples of effects and animation. These were used to build up our own effects. This documentation is private and can only be accessed if given permission by Philips.

An effect is the overall thing which describes how to map colours to lights, for example an AreaEffect can be used to change colours for all lights in a certain area (areas like 'front' or 'leftHalf'). An animation however, can be used to change properties of certain effects over time. For example, a curve Animation is a list of time-value points (e.g. at 0ms the value is 0, at 1000ms the value is 1 and at 2000ms the value is 0.5). When you assign this curve animation to e.g. the blue colour channel of an effect, this blue channel will be animated according to that curve.

## 5.5 System Interaction

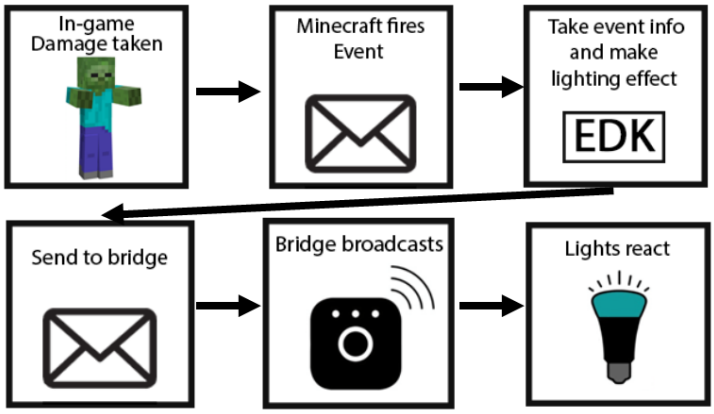



Figure 5.5.1 Flowchart showing how the system interacts

Once an in-game interaction happens Minecraft fires as event. The moment an event is fired, this software starts working. In the code this event is caught and the necessary information is extracted e.g. what caused the damage. Once all this information is taken and manipulated it is then used to create a lighting effect and animation with use the of the EDK. Once the animation is created, it is then sent to the bridge which streams them to the lights. The lights will then react to what has been put into the animation. The software that has been created covers

section 3 and 4 of figure 5.5.1, catching and manipulating an event, creating the lighting animation and sending it to the bridge.

## 5.6 Animations

There were two main animations used in the demo. One was to flash and the second was to flicker. The flash took a range of values such as number of flashes, speed of the flash, position of flash etc. This made it so that it can be reused in multiple places and to create different effects with one animation.

The second animation was a flicker animation. This also took different parameters to change colour, speed and brightness values. The original purpose of this animation was for fire, however by changing certain values it was able to be reused to create different effects. For example, in the water the flicker was slowed down, and this made for a very ambient effect filling the room with an atmospheric blue that only slightly changed.

## 5.7 Effect Importance

The importance of an event was reflected in the lights. For more important events like damage taken, all the lights are light up. For potions drank or when mining ore (less important events), only the light behind the screen is light up. This is because this information isn't as necessary and to continuously have a change in all the lights would become annoying and desensitize users. Things such as fire and water are reflected in all lights. This is because these are the things that will make the most immersion and extend the screen best.

## 5.8 Directional Lighting

For light sources such as fire, it was attempted to make it so that the lights would be directional. This means if the fire is behind the character in game, then it would appear in the back lights of the room. The code for making the angles was a complex one. This was because you had to work out angles based on the positionings of different items and the direction they faced, there was no parameters to just get this. However, calculating the angle worked well. However, it wasn't fully implemented due to restrictions with the Hue EDK, there was no way to pass the animation of the fire between lights smoothly. To pass the animation smoothly between the lights as you turned was found to be too difficult. Every time they got passed to another light it would restart the animation and so resulted in the lights flashing. It was decided that directional lighting would not to be implemented because flashing lights would be distracting to the user.

## 5.9 Smooth Transitioning

A big task tackled in the creation of this software was transitioning between effects. Going from a fire effect to a lava effect was a challenge. These effects had to be prioritised so that when they occur together they didn't interfere with one another. The priority was any flashing animation then water, fire, lava and finally torch. So, if stood next to fire and lava, fire would be

the effect that is shown. The challenge in making this work well was stopping all effects of lower priority to allow for that of a high priority to play.

Another problem with this is if you walked out of the vicinity of one event and straight into another event, for example walking away from fire and going straight into the vicinity of a torch. To suddenly jump from a more dynamic orange light into a smooth white light was too big of a difference to the player and resulted in distracting their attention away from the game. This therefore got smoothed out by keeping all lights on at a dim light and never going fully off, then whenever the animation changed it would return to the dim light before displaying the next animation. Reverting the lights to this dim base and then starting again is not the optimum way as it means there's a bit of a delay. By having the lights never fully off it reduced dramatic light changes that could distract user's attention from the screen.

## 6.0 Illustration of the Lighting Effects

There are two main effects that are used in the code. One is a flicker event and the other is a flash as described above. In figure 6.1 this would be an example of a flicker animation.

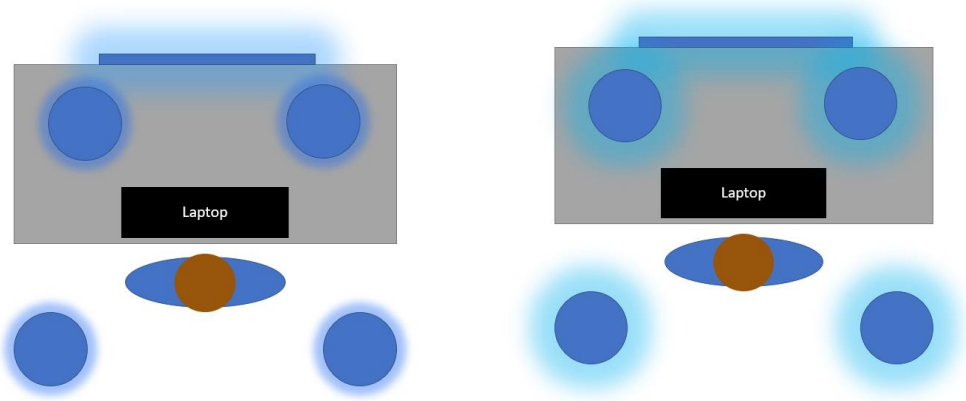



Figure 6.1 Flickering (Water effect)

When a player goes into the water a flicker animation will start with 3 main parameters that define it. One is a colour, the second is the range of brightness and third is time between changes. For the water animation the colour will change every 300-500ms and go between 40% and 70% brightness. The figure shows that all the lights are being used and how they change colour and brightness.

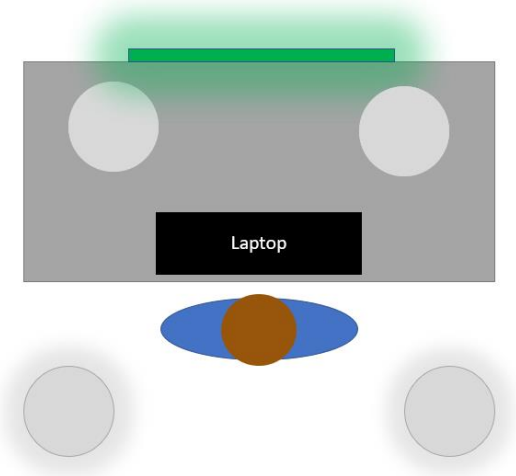



Figure 6.2 Flash (Mining an Ore)

A flash takes 4 parameters. These are the colour of the flash, the number of flashes, length of the flash and which lights. In figure 6.2 this was the scene when the player mined some ore. The colour is the colour of the ore that was mined, as this effect was not considered very important

only the light behind the screen was light up and only for 500ms, so it would just ping. The rest of the lights were all left on a dim white light as they should always be.

# 7.0 Testing

Upon completion of the build it needed to be tested and this was done through user testing. This test was to see if the use of the smart lighting had an impact on the immersion of players. This was done in 2 parts, with two playthroughs of the demo. One with the lights and the other without. Half the participants played with the lights off and then on and vice versa. This is so that the ordering is not an effect on results. The player played in a dimly light room on a 15-inch laptop, using a keyboard and mouse to play. During testing there was as little distractions as possible whilst the test was going on.

The player was given a list of 5 tasks (appendix 3) to complete when playing the game, this is so they had objectives and a purpose and were more involved with the game. The tasks were specifically given so that if followed as much as of the lights were showcased.

After each play through they completed a questionnaire about immersion (appendix 4) and then at the end, a small questionnaire (appendix 5) was given specifically about the lights. The first questionnaire was created from a validated questionnaire for use when studying game experience [17]. This questionnaire has been developed by experts and has been rigorously tested. From this questionnaire questions specific to game immersion were taken. The data then collected from this questionnaire was then used to evaluate if immersion had improved with use of the lights.

The second questionnaire that was given at the end, is used to get more specific answers about how they found the lights. The answers to this along with any notes and observations taken during the test are then used for any code refinements and suggested improvements for utilising the lights better for immersion.

## 7.1 Target Audience

The target audience for this study is preferably gamers who have played Minecraft before. This is because we want to measure the effects of the lights and not the effect of the actual game. So, by using people who have never played Minecraft before will mean we don't know if the results are due to the game or the lights.

For this study if these users can't be found, then those with no experience can be used, however they first need to be given a 15-30-minute tutorial on how to play the game and get used to it. This tutorial will hopefully help make these users focus more on the addition of the lights, as the effect of the game will be reduced after the tutorial.

By having a representative sample, it will ensure that the findings are more accurate and will avoid bias. The number of participants needed for the test depends on how significant the difference is between the two playthroughs. Adding the light looks to make a big change to the environment and so minimum 5 people will be used. This amount will hopefully give enough results to find out whether the lights are having any impact on immersion.

## 7.2 Light Position and Peripheral Vision

The position of lights is important when carrying out this task. The best layout for this user test is shown in figure 7.2.1.

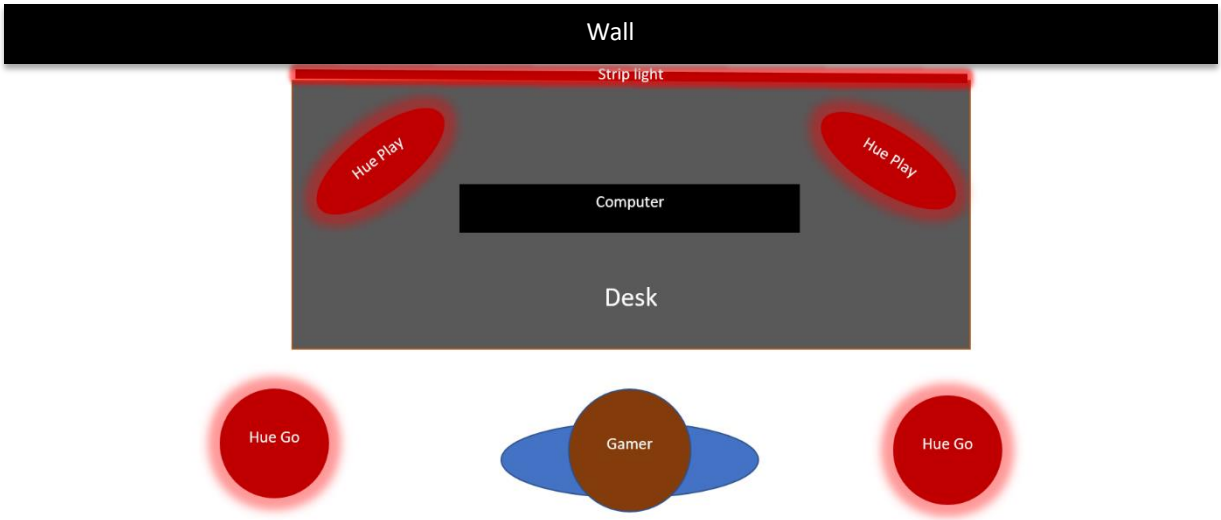



Fig 7.2.1 Setup of Hue lights

This is what is being used in the study, however the exact positions need to be considered and checked for each test. If the lights are turned too much and shining in users' eyes this is going to skew results as this is going to be very distracting, they should never be able to see any bulbs. The lights in-front of the user will be behind the screen and pointing so they shine as much as possible across the walls, they will be about 30cms apart. These lights, however, might be too close together and cause visual crowding. This short distance is due to the small size of the screen of the laptop. However, having them in such a small space will mean than the colours produced by these lights are better perceived. This is because it is estimated that colour perception in the peripheral is highly reduced when beyond 30 degrees from fixation [18]. So, putting them further out from the screen will mean that the front lights effect will be significantly reduced.

The lights behind the user need to be close enough that when they are shining it's noticed but not so close that they distract the player. The eye is made up of cones and rods and in the peripheral, there are more rods which are more sensitive to changes in brightness. The lights need to be put at a far enough angle that the bulbs are not in the peripheral as the changes in brightness in the bulbs will distract users as it will be too concentrated. the lights should be pointed so they shine around the walls behind them.

### 7.3 Starting Position In-Game

To start players from the very beginning in a brand-new game would be a good idea for this user test if the play time was longer. In Minecraft it takes a couple hours to set yourself up to properly explore the game. A specific world within Minecraft needs to be created for users to avoid the lengthy start-up. As the time they play for isn't very long the world needs to be adapted to allow quick progression so that the lighting effects can come into play. This world also needs to be the same for all users.

Setting up this world it needs not to feel fake and as close to a real play through of the game. If the world is too controlled the users are going to not play as usual and this will affect results as they'll be less involved with the game.

### 7.4 Tasks

The users were given tasks (appendix 3) and these were given for the need of giving the user a purpose. Minecraft doesn't have a story as it is an open-world game and so to just tell people to explore will result in people reacting to this differently. Some will not know what this means, especially if they haven't had much experience with the game before. Giving them tasks will help relax them. There were a range of tasks to expose them to a range of lighting effects.

### 7.5 Pilot Study

A pilot study was conducted once all aspects of testing were completed. The person used for the pilot study had previous knowledge of Minecraft and is also a regular gamer.

This study highlighted a couple of problems with the way the test was set up. The first problem that was noticed was positioning of the lights. The lights behind were placed too far back that they said that they barely noticed any change. So, the lights were bought closer to them, when bringing them closer it was made sure that they're not going to cause any glare by having the bulbs shining towards them.

The way results were collected was also questioned. It was initially planned that one questionnaire would be asked at the end of the whole test. However, they bought it to our attention that a questionnaire needed to be asked after each playthrough to gather better data. So, it was changed so that one questionnaire was asked after each playthrough.

# 8.0 Results and Analysis

In user testing the demo, it was focused on investigating whether the lights improved immersion for the user without asking them explicitly. It does this through subjective measures, by using questionnaires. These questionnaires are developed using a standardised, validated Game Experience Questionnaire (GEQ) [17].

From the answers to these questions it is hoped to determine whether they improved immersion or not. If immersion isn't improved much, the reason for this should hopefully be apparent from the data whether it's due to bad testing or the lights being ineffective.

Some of the questions asked are meaningless to this report, however to keep integrity of the GEQ, all questions in the immersion part were asked. Therefore, in discussion of the results some of the results are omitted and not discussed.

## 8.1 Participants

For this user study, 6 users participated. There were 5 people who have played Minecraft before and the sixth user who hadn't played games before. For this last user they were given a 30-minute tutorial on how to play Minecraft and to get use to the controls of the laptop before doing the test. This was in hope to reduce the effect the game will have on them and try to just measure the lights. This user may be the one who can skew results.

## 8.2 Question results

The questionnaire started off by asking about whether the participant found the games story interesting. With use of the lights it was hoped that as they increased immersion for the player, that they would become more interested in the game's story. However, Minecraft didn't have a story mode, it was an open world game, therefore this was not a relevant question for this test.

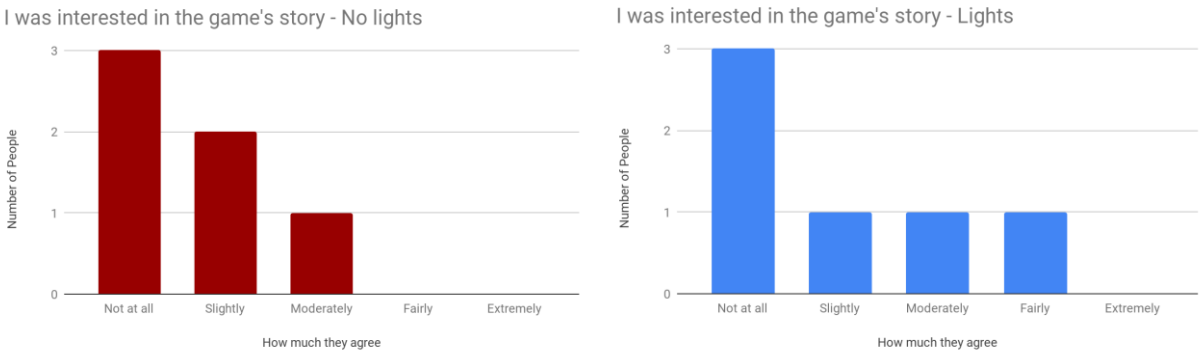



Figure 8.2.1 - Graphs to show how interest in the games story changed

As can be seen from the results there was barely any change between the two different tests. An alternative question that this report can answer is 'can hue lights influence immersion and emotion in open world games, where there may not be a strong immersive storyline?'. Clearly,

from the results this would be a no. However, tests on more different types of games would need to be conducted to validate this.

Question 2 was whether “it was aesthetically pleasing”. This question yielded better results and showed a clear improvement. The biggest changes in answers were from users who had previously played Minecraft. Being that they’ve seen and played the game before, now that the lights have been introduced they find it much more appealing. A game that is more aesthetic, is one that usually evokes more emotional responses and more involvement and therefore is more immersive. The lights improving the game aesthetically is a positive sign towards them improving immersion.

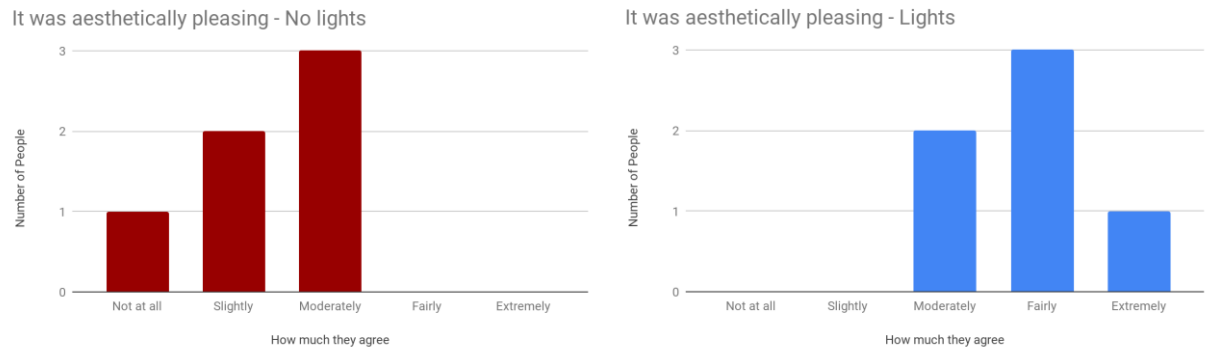



Figure 8.2.2 - Graphs to show how aesthetically pleasing it was

Another question was about how impressive they found the game. This had another significant increase. This is a likely result to see if every user started with no lights and then had the lights introduced in their second playthrough. This is because this user test is affected by the order effect (discussed later). However, due to the mixing of play order, this result shows a better indicates that the lights are making the game more impressive and aesthetically pleasing.

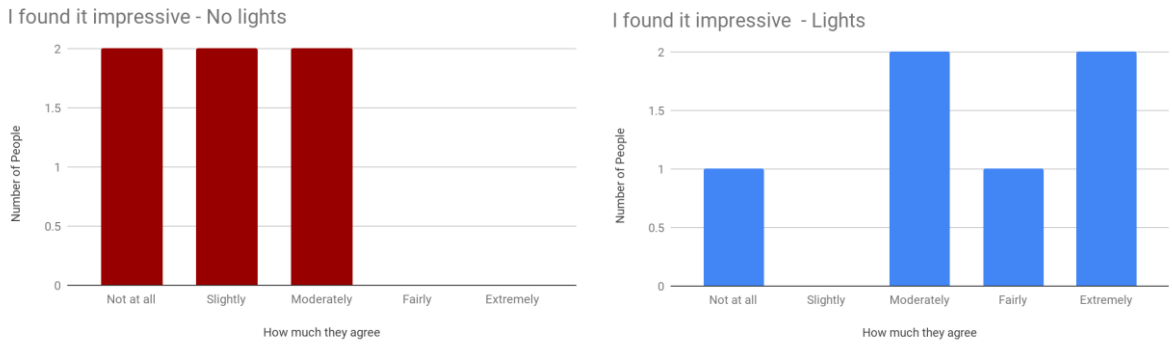



Figure 8.2.3 - Graphs to show how impressive users found it

The following question asked if they found it a rich experience. When playing with no lights half the testers said not at all but with the introduction of the lights none of them said this, almost

all users increased. A richer experience from introducing some hue lighting making the users more engaged and involved with the game.

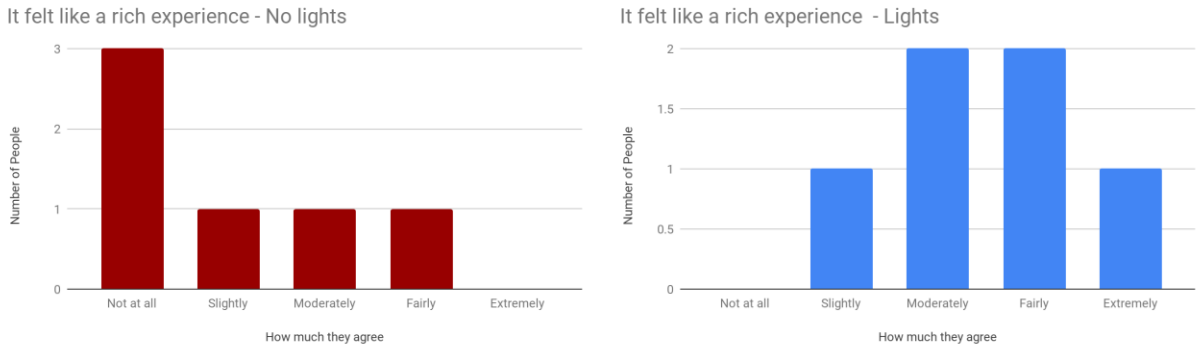



Figure 8.2.4 - Graphs to show if they found it a rich experience, firstly without lights and then with lights

For the question of losing track of time, again there was a slight improvement with the lights. If you lose track of time when playing a game, this is a sign that you are truly immersed. It feels as if you are in the game and are therefore losing track of what is around you. People found that they were focusing more on the game and not noticing the time as much with the lights. This result may have been more significant and showed more accuracy had the play time been longer and the test environment been more comfortable.

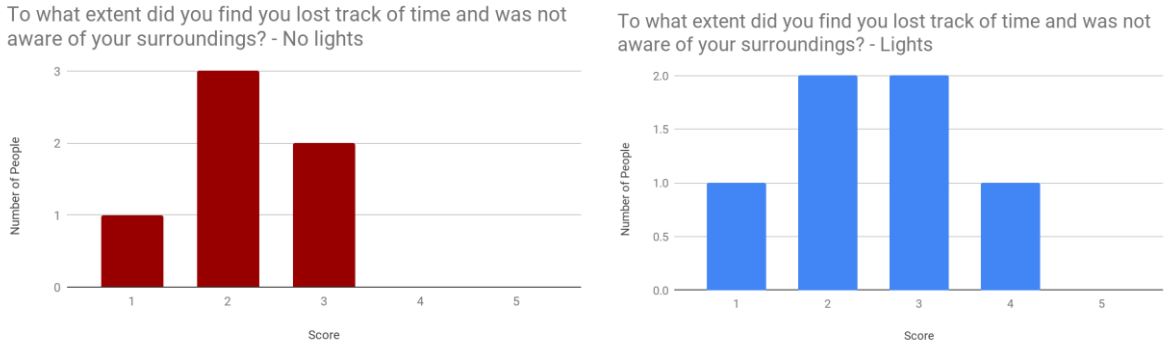



Figure 8.2.5 - Graphs to show if they lost track of time

The question after this yielded similar results. It asked about if they felt they were inside the game. With the lights, people felt slightly more like they were inside the game. This must mean that the lights are having the desired result of making the whole room feel as if it's a part of the game and the user is inside of it.

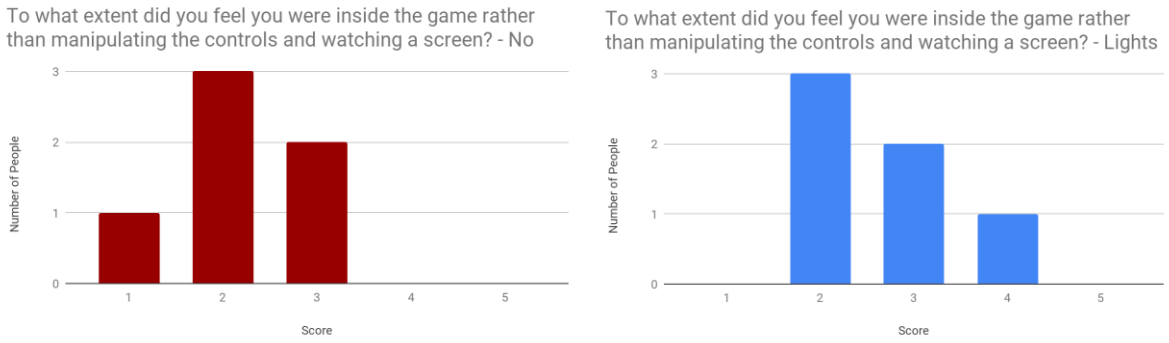



Figure 8.2.6 - Graphs to show if they felt like they were inside the game

The final question was about getting scared by the game. This caused an increase from 2 people to 4. This means the lights are helping in make people feel more immersed in the game. To be able to be scared by the game must mean that the player is getting more engaged and involved. The more engaged you are with something, the easier it is to scare a player with sudden changes.

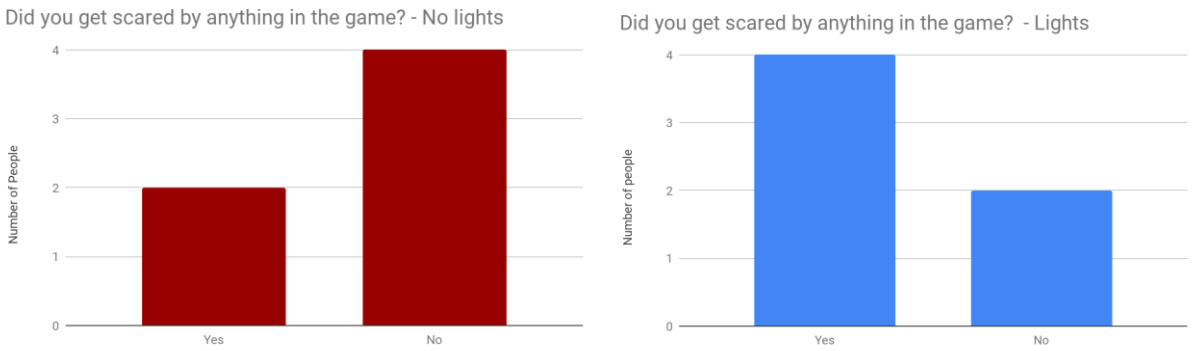



Figure 8.2.7 - Graphs to show if they got scared by the game

## Second Questionnaire About Lights

When the users were asked specifically about immersion the results were evenly scattered (figure 8.2.8). There were not enough users tested to get a clear indication as to how much more immersion the lights added. On top of this immersion can be interpreted by the users in different ways. A definition of immersion should've been given in the question to have clarified this.

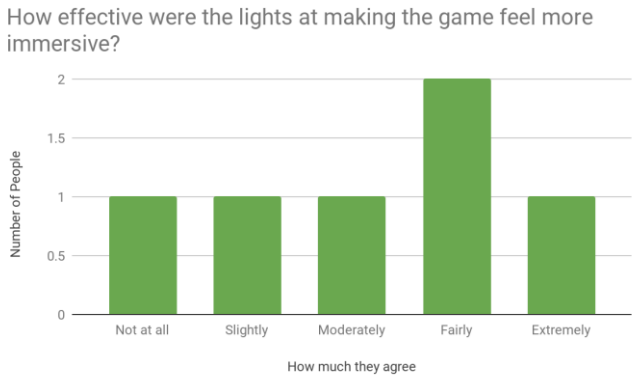



Figure 8.2.8 - Graphs to show if they thought lights affected their immersion

Following this they were asked if they would use them again. All but one user would play games with these lights again. These users must have felt that the lights bettered their gaming experience in one way or another, making them more involved or emotionally reactive.

It can also be seen that in this user test the participants understood what was trying to be achieved with the lights and could see how they can improve the gaming experience making it more immersive. Even though this demo may not have been the most effective, it showed off a basis to what they could be. Therefore, these can be used to redefine the traditional gaming setup and become a new normal for gaming.

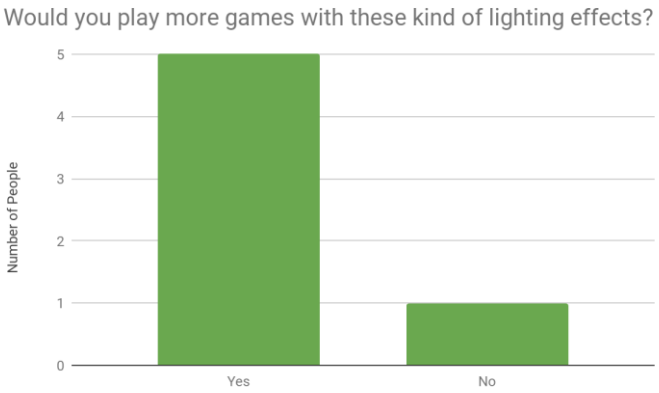



Figure 8.2.8 - Graphs to show if they thought lights affected their immersion

The final questions asked were about which effects they liked and which they didn't. The effects the users liked the most was the nether portal. They also liked the damage and fire effects as shown in figure 8.2.9. However, in general, all lighting effects appealed to at least one user (excluding lightning as none saw this effect).

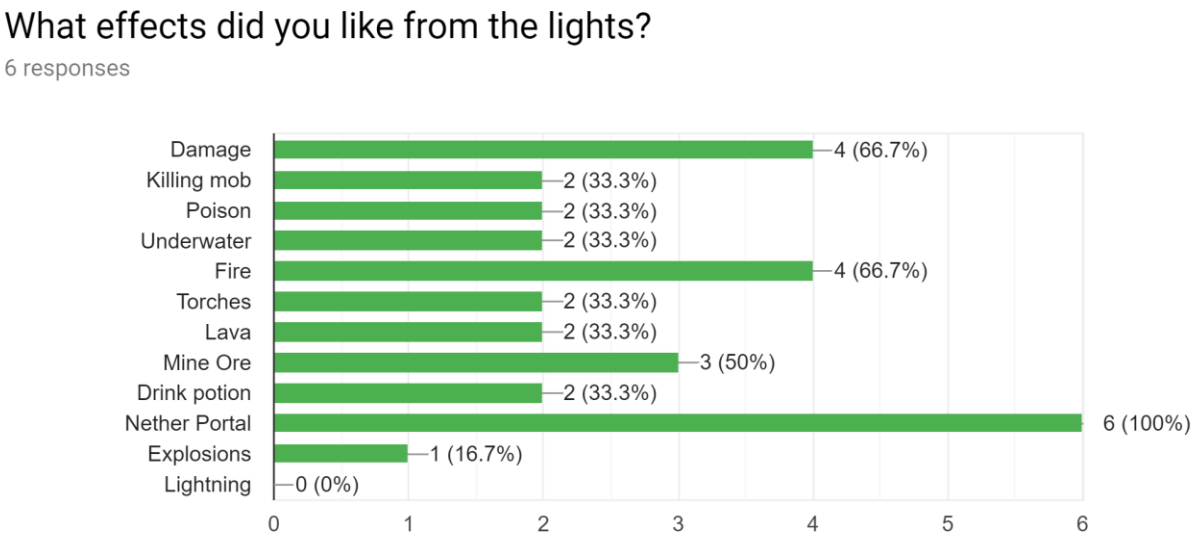



Figure 8.2.9 - Graphs to show which effects users like most

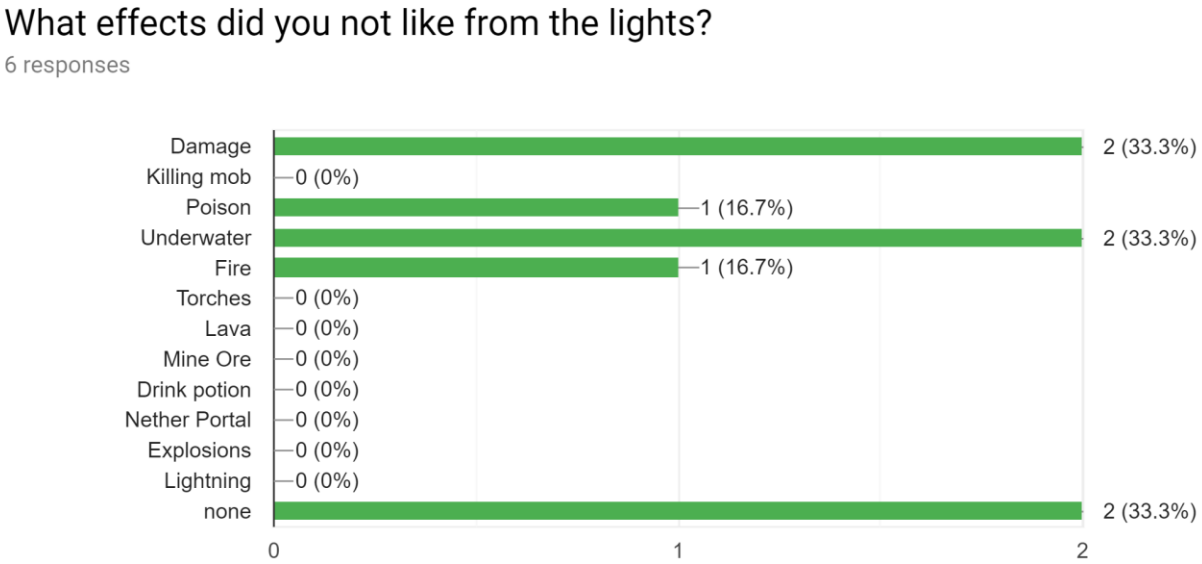



Figure 8.2.10 - Graph to show which effects users didn't like

Alternatively, some users didn't like the underwater effect or the damage. The damage effect was the effect that users experienced most and so is the highest scores for both being liked and disliked.

The reason the users didn't like the damage effect was because of how bright and sudden it was. A problem with the way the test was setup is that the brightness of the room varied depending on the time of day. So, some users played whilst the room was darker than others and so these users may have found that the contrast change was too much. If the user test was done again it needs to be done in a room where there are no windows, so the brightness can be better controlled. In a real-life scenario, users aren't going to be using these lights in a perfectly light room. So, in a real application, the users would have to set the levels of the lights depending on the brightness of the room they're in.

When doing the test, the users didn't see all the lighting effects. Therefore, some effects may not have been voted for as much as others and so it can't be said that some of these lighting effects are bad as they haven't been experienced. Again, a longer user test would have yielded more representative data to discuss.

## 8.3 User's comments

During the test users made comments whilst participating. The most prevalent comment from 3 of the participants was that they didn't notice the difference between the tests until a few minutes in. These users were all ones who played with the lights on in their first play through. They all commented part way through their second, saying that they had only just noticed they'd been turned off. This is positive feedback to have as it means that the users are noticing when the lights are added more than when taken away. It is also showing that the lights are not too dynamic that they're distracting users, as when they're taken away it is going slightly unnoticed.

Two of these three users then made comments at the end of the test saying that the lights need to be more noticeable. But, on inspection of their results all three of them either stayed the same or had better results with the lights. From this it could be assumed that the lights had more of an effect on their subconscious than they realised.

A couple of users commented on the environment they tested in. Comments were made that it was a little uncomfortable and that it felt very much like a test. If this user study was done again ways of making the user more at ease need to be explored.

The difficulty of the tasks was also something commented on. A few users found them easy and completed them quickly and then asked what else to do, others found them harder and didn't finish them in time. If redoing this user test, next time a mission or general task should be given and not individual, small tasks. A task that allows for different difficulties.

## 8.4 Order of Test Effect on Results

The order effect was likely to affect this user study. This is when a user's results are influenced by the ordering of the test. This is caused by many different reasons. In this study by the time they get to the second test they may find it repetitive and uninteresting, especially as they must

do the same set of tasks twice. As well as this, by having the tests so close together without a big enough break, these effects will be heightened.

Switching the order of play (counterbalancing) was used to stop the order effect affecting the results as badly. If the test was done in the same order for each user, it could've been falsely concluded that the first test could be artificially affecting the second one. The users could have become bored and tired (fatigue effect) or may know how to complete the tasks quicker and so not engage with the game as much. Through switching the order, the order effect will affect users individually, but they balance each other out in the results [21].

More precautions could've been taken to further reduce this. One way is to make the tasks more interesting, so the user gets more involved, giving them a mission instead of small individual tasks may have been a better option. Repeating the tasks for both studies was a bad idea. Also, adding a bigger break may have allowed them to reset before repeating it and therefore not find it as repetitive.

## 8.5 Test Conditions Effect on Results

The conditions in which the users were tested were not optimal and could've been improved. Controlling the lighting in the room was difficult due to the big windows, especially as the test were held at different times of the day. Big curtains were used which limited the amount of light, but the lighting for each test was slightly differing which could've had some effects on results, as stated earlier.

Using a laptop and keyboard also wasn't the best setup. Had Minecraft allowed controllers to be connected, the testing environment could have been made more comfortable by using a TV and sofa, this would have made it feel less like a test and allowed them to get more involved with the game. But without being able to connect a controller this restricted this from happening.

A room that was completely empty may have allow for the lights to be better illuminated around the room. Having other furniture around stopped the lights from fully shining all around the room reducing their effects. This may have also have had effects on causing different coloured lights mixing and producing unwanted colours and emotional responses.

## 8.6 Improvements of User Study

There were a few improvements that could've been made to the user study to get better results. Firstly, remedying all the problems with the test conditions, discussed above, would vastly improve the validity and accuracy of the results.

To better test the lights for their effect on immersion, the use of a game that itself was more immersive should've been used, especially a game that has a story mode. Using an immersive story mode, we could've better recorded how the lights affected the user. It would've also

given more opportunity to produce better lighting effects and invoke more emotion along with the game.

Another way to better test their effects would be to use longer user studies. Giving them a mission where they must be more exploratory and look around would have meant they got more involved with the game. Testing the lights in such a short amount of time, with 5 basic tasks was not an optimal way.

Using a bigger user group would have been beneficial, with more data it would've allowed for a more in-depth discussion and allowed for better analysis. It would have helped reveal trends in the data and averages that could've been compared. It would have also made any outliers more noticeable if there were any. Using 6 users to find out about any problems, bugs or improvements was fine, however when it comes to analysis of the results this numbers is too small to evaluate anything too meaningful.

The questions asked in the questionnaire, may not have been the best to ask. Even though they came from a validated place [17], some of the questions didn't make sense to the users. Selecting the immersion specific questions from the GEQ didn't work well and made a few of the participants confused. To keep integrity the full questionnaire should've been used, and then relevant questions should've been compared. This is how it was done in another project that made use of the GEQ and hue lights [3]. They were investigating performance and to get the data they needed they used the whole questionnaire and looked at the relevant parts.

Another improvement that needed to be made is the data that was collected. The way immersion was measured in this project was with subjective measures, through questionnaires after each test. The benefit of using this type of measure was that they were easy to administer, grade and interpret. However, these measures are influenced over time by fatigue and boredom. Also, they are used post-immersion - they do not measure any data when the user is immersed. This is necessary data that is needed to back up the subjective measure's results. This kind of data was completely missed in this project, due to lack of time and not recognising the value it could have had. A potentially better way to measure immersion is through physiological measures. This being the measuring of heart rates, changes in skin conductance and changes in temperature [22]. This would've been some valuable data that could've been collected from users whilst playing, to help backup the claims from the questionnaire.

# 9.0 Software Refinements

When creating this software, there were a few things that were planned to be implemented but weren't due to time and skill restrictions. These are going to be discussed below. As well as this the refinements that should be made based on the feedback from the user test will be discussed too.

## 9.1 Extensions of the Software

The first effect that was removed but attempted to be added was directional lighting. This meant the lights would shine depending on where a light source was coming from. This had to be dropped as the only way it could be found to work was with flashing lights that were too harsh to be use.

Effects that better imitated the object they were copying need to be used too. For example, the fire effect could've been more realistic, by making it a bit more dynamic and random. This was not achieved due to limited knowledge on the use of the Hue EDK. Had more time been permitted, a better knowledge could've been developed and therefore better effects produced.

One secondary object that was spoken about prior, was making a module that would take the screen and predict where light sources were coming from and reflect this in the lights. This was not made as it was later discovering in development that you could access this information in game. There was no need for a model that predicts them. However, as mentioned above there was an attempt at making directional lights based on light sources, but this effect didn't work very well and so in future would need to be improved.

The use of biometrics was also considered, to help intensify some of the emotions. This was going to be done through use of a heart rate monitor. As the heart increased the lights would increase saturation or flickering for example. However again Minecraft isn't a game that is going to give a good representation of how this could work. Due to the lack of a story mode there are not many situations where there are noticeable changes in heart rate. So, to have implemented this wouldn't have added enough value for the time it would've taken. However, using biometrics to gain data would've been beneficial to the analysis of this report as discussed above.

## 9.2 Refinements Based on Feedback

As stated above, the effects users didn't like the most were the underwater effect and the damage effect, and this was because they were too bright. The users who didn't like these events played in a room that was darker than the rest of the users and so the change in brightness was too much. To fix this an option to adjust the lights to the brightness of the room should be provided.

All users liked the nether portal effect, and this is the one every user noticed. This was the most dynamic of them all. Therefore, some of the effects could benefit from being more than just a

flash. For example, poison, currently it just flashes, using an effect like the nether portal - that makes the user feel a little disoriented would be better. When doing this though it needs to be done with caution, so the user's attention is not distracted away from the screen. The nether portal effect is used when the played is inactive and this is why it can be very dynamic. If this was used when the user is moving about it could have adverse effects.

Another suggestion made was changing the base lighting of the room depending on time of day in the game. This will give more suspense when it becomes night in the game and will put the player on guard, this could also dramatize the lights even more.

## 10.0 Conclusion

The need for an update in the traditional gaming setup is apparent, especially as the gaming industry is estimated to grow by around $40 million over the next couple of years. The idea of using Philips Hue lights to make game design more immersive was thought up. Throughout this report the way this can be done has been discussed. The best way thought to do this was established and a demo using this was created. This was done with Minecraft.

After research and discussion, it was thought that the most optimal way for this demo to be created was to make lighting effects like that of sound. A lot of theories and techniques of Michel Chion were discussed and used. Through the theory of these techniques being applied to hue lighting, a promising demo of the way the lights could be used was produced.

This demo was then subject to user testing in hope to establish whether hue lights influence the immersion of the player. Six users tested the system and filled out questionnaires on their experience with it. The results were then discussed and used to draw upon what improvements needed to be made.

As discussed above, there were a few changes that needed to be made both to the test and to the demo. These included using a different, more immersive game, changing the brightness of some effects and making the effects more realistic. However, with the time and skill levels these were not achieved.

Although, even with these changes, what was produced went beyond the primary objectives stated at the beginning of this report. On initial planning of the project, only basic interactions were planned to have been made, as the look of both Minecraft and the Hue EDK looked complex. However, once a good knowledge of the Minecraft code was achieved a lot of more detailed interactions were able to be created, resulting in a much more interactive demo.

There were also secondary objectives, these included making a model that detected light sources and the use of biometrics. None of these were implemented as early in the designing of the system, it was thought that these would not be very efficient in making the lights more immersive. Making better in-game interactions was thought to be a better approach. As well as this, Minecraft was not the right type of game for these features to have worked well on.

If this project was redone with the knowledge that is known now there are a few things that would be changed. The user testing setup and questionnaire would be done in a much more efficient and effective way. Using better questionnaires, better data collection techniques, a better testing environment and more participants, are a few of the main ways to improve. Some of the animations in the code could've been made better and more realistic, focusing on improving some of these, rather than adding in such a range would have been more valuable.

A more thorough understanding of the Hue EDK would've been a big benefit too. Producing the lighting effects was difficult and were not produced to the best standard. Spending more time on learning and understanding it would have resulted in better and more realistic animations.

In conclusion, from observation, comments and results of the questionnaire, it would be hard to deny that the lights didn't improve the user's experience with the game. However, it is harder, from the data collected, to conclusively say that it improved the immersion of the game. Results indicate that it has done so, with every user finding it more aesthetically pleasing with the lights and feeling that the lights enriched their experience.

However, as questionnaires are a subjective measure they're vulnerable to producing unstable and inconsistent responses. What was needed in this research was the backing of different types of data such as physiological measures. Had this been done too and produced positive results in favour of the claim, then we could be more conclusive in our claim. However, until then it can only be said that the external lighting has potential in providing a more immersive experience and future research is needed to fully determine this.

## 11.0 References


[1] Chion, M. 1994. Audio-vision: Sound on Screen. Translated by Claudia Gorbman and Walter Murch. New York: Columbia University Press

[2] Mojang 2009-2018, Minecraft, video game, PC, Mojang, Sweden.

[3] Dahlström, E. (2017). Improving First-Person Shooter Player Performance with External Lighting. Masters. KTH ROYAL INSTITUTE OF TECHNOLOGY. [Accessed 05 Oct. 2018].

[4] fliflialbumreviews, V. (2015). Different of Sound within Film.. [online] Fli's Music Blog. Available at: https://flismusicblog.wordpress.com/2015/01/07/different-types-of-sound-within-film/ [Accessed 20 Oct. 2018].

[5] Piotrowski, C.; Armstrong, T. (2012). "Color Red: Implications for applied psychology and marketing research". Psychology and Education: an Interdisciplinary Journal. 49 (1–2):55–57.

[6] Philips (2018). Synchronise your Lights with Games. [image] Available at: https://www2.meethue.com/en-gb/entertainment/gaming [Accessed 20 Oct. 2018].

[7] MICROSOFT, [no date], Minecraft Background Image [online]. [image]. [Accessed 26 October 2018]. Available from: https://www.microsoft.com/en-lb/p/minecraft-master-collection/9pmtbb8xs937?activetab=pivot:overviewtab

[8] Ukie.org.uk. (2018). The games industry in numbers | Ukie. [online] Available at: https://ukie.org.uk/research [Accessed 21 Oct. 2018].

[9] Naoki Kimura and Jun Rekimoto. 2018. ExtVision: Augmentation of Visual Experiences with Generation of Context Images for a Peripheral Vision Using Deep Neural Network. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18). ACM, New York, NY, USA, Paper 427, 10 pages. DOI: https://doi.org/10.1145/3173574.3174001

[10] Alvin Raj and Ruth Rosenholtz. 2010. What your design looks like to peripheral vision. In Proceedings of the 7th Symposium on Applied Perception in Graphics and Visualization (APGV '10). ACM, New York, NY, USA, 89-92. DOI: https://doi.org/10.1145/1836248.1836264

[11] MADIGAN PH.D., JAMIE, 2012, The Psychology of Video Game Immersion. Psychology Today [online]. 2012. [Accessed 2 November 2018]. Available from: https://www.psychologytoday.com/us/blog/mind-games/201207/the-psychology-video-game-immersion

[12] BROWN, EMILY and CAIRNS, PAUL, [no date], A Grounded Investigation of Game Immersion. Www-users.cs.york.ac.uk [online]. [Accessed 2 November 2018]. Available from: https://www-users.cs.york.ac.uk/~pcairns/pubs/Immersion.pdf

[13] How lighting impacts your mood and space, 2016. https://www.property24.com/[online],

[14] STAFFORD, PATRICK, 2017, What will the game industry look like in five years?. Polygon [online]. 2017. [Accessed 4 November 2018]. Available from: https://www.polygon.com/features/2017/11/14/16533054/the-game-industry-five-years-2022

[15] (1.10.2) Minecraft Forge Modding Tutorial #6 - Events, 2019. YouTube [online] [Accessed 11 February 2019], Available from: https://www.youtube.com/watch?v=10IoypxjZLA

[16] Thayers Arousal-Valence Emotion Plane - [Accessed 11 February 2019] Available from: https://www.researchgate.net/figure/Thayers-arousal-valence-emotion-plane_fig1_226269425

[17] IJsselsteijn, W. A., de Kort, Y. A. W., & Poels, K. (2013). The Game Experience Questionnaire. Eindhoven: Technische Universiteit Eindhoven. [Accessed 14 February 2019] Available at: https://pure.tue.nl/ws/files/21666907/Game_Experience_Questionnaire_English.pdf

[18] Am J Optom Physiol Opt. (1986). Color Vision in the Peripheral Retina. [Accessed 14 February 2019] Available at: https://www.ncbi.nlm.nih.gov/pubmed/3953765

[19] "The Psychological Impact Of Light And Color - TCP Lighting". 2019. TCP Lighting. [Accessed 16 February 2019] Available at: https://www.tcpi.com/psychological-impact-light-color/.

[20] Küller R, et al. 2019. "The Impact Of Light And Colour On Psychological Mood: A Cross-Cultural Study Of Indoor Work Environments. - Pubmed - NCBI". Ncbi.Nlm.Nih.Gov. [Accessed 16 February 2019] Available at: https://www.ncbi.nlm.nih.gov/pubmed/17050390.

[21] Shaughnessy, J. J., Zechmeister, E. B., & Zechmeister, J. S. (2006). Research methods in psychology. New York: McGraw-Hill. [Accessed 20 February 2019]

[22] Insko, B. E. (2003). Measuring presence: Subjective, behavioral and physiological methods. In G. Riva, F. Davide, & W. A. IJsselsteijn (Eds.), Being There: Concepts, effects and measurement of user presence in synthetic environments (pp. 109–120). Ios Press. [Accessed 10 March 2019]

# 12.0 Appendix

## Appendix 1 - Interim Log

**24/09/18 -** This was my first meeting with my supervisor. Here we discussed general information about the project and my skills and what I want to achieve by the end. We discussed the types of games I can use and the resources that I'll need. We also discussed about making sure I make my project quite open so that I can make extensions or contractions if they are needed.

I was also supplied with a few research papers that I could read to help me think up some ideas of what direction I wanted to take my project.

I was also put into contact with someone in Philips as an industrial contact and was told to arrange a skype meeting with them to discuss some of my ideas and to help me think of some new ones.

**03/10/18 -** This was my first skype meeting with my industry contact. We discussed the ideas that I have, and he told how I could implement these and then game me some other ideas to think about. We also discussed the games that I can do. My originals that I thought of he said wouldn't be the best. This was due to them being first person shooter games and as the focus of my project was immersion, he suggested to do open world games.

He also spoke a lot about having to screen grab if I don't have access to the code, so he suggested something open source if I wanted to do more. But, said it would still be possible and I could still do a lot.

He was keen on me doing something to do with biometrics. This was something I was interested in, however after discussion we concluded that with my experience and time period that this would be too ambitious.

**09/10/18 -** My second meeting with my supervisor was to discuss what I had spoken about with the industry placement. I explained some of the ideas I had come up with after discussing with him and he agreed with everything and told me to start investigating more. He sent me another couple papers and suggested some new ideas.

We also discussed ordering the Philips lights and agreed that I could order them after the meeting so that I can get them setup and start experimenting with them.

After this meeting I was able to finish my proposal as I had some more concrete ideas in my head with how I was going to execute this project and the direction I wanted to take it in. It also helped define the areas I should really start some in-depth research and meant that I could start collecting resources to put into my interim report.

**23/10/18 -** This meeting was to talk about ethics in my project. As I will have people testing my software, I will need to gain approval through the university and to write about this in my interim report. During the meeting we talked about how I will need to discuss code of conducts and look

at any legislation that could affect my project. In the chat we had neither of us could think of any legislation that needed to be considered and the only user group we had to make considerations for was epileptics as we are using lights.

## Appendix 2 - Proposal

Candidate No: 149111

Dr. Sriram Subramanian

# Hue Lighting for Game Design Proposal

The aim of this project will be to make use of Phillips Hue Lighting for game design. The use of audio (music and sound effects) in video games plays a significant role; it is used to make a more immersive experience for the player. In this project I want to make use of hue lighting to create similar effects to sound, ultimately making use of hue lighting to add more immersion and tell a greater story. Lighting is one of the most essential elements in creating an atmosphere and only making use of the monitor means a lot of opportunity is forgone. Bringing light into the whole environment will add more life to a game, make better composition, as well as aid the gamer.

The game I propose for doing this project is going to be Minecraft. This is because it is an open world game in which players explore the world. Games that players explore I suspect are going to be the games that lights can add the most immersion to. Using a fast action game such as Overwatch would not be of any benefit from hue lighting as they will not take notice of the effects due to their fast pace nature.

For Minecraft it has a lot of elements where the lighting can be used effectively. Things such as changing weather, fire, explosions etc. are all used in the game and this type of in-game environment can effectively be amplified with the lighting.

A game I was highly considering was Destiny 2, however this game isn't open source. Minecraft is an open source game and so this will allow me access to a lot more information and therefore allow for better use of the lighting. If Destiny 2 was chosen it would mean I would have to use a lot of screen grabbing and computer vision techniques to reflect the screen with the lights. Having access to in-game data should allow me to make more intelligent lighting effects.

In this project I want to make a few good examples of how the lights can be used in such an open world environment, whilst also drawing on other ideas that could be implemented in all game design. With the time scale I don't think I will be able to implement all my ideas to make the most immersive game; however, I believe that I can draw on some fundamentals and give examples of these. Also, giving some other suggestions of what else could have been done, had I been given more time and resources.

To start with this, I will start with making effects for things such as when stood close to fire and lava, when explosions occur close by and being attacked or approached by enemies. These elements I think will be a good representation of how lighting can be used and the effects that could be made with the lighting.

Extensions upon this are making specific lighting patterns for more specific cases. When entering specific environments like the nether (an underground world) it is very dark, and gloomy and a specific light sequence could make for a more intense situation. Here is where more colour theory and theory behind colour in the peripheral vison will be used to make the most immersive and atmospheric effects.

The introduction of machine learning, or physics could also be another extra I could add. After reading a research paper about 'Augmentation of Visual Experiences with Generation of Context Images for Peripheral Vision Using Deep Neural Network' it opened the opportunity for me to create my own version of this using the hue lights. What this algorithm does it predict where the light sources are coming from in the images supplied. This could a very useful and effective algorithm that I can then use to reflect in the lights.

Making use of the music and sounds in the environment will also be another extension I could make. So, when the music is becoming more intense in a fight scene then make the lights coordinate with this music.

Another big extension would be to make use of some biometrics e.g. heart rate monitors and brain wave scanners. Using these to intensify lights or make different pattern based on a player's state would be of interest and would also mean I would collect data that isn't subjective to the player. With current techniques I will be getting subjective feedback from users, to get biometric results could be of more use.

| Primary Objectives |
| --- |
| When stood near fire I want the hue lights to come on. This can easily be measured but will go in stages. If it just comes on when near fire then I have done the task, but I want to make them flicker like real fire and make the direction so only lights come on of where the fire is coming from. |
| Changes in weather can also be shown. E.g. when lighting strikes the hue lights could flash. For this I need to find information in the code of when lighting is about to strike and then make the lights flash in time or to assess what is on screen and mimic the flash on screen. |
| When approached by a monster and they are in a certain vicinity then the lights could turn orange to indicate danger and intensify as they get closer. |

| Extension Objectives |
| --- |

| |
|---|
| The use of machine learning to make lights light up based on the predicted area of the light sauce. This will be measured by lighting up lights based on where it thinks the light sources are coming from. The implementation of this is done using deep neural network. I will first need to produce context-images and then I need to represent these images with the lights. |
| Use of sound to affect the effects of the light e.g. when music is more intense then make them flash faster etc. For this I'll need to sample the sound coming from the game and then based on pitch and frequency make different effects happen. |
| Using biometrics such as heartbeat monitors so that the lights will become more intense when their heart beat raises. For this I need to first link up a biometric device to my software and then take that information and transfer it so to the lights. |
| Specific psychological lighting patterns for scenarios such as when entering different environments etc. Here I will need to research into the psychology of colours and lighting patterns, I then need to assess if the lights can do these things and then code up these patterns. |

This project will make use of a lot of skills and knowledge that I have used throughout my degree.

My first biggest take away from my course is my placement year. All the skills I have learnt throughout that year are applicable to this project. Things such as working in an agile way, interacting with code and performing research to solve problems. The software Engineering module is going to be put to use in my management of this project and use of things such as GANTT charts and other diagrams that could come in useful. Data structures and other programming modules is all going to help in designing and building the project. I will be interacting and making use of API's and other people's code, which has been taught throughout different modules. The professional skills module will aid in my report writing and using the proper techniques to document and write my dissertation.

The resources required for this project will be the Phillips hue lights and hubs. There is potential for games to be bought, Minecraft is a free if played single player and so doesn't need to be paid for. When testing this out there may be needing to buy a gamepad to make it so that users are easily able to play the game. A lot of people don't know how to play using a keyboard and mouse and so this may be necessary. Any learning material such as other professional papers and books. One current book that looks like it will be of big help is Michel Chion - *Audio-Vision: Sound on Screen.* This is a book that draws on the big factors that sound and the screen work together; it will have ideas that I could manipulate into working when adding ambient lighting. If there are any extensions, then these couple possibly require more hardware depending on what the extension is.

| | Monday 1 Oct | Tuesday 2 Oct | Wednesday 3 Oct | Thursday 4 Oct | Friday 5 Oct |
|---|---|---|---|---|---|
| 08:00 | | | | | |
| 08:30 | | | | | |
| 09:00 | | | | | |
| 09:30 | | | | | |
| 10:00 | | | | | *Comparative Programming* (Laboratory 1) Chichester 1 CHI 017/018 |
| 10:30 | | | | | |
| 11:00 | | | | | *Introduction to Computer Security* (Lecture 1) Fulton Building FULTON B |
| 11:30 | | | | | |
| 12:00 | | | | | |
| 12:30 | | | | | |
| 13:00 | | *Human-Computer Interaction* (Lecture 1) Chichester 1 CHICH 1-LT | | | *Human-Computer Interaction* (Seminar 4) Chichester 1 CI027 |
| 13:30 | | | | | |
| 14:00 | *Introduction to Computer Security* (Laboratory 2) Chichester 1 CHI 014/015 | | | | *Comparative Programming* (Lecture 1) Silverstone SB 121 |
| 14:30 | | | | | |
| 15:00 | | | | | |
| 15:30 | | | | | |
| 16:00 | | *Introduction to Computer Security* (Lecture 1) Fulton Building FULTON B | | | |
| 16:30 | | | | | |
| 17:00 | | *Computer Science Project* (Class 1) Shawcross AS02 | | | |
| 17:30 | | | | | |
| 18:00 | | | | | |
| 18:30 | | | | | |
| 19:00 | | | | | |
| 19:30 | | | | | |
| 20:00 | | | | | |
| 20:30 | | | | | |
| 21:00 | | | | | |
| 21:30 | | | | | |

Fig.1 Timetable

Wednesday and Thursday will be days that I will dedicate to doing most of my project work. As well as this I will be adding another 8 hours over the weekend.

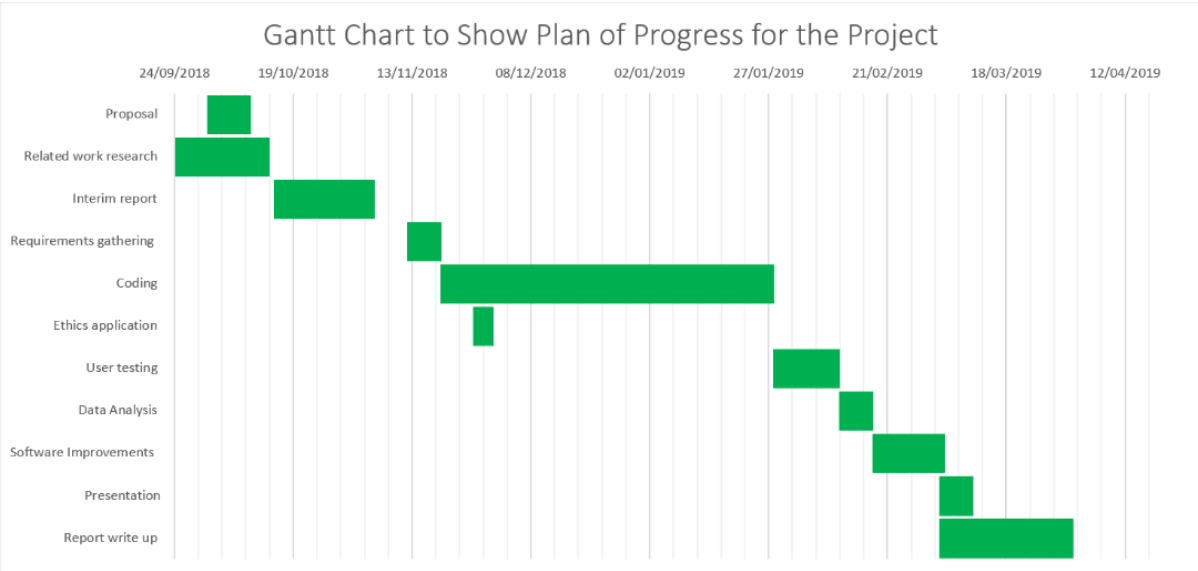



Fig. 2 Gantt Chart

Fig. 2 shows my planned periods of time that I wish to spend on each project. This includes a 2 week break for the Christmas break during my coding stage. With what I have currently scheduled for each task it looks to be enough time for each stage. However, I have left time at the end. This is because there will obviously be unaccounted for tasks and problems that will occur throughout the project and so when I need to spend more time on a task I will still finish before the deadline.

# Minecraft User Testing Tasks

1. Put on a full suit of armour (found in the chest in the house), and using any items to help, kill three different types of mobs (enemies).

2. Using the pickaxe found in the house, go down into the caves and mine 5 different kinds of ore.

3. Enter the nether portal and teleport to another dimension then kill a mob.

4. Go into the water and kill a squid and collect their ink sack.

5. Go to the village across the lake to find a carrot and eat it.

If anything is unclear or you don't know how to do something, please ask and it will be explained further.

## Appendix 4 - Questionnaire for Game Immersion

# Game Immersion

This questionnaire is to be filled in after your run through of Minecraft.

* Required

1. **What is your name?** *

_____

2. **I was interested in the game's story** *
*Mark only one oval.*

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Fairly
- ◯ Extremely

3. **It was aesthetically pleasing** *
*Mark only one oval.*

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Fairly
- ◯ Extremely

4. **I felt imaginative** *
*Mark only one oval.*

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Fairly
- ◯ Extremely

5. **I felt that I could explore things** *
*Mark only one oval.*

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Fairly
- ◯ Extremely

6. **I found it impressive** *
*Mark only one oval.*

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Fairly
- ◯ Extremely

7. **It felt like a rich experience** *
*Mark only one oval.*

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Fairly
- ◯ Extremely

## Section 2

8. **To what extent did you find you lost track of time and was not aware of your surroundings?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Not at all | ◯ | ◯ | ◯ | ◯ | ◯ | Extremely |

9. **To what extent did you feel you were inside the game rather than manipulating a game pad/keyboard and watching a screen?** *
*Mark only one oval.*

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Not at all | ◯ | ◯ | ◯ | ◯ | ◯ | Extremely |

10. **Did you get scared by anything in the game?** *
*Mark only one oval.*

- ◯ Yes
- ◯ No

## Appendix 5 - Questionnaire for Lighting Effects

### Game Immersion

* Required

1. **What is your name?**

_____

2. **How effective were the lights at making the game feel more immersive?** *

*Mark only one oval.*

- ◯ Not at all
- ◯ Slightly
- ◯ Moderately
- ◯ Fairly
- ◯ Extremely

3. **Would you play more games with these kind of lighting effects?** *

*Mark only one oval.*

- ◯ Yes
- ◯ No

4. **What effects did you like from the lights?** *

*Check all that apply.*

- ☐ Damage
- ☐ Killing mob
- ☐ Poison
- ☐ Underwater
- ☐ Fire
- ☐ Torches
- ☐ Lava
- ☐ Mine Ore
- ☐ Drink potion
- ☐ Nether Portal
- ☐ Explosions
- ☐ Lightning
- ☐ Other: _____

5. **What effects did you not like from the lights?** *
*Check all that apply.*

- [ ] Damage
- [ ] Killing mob
- [ ] Poison
- [ ] Underwater
- [ ] Fire
- [ ] Torches
- [ ] Lava
- [ ] Mine Ore
- [ ] Drink potion
- [ ] Nether Portal
- [ ] Explosions
- [ ] Lightning
- [ ] Other: _____

6. **Any other comments?**

_____

_____

_____

_____

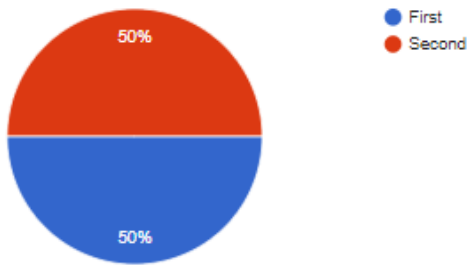
_____

Powered by
Google Forms

## Appendix 6 - Results for Questionnaire for Game Immersion - No Lights

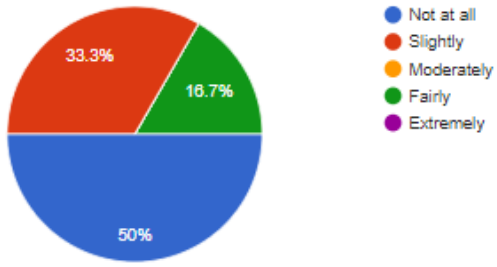
### Which run through is this?

6 responses



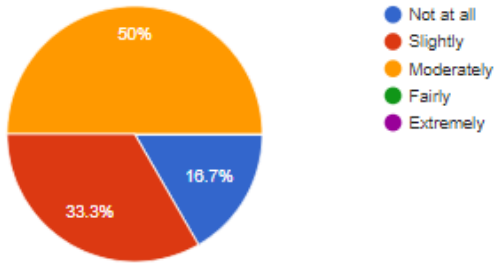

### I was interested in the game's story

6 responses



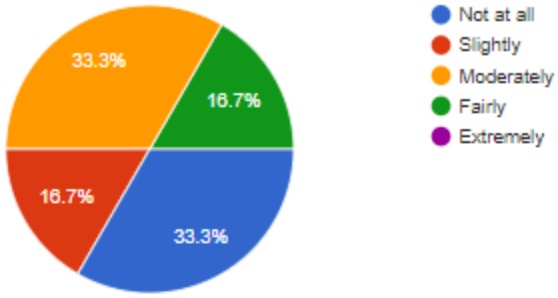

### It was aesthetically pleasing

6 responses



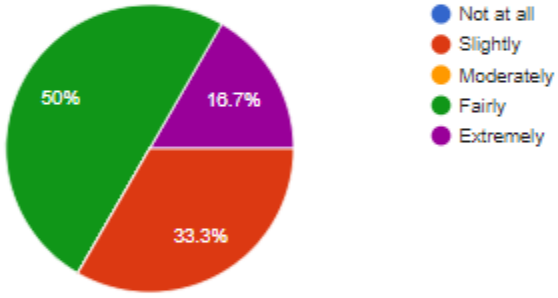
## I felt imaginative

6 responses



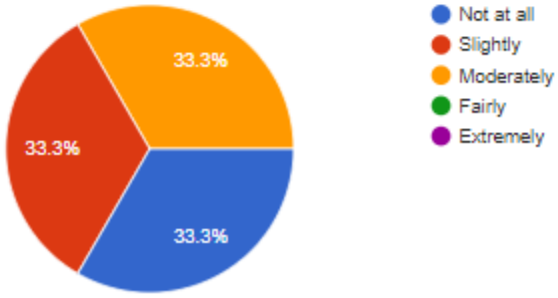

## I felt that I could explore things

6 responses



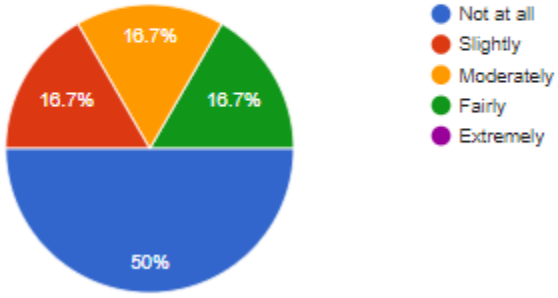

## I found it impressive

6 responses



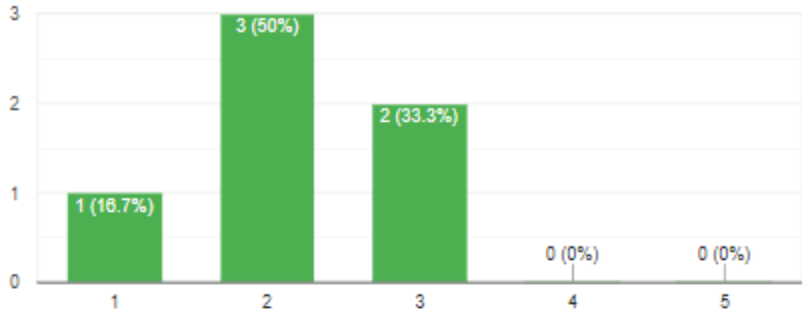
## It felt like a rich experience

6 responses



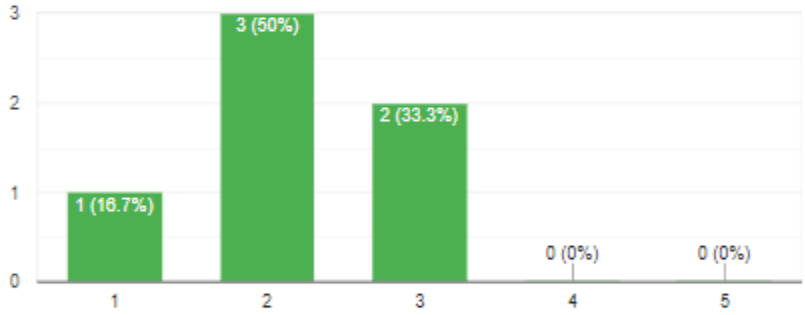
To what extent did you find you lost track of time and was not aware of your surroundings?

6 responses



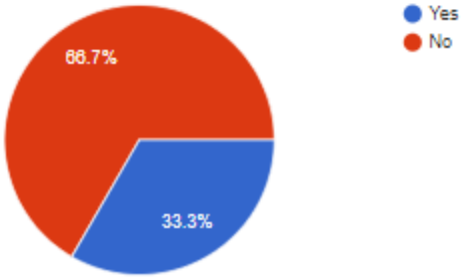

To what extent did you feel you were inside the game rather than manipulating the controls and watching a screen?

6 responses




Did you get scared by anything in the game?

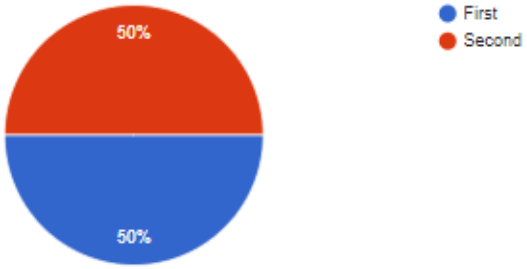
6 responses



## Appendix 7 - Results for Questionnaire for Game Immersion - With Lights

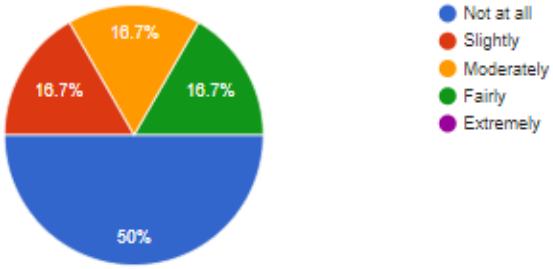
### Which run through is this?

6 responses



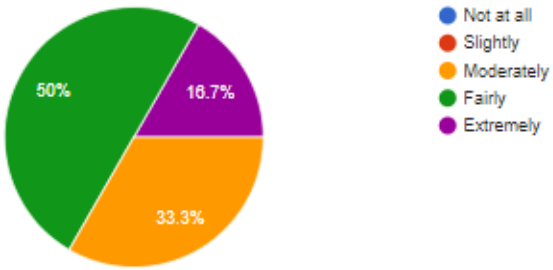

### I was interested in the game's story

6 responses



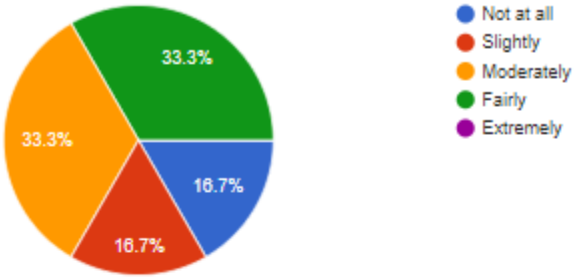

### It was aesthetically pleasing

6 responses



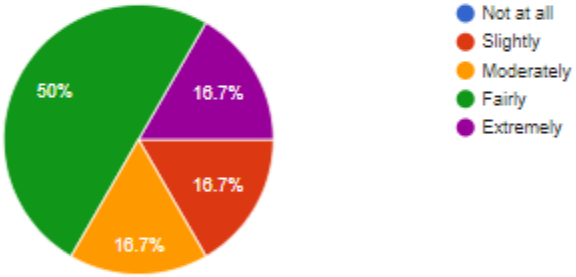
## I felt imaginative

6 responses



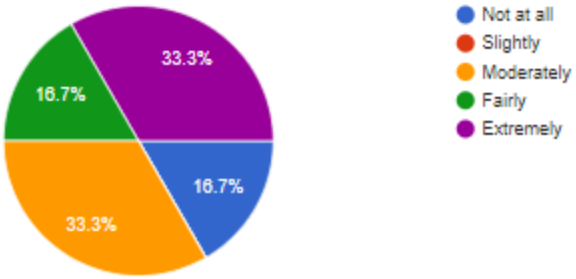

## I felt that I could explore things

6 responses



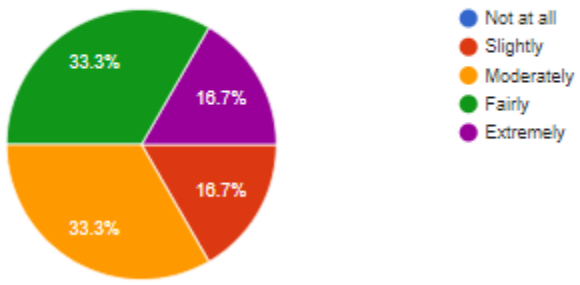

## I found it impressive

6 responses



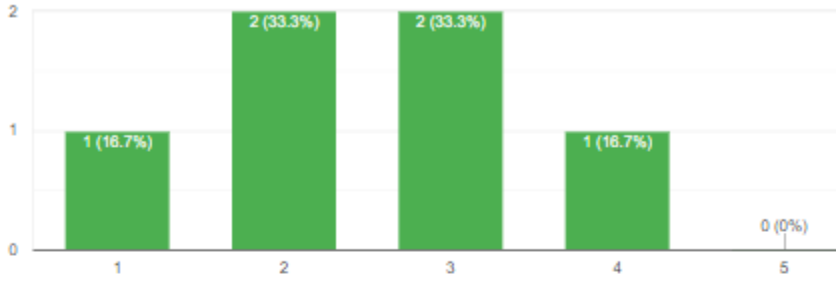
## It felt like a rich experience

6 responses



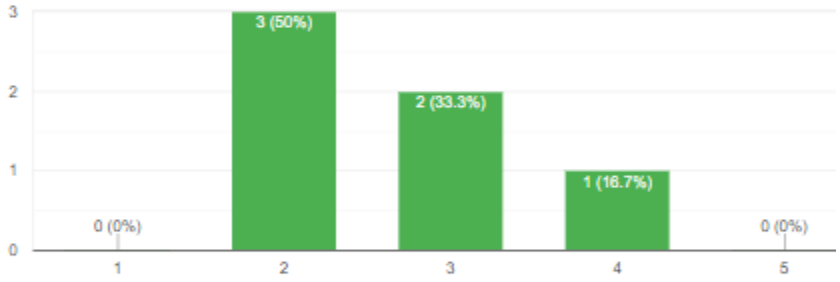
To what extent did you find you lost track of time and was not aware of your surroundings?

6 responses



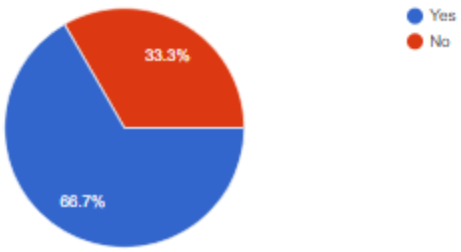

To what extent did you feel you were inside the game rather than manipulating the controls and watching a screen?

6 responses




Did you get scared by anything in the game?

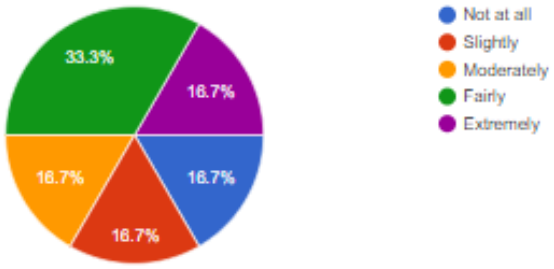
6 responses



## Appendix 8 - Results for Questionnaire for Lighting Effects

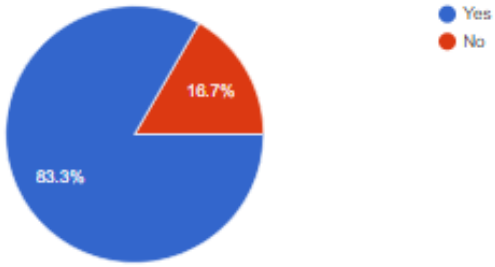
### How effective were the lights at making the game feel more immersive?

6 responses



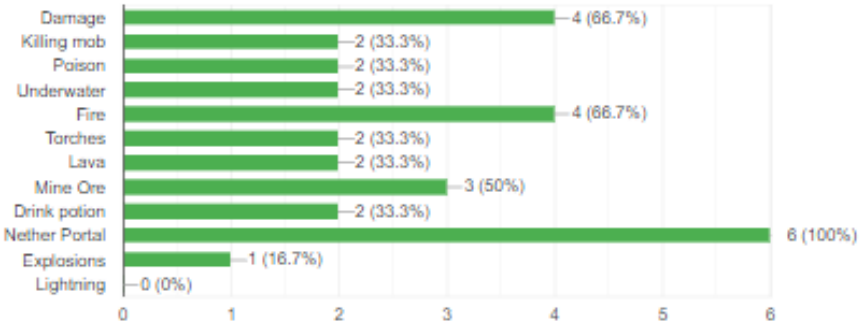

### Would you play more games with these kind of lighting effects?

6 responses




### What effects did you like from the lights?

6 responses



What effects did you not like from the lights?

6 responses