DEVELOP A SOFTWARE TO ENHANCE CONTROL FOR PHYSICALLY CHALLENGED INDIVIDUALS IN A SMART HOME ENVIRONMENT.

IQRA IQBAL

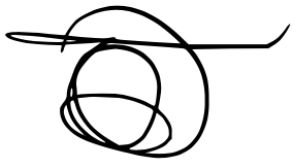
6G6Z1101 PROJECT

A REPORT SUBMITTED TO MANCHESTER METROPOLITAN UNIVERSITY
FOR THE DEGREE OF BACHELOR OF SCIENCE
IN THE FACULTY OF SCIENCE AND ENGINEERING

NICK WHITTAKER

DECLARATION

No part of this project has been submitted in support of an application for any other degree or qualification at this or any other institute of learning. Apart from those parts of the project containing citations to the work of others, this project is my own unaided work.

Signed 

ACKNOWLEDGEMENTS

I would like to thank my family and friends who have supported me and been patient with me through this difficult project. I would also like to thank my personal tutor, Nick Whittaker for guiding me throughout the whole year and Kris Welsh who has countlessly helped me fix any issues I have had and motivated me from the beginning.

ABSTRACT

The purpose of this project was to create an autonomous house environment to enhance a disabled individual. The aim was achieved through using an EEG headset to turn a phidgets kit LED light on or off. The outcome was successful as it included 3 different aspects to improve the user experience. Firstly; the programme which consisted of the initial function of the light change, a training exercise for the user to grasp the concept of using an ECG headset and an android mobile application. An API was also built that included the basic functions and methods.

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ABBREVIATIONS

API	Application Program Interface
API	Application Programming Interface
ECG	Electroencephalogram (Recording of brain activity)
EEG	Electroencephalogram
EMG	Electroencephalogram
GHz	Gigahertz
IDE	Integrated Development Environment
IoT	Internet of Things
JSON	JavaScript Object Notation
MQTT	Message Queuing Telemetry Transport
MQTT	Message Queuing Telemetry Transport.
OS	Operating System
SMART	Self-Monitoring Analysis And Reporting Technology.
UCD	Use Case diagram

1. INTRODUCTION

The internet of things is a platform that is exponentially growing. The term IoT was introduced by Kevin Ashton in 1999 where an initial idea of the concept appeared, however it is now suggested in 2020 it will be worth $8.9 trillion in the market with 212 billion thing connected things. (Larry Dignan,2013) This reinforces the popularity and the importance to explore this topic further.

The phrase IOT is used to explain **"the ever-growing network of physical objects that feature an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems." (Forrest Stroud, 2019)**

This ideology has then been transferred to the concept of SMART homes where home appliances are being controlled via a smartphone device. Overall the aim of a SMART system is to help aid and assist the individual with everyday house hold tasks.

This not only favours the user in ease but financially too as it means appliances are operated efficiently therefore saving them energy.

So now that it is clear how significant this system can be to the user, applying the same concept to an individual with a disability will enhance the benefits even more. Across the UK alone 13 million people have a long-term disability of that are which are 44% adults over pension age hence the reason why this project is targeted at these groups of individuals. (GOV, 2017)

1.1 AIM

The overall purpose of this system is to introduce a SMART home system to a physically challenged individual allowing them to activate/deactivate an LED using brain activity, enhancing their environment. An additional mobile application will also be integrated within the system as a safety feature but also providing them the ability to control devices independently via a mobile phone when not in their SMART home. To allow future enhancements and adjustments to be made on this system, an API will also be developed, providing a set of essential methods in the current system.

1.2 OBJECTIVES

In order to ensure the project is a success vital steps must be executed.
Firstly, researching and critically analysing various aspects of the system.
By breaking down the core concepts and exploring the options will prevent and minimize downfalls on lack of knowledge. The designing stage is next where the theory of how the system will come together followed by the implementation stage presenting what was possible to carry out. Testing and a full system evaluation will then be conducted summarising how successful the project was.

This report will outline the process above from the initial research to critically testing the programme.

2. LITERATURE REVIEW

Prior to starting the project, research was conducted to critically analyse fields, or specific areas that will impact and aid the development of the final outcome. It helped gain a deeper understanding on the various different routes that this project could peruse.

1.3 EXISTING SMART SYSTEMS

There a numerous existing SMART home system already developed and widely used in the field today, therefore further research in this sect would be crucial as it would allow enhancement on either existing systems or adapting and incorporating current concepts in this design for physically unable people.
Some popular existing SMART home systems are listed below;

1.3.1 SMART LIGHTING AND OUTLETS

The SMART Lighting market sector is rapidly evolving and is claimed to be "one of the best tools for increasing access and visibility in your home."**(Karin Willison, 2017)** Hence the desirable aim for this project is to make a disability friendly light system.

An example of a successful model is the Philips Hue White and Colour Ambience Starter Kit. This model allows the user to operate the light via smartphone and has 16 million colours for the user to change the light dependant on their personal preference. The app is simple allowing the user to have easy access therefore, increasing the accessibility. Another good feature of the Phillips Hue is that it can be controlled by voice using Amazon Alexa. **(Karin Willison, 2017)** It also appeals to its audience through its ability to alter the light intensity **(Mike, 2017)** However, this product consists of some downfalls too. The users disliked the extra components that are needed to aid the system. A bridge is needed to be kept powered all the time, which is wired to your router, which is a disadvantage as it causes the system set up to be a little confusing. **(Mike, 2017)**

Figure 1 - Philips Hue Mobile Application

As for the application element the rating and reviews from play store users and App store are quite low. The application interface is very clear, but the design aspect is not the issue here. At an average score of 3/5 the audience was left disappointed in the application functionality as the list of promised features kept failing. (Matticas, 2019)

Nevertheless, this product is perfect for an induvial who is disabled as the main control of lights is done through a smart phone or voice activation.

The Mipow Playbulb Colour is another SMART light system, however despite the main outcome being the same, their target audience is completely different as it is aimed for children. This company has implemented a speaker feature as well as a colour-changing SMART light, and to target the niche audience even more the lights can change via movement (dancing). This is all controlled again via a smartphone. Due to the target audience being aimed for kids the costing of this system is also cheaper than regular models and is priced at £50. (David Phelan, 2018)

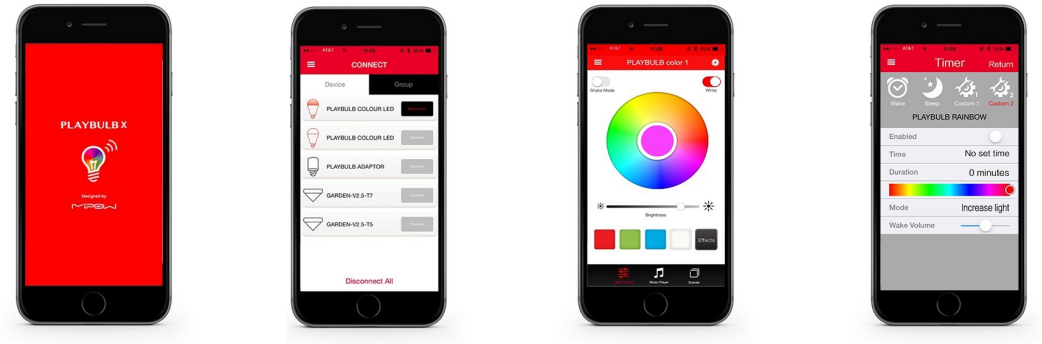


Figure 2 - Mipow Playbulb Mobile Application

The overall system is successful as features like Bluetooth connectivity is strong and stable. The audio quality is loud and the ability to pair many devices is a key exciting feature. **(Marie Black ,2015)** However the overall application was rated 2.8/5 on app stores suggesting the user experience lacked as some found the design to be unappealing and "clunky" **(Devin Watts, 2018)**

From this research it shows even though the initial concept is to control a light, your target audience can dramatically change a product and how due to certain circumstances, features can be added or altered. Thus, this research will impact on this project as many areas need to be considered to ensure the final outcome is tailored for the selected audience.

1.3.2 SMART DOORBELL

This household SMART system is a simple yet effective model. It allows the user to see who is at the by using a motion-sensor camera, therefore a two-way communication between the doorbell and the smartphone is made. The user can then also remotely unlock the door. Hence this system is suitable for an induvial who is physically unable to move easily - for example suffering from a chronic illness or being in a wheel chair. **(Karin Willison, 2017)**

The Nest Hello is a popular SMART doorbell operated using a mobile application, with object recognition and 24/7 recording many users are buying this system and are happy with the "clean, modern design". However, a major disadvantage of this system is that the set-up requirements is very technical and there is no Alexa integration. **(Matt Halpin,2019)**

1.3.3 SMART HEATING AND COOLING

The Ecobee3 is a system which can control your house temperature in different rooms. It is done via communications through the smart phone via WI-FI and the boiler relay. It can be operated through with voice activation with Alexa or through a smartphone. This provides the user with options so they can then choose which method they prefer depending on their condition.(Karin Willison, 2017) Both options accommodate for set disabilities as the requirement of physically moving to turn the heating on is eliminated. One of the key advantages of this system is the interface is very easy to use, therefore allowing the user to make the most out of the features. It also provides the purchaser with the option to expand and add more sensors. There are 2 main disadvantages within this system. Firstly, it requires a lot of power when being operated, secondly not all heating/cooling systems can implement this SMART feature due to incompatibility. (Glorias Rosse, 2016)

Overall there are so many existing systems that cater for disabled people depending on what type of disability they have. For example, Amazon Echo is a common source for the perfect home system that can be easily integrated for the user to incorporate with all SMART systems across the house. Allowing you to control common household tasks via voice. The Amazon Alexa app additionally provides the user an interface for them to use when not at home. Psychological disorders like dementia allows someone to set reminders or alarms through Alexa overcoming the issue of memory loss.

Upon researching, I have found that as of yet there is not a well-established product in the market that allows you to control a light via brain activity.

1.4 EXISTING TECHNOLOGY SYSTEMS INTEGRATED WITH DISABILITIES

There are some existing SMART systems developed which is aimed at disabilities. The following section will evaluate these systems and analyse the features that are used specially to target the disability.

The first system created by MorÃ-n-Castillo et al in 2001 aimed to move a wheel chair by using the Neurosky data that measures the number of eye blinks. The target audience for this system is aimed at people who have motor disabilities and works by using an Arduino alongside an electrical circuit to move the wheelchair.
The system was tested on non-disable people in which 80% of cases successfully worked. When critically analysing this system a number of flaws are indicated. Firstly only 80% of scenarios worked correctly, even though only two people found the outcome didn't work, the people testing this were not disabled. Hence the result gathered may be different when applying this system to the target user. Another area that led the audience to confusion was the obscured data being measured. The value of eye blinks in this system does not correlate to the design. Consequently, the practicality of this prototype is flawed. On the other hand, an advantage of the software is that fundamental design does work and the system can be used by an induvial who may not have prior knowledge on this subject matter. (MorÃ-n-Castillo et al, 2001)

Ahmad Danial Abdul Rahman created a system to control a prosthetic arm using attention and meditation levels. The aim of this project was to restore and allow mobility in patients that suffer from moto disabilities and are restricted on movement. Arduino controller was used to pass and process the data of the Neurosky wavelength levels and also acted as a controller for the prosthetic arm. An advantage of this system is the accuracy and the wide range of functions the arm could carry out; different gestures like rotating, bending fingers, grasping and releasing were all included in his design.

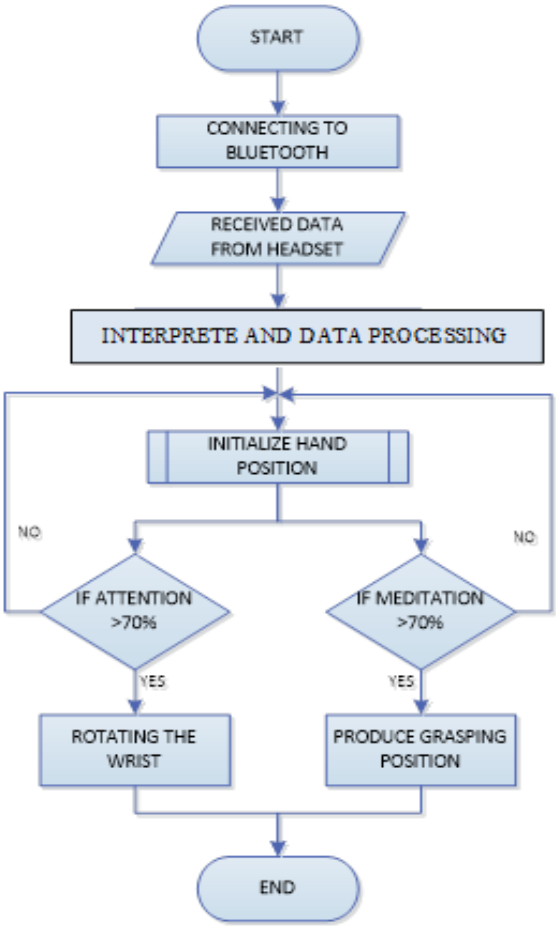


Figure 3 - Software flowchart of the system (Dania, 2019)

Another advantage is the clear system flow chart designed before implementing the system. As it provides a clear structure to the system eliminating any visible errors prior to starting the developing of the system. (Dania, 2019)

1.5 NEUROSKY MINDWAVE HEADSET

Neurosky is a brainwave sensor that allows developers to manipulate this data to produce an application or system. The headset itself was created in 2005 and uses electroencephalography (EEG) and electromyography (EMG) technology to measure the brainwaves in the user. It monitors the communication between the neurons in the brain to calculate a numerical value of the electrical activity. (Adam Sinicki, 2018)
Every activity carried out by the human brain is made up of electrical signals that collate down to atoms. Atoms are made of protons that have a positive charge, electrons that have a negative charge and neutrons that have a neutral charge. The flow of electrons allows electricity to be conducted which can work with the headset to produce a set of data.
The data collected is sectioned into meditation, attention, blink rate, brainwave bands and raw data. From this data manufactures have developed exciting applications and wearable devices like MyFitnessPal which allows users to monitor their own health. (Neurosky, 2018)
Attention value represents the users focus intensity level which ranges from 0-100. Meditation value corresponds to the user's calmness value which again ranges from 0-100.
There are now many different models that are specific to target skills and outcomes. Neurosky Midwave mobile 2 – brainwave starter kit is the newest and updated addition of the kit; it is best suited for this project as the wireless EEG headset uses sensors that detect brainwave signals (alpha and beta) and passes this data safely. (Neurosky, 2018)
In terms of the developing tools that are compatible with the Neurosky headset device, there are many existing APIs available in C/C++/C#/Java languages. Think Gear Connecter is a software that is compatible with windows and mac operating systems. It runs in the background to allow the communications between applications and manages the connected devices to receive the information. (Neurosky, 2018)

Octoblu is a platform that takes inputs from sources and allows control of different outputs like the Philips Hue lights. The developer then adapted this concept and was skilled enough to connect to the Hue lights to send the data output signals. One of the pros of this system is the data actually responds to brainwaves suggesting the results are accurate. It is also extremely lightweight, therefore in terms of usability, it is very practical to include in a SMART system. Due to the device being wireless the downfall of this product is the range is restricted to 10 meters, nevertheless this project is targeted for a SMART house hence ideal for this project. However, another negative aspect of this device is that some developers have stated that the results scale from wide ranges and the algorithm is slow to adapt so the data can fluctuate. (Neurosky, 2018) But in order to make the data more accurate and to cancel out electrical noise, a clip is attached to your earlobe to filter out non-brain activity, hence this is a positive aspect of the design. (Andrew, 2012)

1.6 PHIDGETS KIT

A phidgets kit, created in 2001, allows the developer to design a piece of software that interacts and engages with a specific sensor that is connected to the processor. It is very quick and easy to use due to the simplicity of the design so much so over 10 programming languages support the phidgets API. The phidgets API allows programmers to save time as common syntax programming is included such as Methods like getters and setters, Event handlers and Constants. (Phidgets, 2019) A disadvantage of using Phidget kit is that the physical user interface cannot be independent, and so it is compulsory for it to be connected via a computer. It can also be expensive therefore if there are budget limitations it is recommended not to use this kit.On the contrary there are many advantages in using this kit. Firstly, using the library is very simple. By importing the short code shown below you are able to access the methods.

```
import com.phidgets.*; // to get access to Phidgets objects
```

The library itself is very consistent too in initialising variables and executing methods. (David Ledo, 2015) Another feature that makes them ideal to use for the development of a SMART home system is that they are robust. They are also easy to replace therefore making them widely available to order.

1.7 ARDUINO

Arduino is a widely available product across the web and is used to allow develops to create their own gadgets. This is done via the Arduino IDE which accesses the user to create programs that communicate with the hardware. (Nick Heath,2018)
It is an easy and simple platform to set up as the main circuit board contains all the LED, actuators, oscillators and other components. This one piece of hardware can then be connected to a device using a USB cable. However, a disadvantage of this product is how expensive the device can be and the lack of memory and power can be frustrating. (Ismail Sarwar,2016)

1.8 API

An API is an application programming interface which allows the communication of 2 applications. It consists of a set of procedures and methods which allows applications to request and send responses. The majority of APIs are written in JSON as it allows the data to parse in JSON format making it easier for developers to use. **(Tyler Elliot Bettilyon, 2018)**

An advantage of using an API is it provides a layer of protection as the data is not exposed to server **(MuleSoft, 2019)** A good API allows the developer to programme easily by placing all the methods together.**(Vangie Beal)** Using an API also means you are efficient with your time as methods are integrated and shared more effortlessly. **(David Berlind, 2018)** They are built with the intention to allow 3rd party developers to enhance and expand on the current foundations provided by the company. **(Tyler Elliot Bettilyon, 2018)**

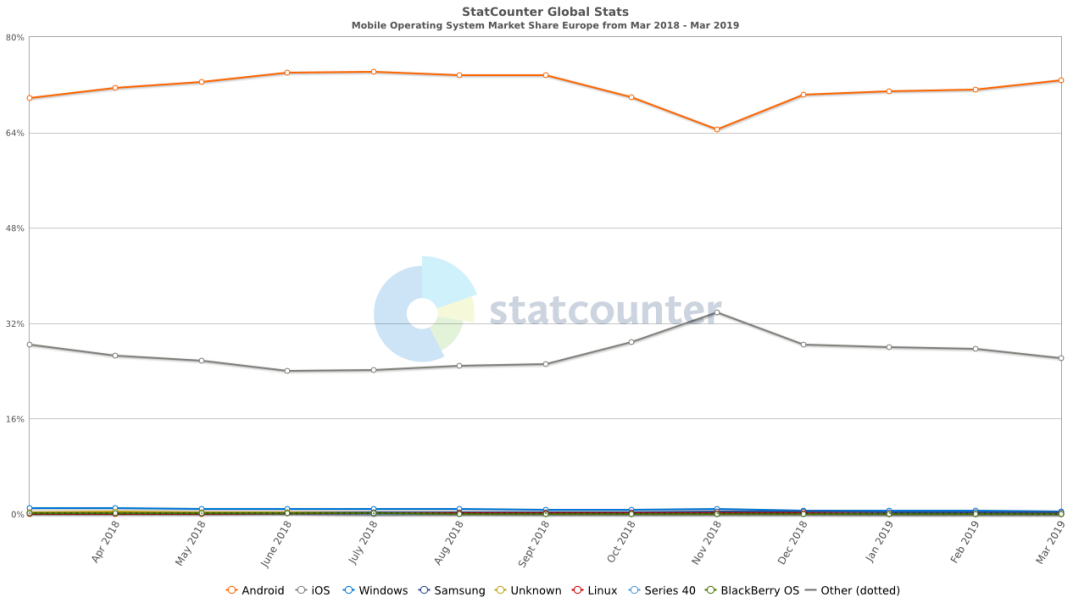


Figure 4 - Mobile Operating System usage statistics (Mar 2018 - Mar 2019)

1.9 IOS

Apple developed and created the iPhone operating system in 2007 which is exponentially increasing in users. So much so applications supported by iOS is immensely competitive as it consists of 2.2 million apps in February 2019. (Sam Costello, 2019) Developers use XCode which is Apple's IDE. Languages like swift, objective-C, C are used to program the iPhone applications.

1.10 ANDROID

Android is a mobile operating system that was created in 2007 by Google. As soon as the SDK was officially released a month later over 1 million users had downloaded this highlighting how popular it was globally. (Rogers, 2009) It is now the world's most popular operating system. (Smith, 2017) Majority of Android is written in Java alongside with many APIs designed in java too for developers. One of the best IDE's for Android Application development is Android Studio which is also created by Google; it allows the user to test and run their application live on a Android virtual device emulator or their own android device. This implementation is a key successful feature that saves time and provides a visual result.

	iOS	Android
Advantages	▪ **Quicker to develop and the application -** The code is more compressed. ▪ **Fewer bugs occur in iOS -** Due to strict development guidelines that the developer must follow to have permission to publish the application. ▪ **The developing tool used –** Xcode is a lot faster and consists of many versions which from time has only become more perfected. The IDE helps the developer by highlighting warning errors and including an option to run a debug stimulator. ▪ **Secure –** Apple uses a framework that increases the security of the data in the operating system	▪ **Biggest market -** This expands your audience to a lot more users worldwide. ▪ **Less requirements are needed for developing the application and publishing it on the app store –** This is due to Android being an open source. Applications can be published very quickly and cheaper than iOS too. ▪ **Bigger Audience -** Financially the costings of an android OS device can differentiate, catering for all types of users. ▪ Hence the more users there are the more your application can spread and gain recognition. ▪ **More variety in devices –** Financially the costings of an android OS phone can differentiate, catering for all types of users. Hence the more users there are the more your application can spread and gain recognition. ▪ **Built in security –** Files are encrypted protecting any data when needing to do so. There are also clear messages to request permission to access different features.
Disadvantages	▪ **Smaller market –** Compared to android user the target audience for an iPhone is aimed at more economically developed countries therefore the audience is limited and restricted.	▪ **More Bugs -** Due to the development and publishing process being so quick, more bugs may occur

Table 1 - iOS VS Android

1.11 ECLIPSE

This is a free open source software which was created in 2001. It is mostly written in Java however supports many different other languages. For this project the suitable and efficient language to use would be Java hence Eclipse perfectly meets the criteria. The official website also states it is a "Framework for a wide range of technology domains such as the Internet of Things". A benefit of using Eclipse is it checks the syntax for any errors therefore reducing time on fixing any errors due to syntax. (Eclipse, Not stated)

An Advantage of using eclipse is it indicates errors and allows the developer to save time due to the software containing many features and shortcuts.

On the contrary if an individual has not used this IDE before it can be quite overwhelming as there are many concepts to learn. It also can not alter non efficient code therefore, the individual must ensure coding styles and designs are correct. (Salman, 2010)

1.12 ANDROID STUDIO

This software allows you to build an application for all android devices with ease. It consists of a visual layout editor therefore making it very simple for the user to create the interactivity features on the app. There is also a built-in emulator which can install and run the application. This software supports many different languages like Java, C, C++ and Kotlin. Consequently, this software would be very ideal to use in this project as a user interface application is needed. This software also supports a mac operating system therefore increasing the accessibility. (Android Studio, 2019)

1.13 HOW DATA IS PASSED?

In order to pass data between devices a critical analysis should be conducted to evaluate the popular methods used in everyday life.

1.13.1 BLUETOOTH

Bluetooth is a very common method used for wireless communication. Majority of devices use Bluetooth due to how cheap it is. Due to this factor the widespread of Bluetooth devices continues to rapidly grow from 2004.

It is used for short range data transfer between devices as is operated with frequencies between 2.4 – 2.44 GHz. In simple terms it works by sectioning the data being transmitted into packets which then get sent to a Bluetooth channel. (Jaycon ,2017) Bluetooth technology is used in computers, laptops and accessories that are used alongside such as keyboard or speakers. Bluetooth is then implemented to remove the usage of wires and to send data like a document to the local printer. Other areas where Bluetooth is enforced is in health, home and a car. From fitness equipment that uses Bluetooth to send heart rate and calorie data to the purchasers' smartphone, to integrating a hands-free system in a car that uses Bluetooth to answer receiving calls, show GPS directions and play music. (Edward Mercer, not dated)

1.13.2 ZIGBEE

This protocol was found in 2003 and uses a personal-area mesh network to communicate the data with a wider area. The wireless nodes are spread out from one another boosting the transmission hence a very stable connection. From one network 65,000 nodes can be supported by Zigbee, for this reason it is commonly used in a SMART home environment. This includes big companies like Amazon, Phillips and Samsung implementing this protocol in their systems like the Philips Hue which communicates with the bulbs in the SMART home. (Tillman Et al, 2019)

1.13.3 MQTT

MQTT protocol stands for Message Queuing Telemetry Transport and was discovered in 1999. It uses a "publish and subscribe system." Where the data is sent to an output and then read and published, this simple protocol is specifically designed for IoT applications. **(Santos, 2017)**

1.13.4 WI-FI

Wireless connectivity allows communication between devices without using physical wires. This works by using a hub which receives internet data, this is then converted to radio signals and are transmitted. **(Jeff Baker, 2018)**

	Bluetooth	Zigbee	MQTT	Wi-Fi
Advantages	▪ **Flexible** - Can connect to numerous networks not just your home. ▪ **Cheap** – Widening the target audience as it is available to more individuals worldwide. It is cheaper due to low power consumption. ▪ **Supports all the main operating systems** (Android, Windows 8, iOS, OS X). ▪ **Secure data** – The data is encrypted as it uses cyclic redundancy check	▪ **Data is protected** – The integrity of the data is checked and authenticated using an advanced function. (AES block cipher) ▪ **Large range** – bigger network therefore transmitting data in a bigger area ▪ **Set up is simple and easy**	▪ **Very stable** ▪ **MQTT works at a wide range** - it can communicate with 16 different messages. It also allows you to send asynchronous messages. ▪ **Data is encrypted –** The network uses secure sockets ▪ **Efficient** ▪ **Robust**	▪ Data can be passed within a 100m range ▪ **Encrypts** the data as it uses a WEP ▪ Installing and set up is **quick** and easy ▪ **Widely available** as majority of existing devices use this method
Disadvantages	▪ **Limited range** of **10m** - it uses a mesh and star method to transmit data.	▪ **Short range** - It used a mesh only system to transmit the data therefore cannot be catered for outdoor use. ▪ **Not as secure –** Compared to Wi-Fi security	▪ The protocol **relies on a broker** being available for the messages to be transmitted.	▪ The **time taken** for the data to passed can vary as it is dependent on how many users are connected to the network

Table 2 - Advantages and disadvantages of the methods used to pass data

(Jin-Shyan Lee et al, 2007) (Tracy, 2016)

1.14 TESTING METHODOLOGIES

There many existing frameworks in the field used by developers to ensure projects are planned and managed correctly. In this section I will discuss further on the different recognised testing methods used in industry and individually analyse each one.

1.14.1 AGILE

Agile is method to manage the development of a software and was discovered in 2001. It consists of main values that ensure the software is managed correctly. The main significance of the model is the process reacts and responds to an issue at ant stage, instead of following and sticking to a plan. It also suggests that a condition of the software, whether the code is working, or the practicality of the code is more important than the initial plan documented. An advantage of this model is when a problem occurs, it is targeted and responded instantly therefore a faster turnaround of building a successful system. On the contrary a lot of time and attention is required when carrying out this product as it is very fat pace. A long-term aim must also be established from the beginning to allow all users to understand the goal.
(S. Ilieva,2018)

1.14.2 WATERFALL MODEL

This methodology was introduced in 1970 and is widely used and recognised y software developers. It requires the system to be fully planned out and stages to be completed step by step. Many individuals state this model is not practical for projects that require testing during and in between stages. However, an advantage of this methodology is due to the careful planning of the structure, it decreases the number of issues within then system and provides stability. (Mike McCormick,2012)

1.15 SUMMARY

This chapter was beneficial as it provided the project with structure and support. It enabled the developer to explore the options and potential routes to take and evaluated what areas to avoid. A key factor that will be implemented in this report is the agile methodology. This is integrated earlier on as it lays the foundation for the product.

3. DESIGN

This section will consist of the design aspects, it will outline the requirements and provide a visual representation in achieving the outcome. Crucial features like communications and device interactions which impacts on the development of this product will also be discussed further here.

1.16 REQUREMENTS

1.16.1 REQUIREMENTS FOR THE SYSTEM

- It is not required for the user to physically move to switch on/off the light
- It is essential for the system to communicate with the light system and an ECG headset
- The system is expandable for further development and enhancement

1.16.2 REQUIREMENTS FOR THE MOBILE APPLICATION

- An easy, friendly user experience
- Ensure the user is able to communicate at any range
- (Able to use the application from the SMART home and outside too)
- Data stored must be secure

1.16.3 REQUIREMENTS FOR THE API

- Easy to read and use even with no documentation
- Include appropriate methods that are specific to the system

1.17 SOLUTIONS

To ensure all requirements are successfully executed at a good standard a set of necessary solutions are listed below.

1.17.1 OVERALL SYSTEM

- Using the Phidget API and the ThinkGearConnector will allow the 2 devices to communicate with each other which is a critical element of the system.
- The system created will include detailed comments, a thorough READ ME file, a screen recording to provide a visual result of whet the system should do and an API that includes the main beneficial methods used in the system.

1.17.2 MOBILE APPLICATION

- A user-friendly experience will be achieved by making the interface of the mobile application very simple and an easy set up for the target audience to follow. This will allow the individual to grasp the application quicker and will minimise confusion.
- Data transmission will be done through a chosen encrypted protocol

1.18 DEVELOPMENT MODEL

The development model being used in this system will be Agile. This is where continuous testing and developing is perused during the project, which will allow constant progression and enhancement on the design and system. It is important to use this model as many tests must be done in order to reinsure and check the headset data is being transmitted and the system functions. Another implementation that needs to solidified is the concept of the LED changing status (light on or off) hence the system would need to be constantly checked and tested.

1.19 HARDWARE

The list below identifies the hardware that will be used to aid the system prototype.

- Phidgets Sensor kit – LED
- Router
- Mobile Phone device
- Laptop

1.20 SOFTWARE

- Eclipse – This IDE is one of the most used software's for Java and will be used in this project as it allows libraries to be implemented easily. It is also an open source that has a simple, easy user interface that will support and assist the system development.
- Android Studio – The software will be used to develop the Android mobile application. The main feature which benefits the development of the application is the GUI (Graphical user interface) aspect. This will allow the design to be implemented very quick and easy because of the straightforward drag and drop element.
- ThinkGearConnector – This software will help connect the headset easily to the laptop device and is a necessity for the transmission of brain wave data to occur.

1.21 LANGUAGE

Java will be used to build the system as the language is very easy to identify errors that may occur. Not only is Java very popular worldwide but it is also very secure due to of the Java virtual machine and the complier. It is also a robust language and object-orientated. The language can be easily transferred on to different platforms and devices, thus this feature will allow me to create a system that can be reused by other developers; which is an aim for the project to be developed further.

1.22 INITIAL PLANNING STAGE OF THE OVERALL SYSTEM

In order to build the SMART automation system successfully an overview of the system must be designed. This can be done by drawing a UCD that will help visualise the requirements of the system. It identifies how the user will interact with the functions and actions within the system.

1.22.1 SYSTEM OVERVIEW UCD

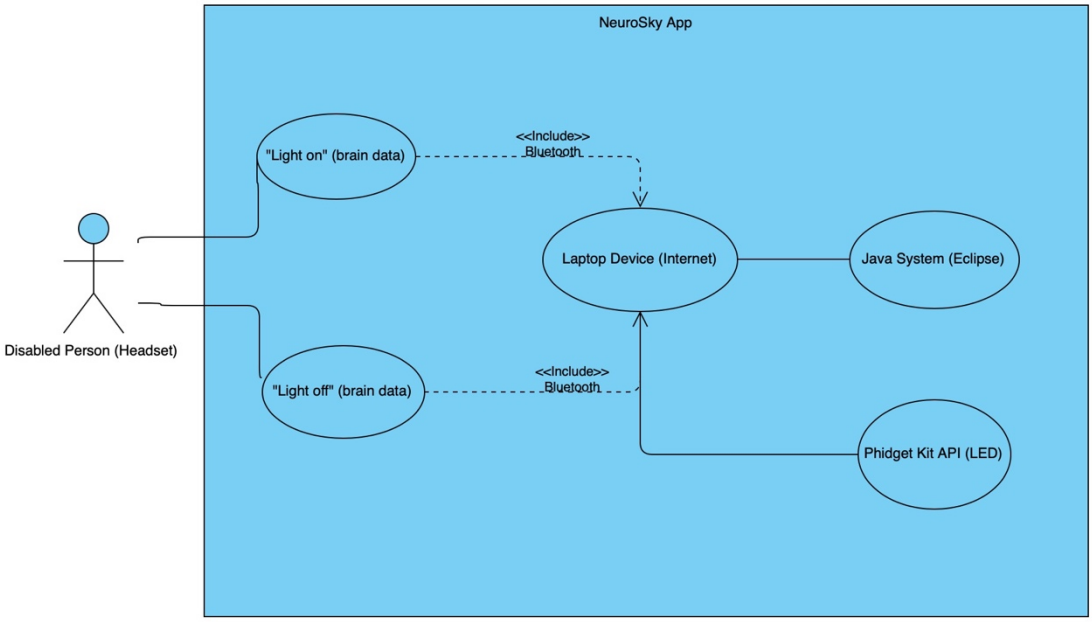


Figure 5 – UCD System overview

The headset will send “Light on/off message” using the brain data, which is transmitted via Bluetooth to the laptop device, which can only occur if an internet connection is established. On this device the system, which is written in Java using Eclipse will be connected to the Phidget kit API allowing the communication between the headset and the LED to occur.

1.22.2 OVERALL SYSTEM DIAGRAM

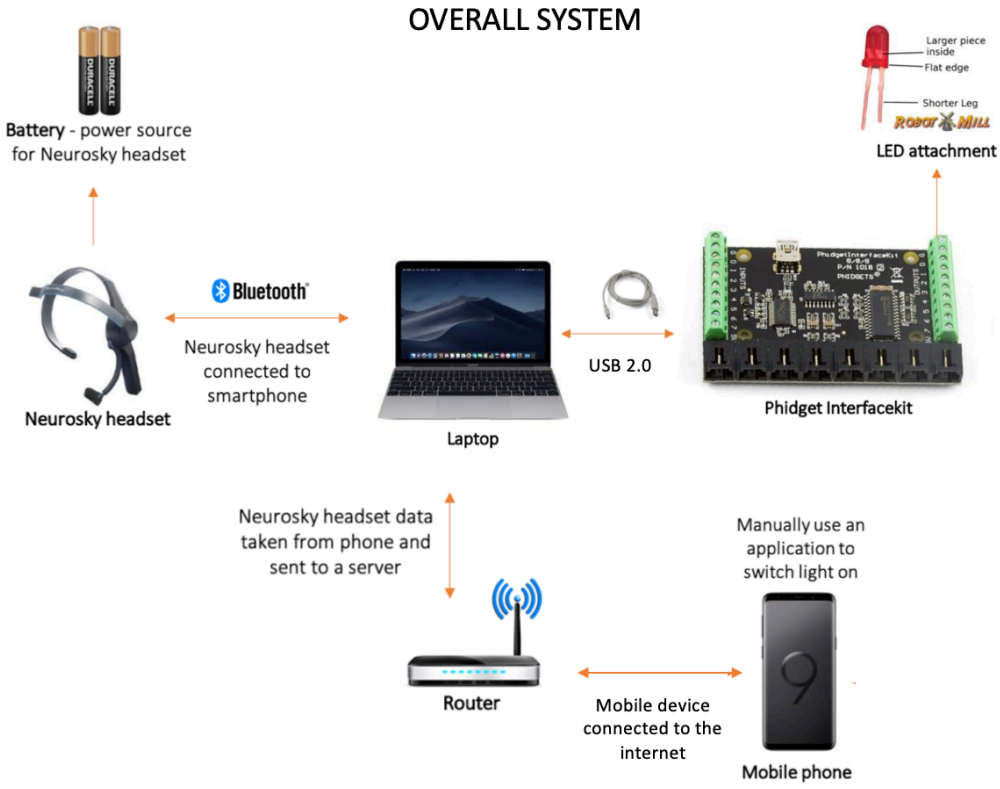


Figure 6 - Sensor network diagram of the overall system

Figure 6 portrays how the system is connected in a visual form. It includes any hardware and power supplies that need to be functioning in order to run this system. It also displays any pre conditions that must be secured and stable for the system to be executed. This includes an internet connection as both devices (Mobile phone and Laptop) depend on the router.

1.23 LED AND NEUROSKY SYSTEM DESIGNS

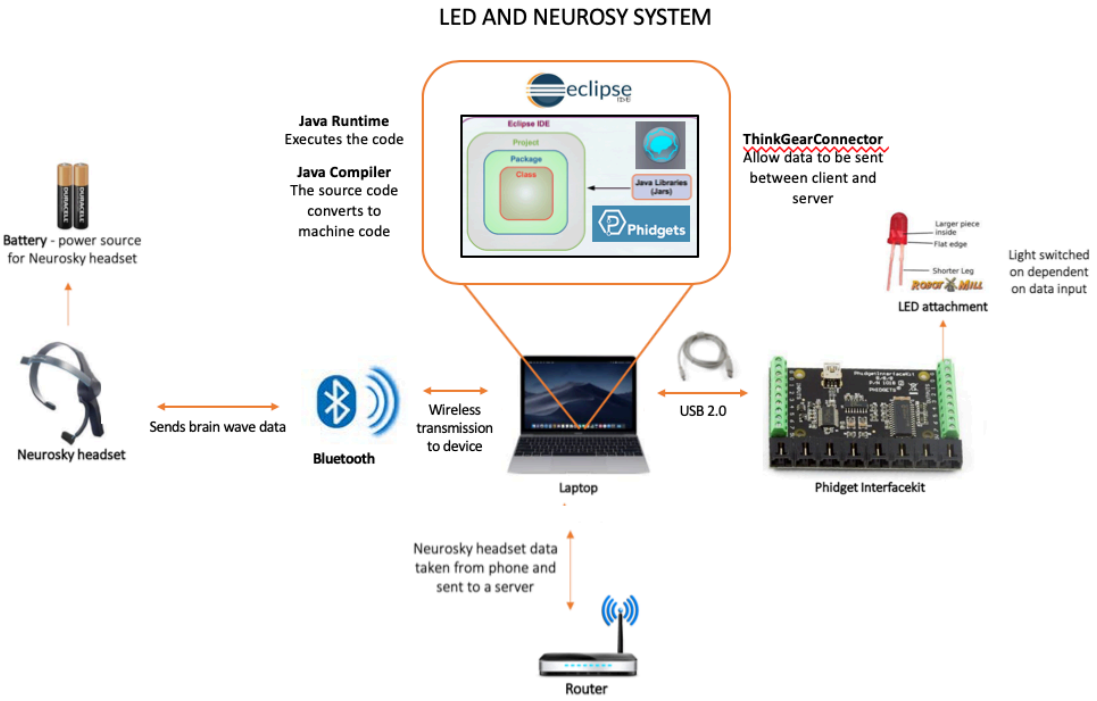


Figure 7 - Sensor network diagram of the LED and Neurosky system

Figure 7 provides more detail about the communication between the LED phidgets kit and the Neurosky headset. The headset which is powered by a battery source must be connected to the Bluetooth as it allows the brain wave data to be transmitted and shared to the processor which is a laptop device. Hence due to the laptop being a receiver of this data, it is must be compatible with Bluetooth too. A software developed by Neurosky called ThinkGearConnector will be running alongside allowing the data to be received. This also means a steady internet connection is compulsory. Bluetooth is a smart protocol to use in this system as it is wireless, therefore the user is able to wear the headset without being restricted on wires. In particular it is also favourable as it can reduce interference from nearby or other devices that are using the same protocol, thus the brainwave data is accurate.

The device will also contain the Java system where a set of classes collated together will compile to run and execute the code using Eclipse. The software developed will contain a set of methods, if statements and conditions that will obtain the brain wave data and depending on the numerical value the LED will be invoked. This will be done via the phidgets kit API methods therefore successfully creating a system where the 2 devices are communicating with one another.

1.23.1 NEUROSKY DATA

The Neurosky headset records a range of different numerical data, however choosing what data is needed for this system is essential. The EEG sensor can record meditation, attention, blink rate, brainwave bands and raw data. The desired data which will assist the SMART system would be attention. This is because when a user is thinking about turning a light on their alert levels will increase as the individual will focus on performing that activity. Meditation is also recorded by the headset however the initial task of turning the light on does not need the brain to measure any calmness in the thought process. Blink rate could be used but in terms of the relationship with turning a light on/off it seems bizarre as there is no correlation between the number of blinks and the activity. Therefore, the algorithm for attention is the most practical data to measure as when the purchaser is told to turn the light on or thinks about executing this activity, the brain will fire out electrons creating a charge which is due to the levels of attention.

1.24 NEUROSKY MOBILE APPLICATION DESIGNS

The mobile application will be developed using an android operating system considering they have a huge existing market. This factor is crucial for the design element as more users will be able to download and benefit from this application. Another important factor as to why an Android application is chosen is the built-in security that comes alongside using the operating system. This is an important user requirement as data protection is a vital feature in a SMART home system.

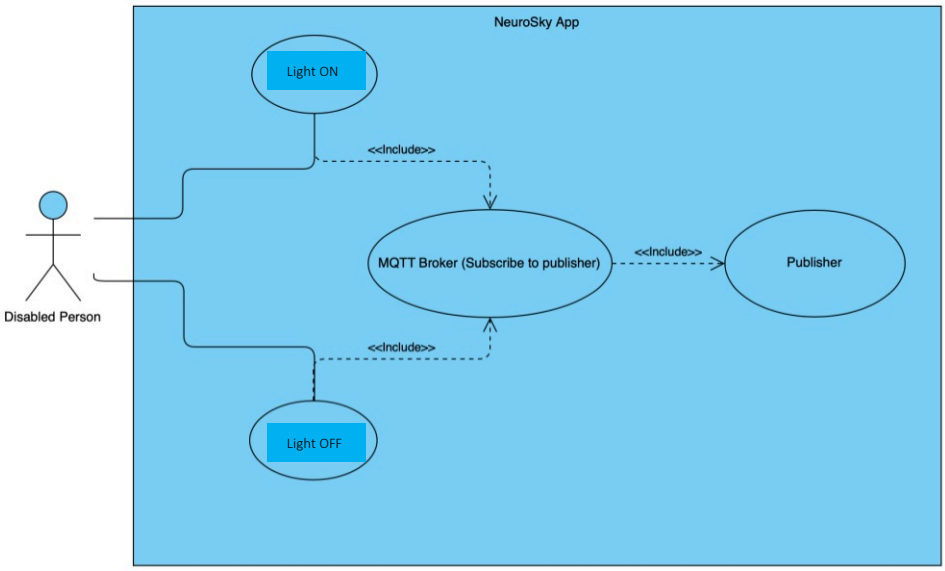


Figure 8 - Mobile Application UCD

Figure 8 displays the use cases within the mobile application. It shows what actions the user can take within the mobile application, a detailed description of the relationships and the entities within this app is as follows. The user will first open the application where 2 main options will be available for the person to pursue. Path 1 entails turning the light on, and path 2 is taken when the light must be turned off. Both options once clicked, send messages to the MQTT broker which then publishes it to the devices that have subscribed. This UCD only contain the main elements in the application, however in figure 9 this system is expanded further, and the practicality and features of the design are discussed.

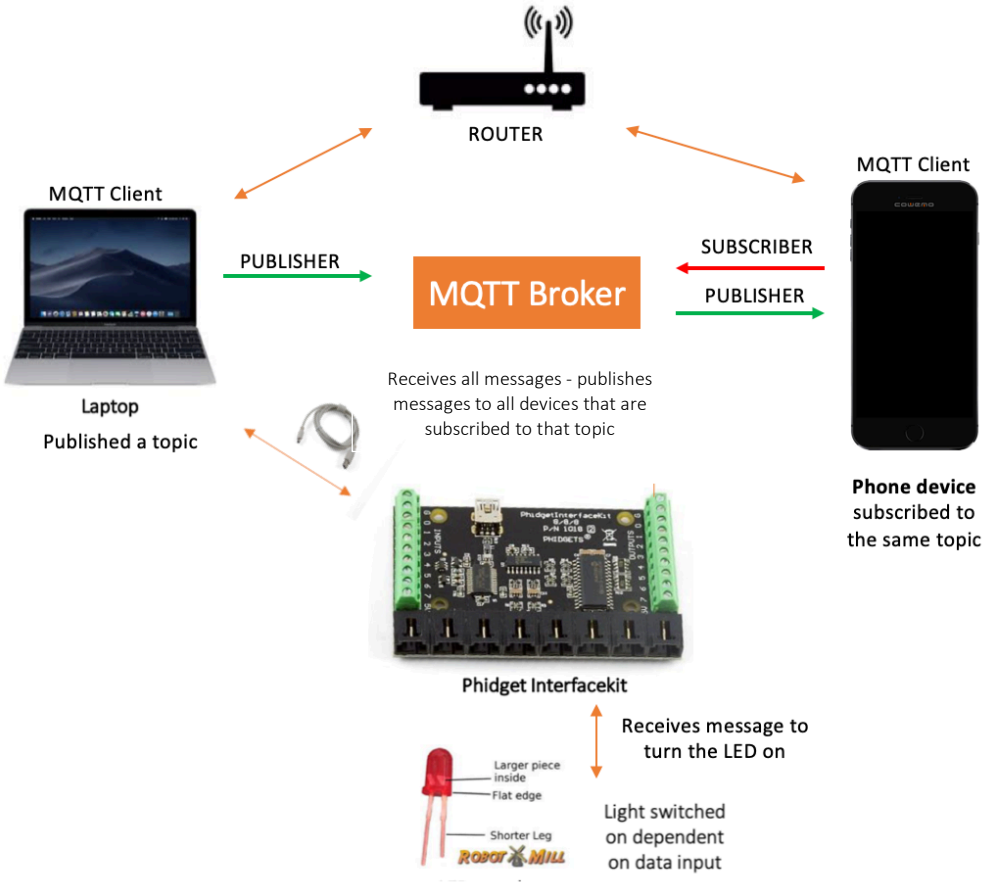


Figure 9 - Sensor network diagram of the Neurosky LED mobile application

This diagram illustrates the network design of how the mobile application will be successfully developed. The main protocol used within this system will be MQTT. This is due to the simplicity of the messaging protocol and low bandwidth needed to send a message. MQTT also uses security mechanisms to encrypt the data and ensure identities are verified. Another justification as to why MQTT is the desired protocol in this application is because the target audience is for older disabled adults. Many disabilities include side effects of memory loss hence this will enable individuals who may have forgotten to switch the light off at home to carry out this action out of range of their environment. This means this application can control the LED system at any range, which is a huge strength in this system.

Concluding that these features are therefore ideal for a SMART automated system.

The system is first initiated by using a publisher and subscriber system. The laptop device acts as a client which is published to a topic. This is then sent to the MQTT broker where all messages are received. The phone device must then be subscribed to the same topic in order to receive the message from the broker. Both devices included in this system must be connected to a secure internet connection to allow communication of the app and LED.

1.24.1 INTERFACE

The interface of the mobile application must be simple due to the targeted audience. This means the fewer features in this application the better, as it avoids any confusion. Introducing just a smart phone device can be overwhelming for the elderly, therefore integrating a whole new SMART system can become daunting. Hence the application must be user friendly and practical.

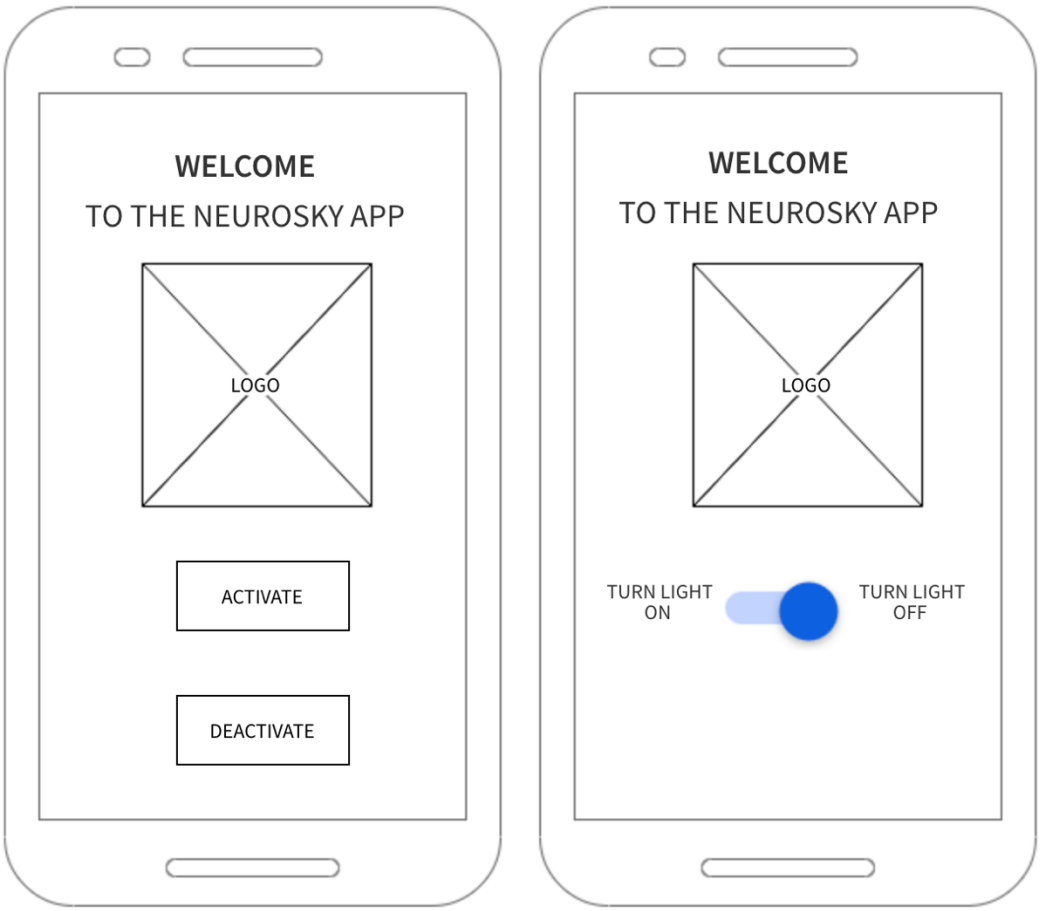


Figure 10 - Mobile Application user interface design

Figure 10 shows the 2 user interfaces designs created. In terms of features both designs are the same, but the main difference is one option includes using 2 separate buttons that are labelled clear for the user. Whereas, the other design adopts a switch feature that the user can smoothly swipe from one another. The main concept of this design is how clean and straightforward it is. This uncomplex model is fitting for elderly disabled people as all the actions of the system is situated on one page. This saves time for the user when reading on how the app functions and any unnecessary advanced features the elderly would ignore/not use.

The logo will also be placed within this app as it will provide a visual cue of what this app does, which is audience appropriate as some may not be able to read clearly. It will also add a vibrant appealing interface for the user encouraging them to purchase this system.

1.25 OVERALL SYSTEM API

In terms of designing the API for this project, steps were taken to ensure all basic methods were included. A list was put together to first indicate what protocols are necessary to incorporate and what existing methods in both libraries should be merged.

- Method called to connect Neurosky Headset and Phidget kit
- Method called to connect to Phidget RFID board and LED only Method called to connect to Neurosky Headset only
- Method to get Phidget data
- Method to get Neurosky attention data
- Method to get Neurosky meditation data (For future developers as some may not want to use Attention levels)
- Method to turn light on
- Method to turn light off
- Method to disconnect Phidget kit
- Method to disconnect Neurosky head set

When all methods are established the set of code will be exported as a JAR file and imported.

4. IMPLEMENTATION

This section will discuss and analyse the implementation of the SMART home system. It will include the techniques used to enable the system was developed successfully, any alterations from the initial design plan in the chapter above will also be further discussed here and justified, alongside with any features that were executed from the design plan. It will consist of details on the testing strategies used and the results gathered from testing the system.

1.26 SMART SYSTEM IMPLEMENTATION

In order to begin the development of the system, a clear step by step plan was implanted allowing the process to flow smoother and by breaking down the system into several stages it ensured the progress was executed in a logical order.

1.26.1 PHIDGETS KIT API

The first stage was implementing the Phidgets API into the system; due to previous use of this API the methods were familiar, and the coding element was a very easy concept to understand and use due to the official website listing all the methods within this API.

```
private void turnOnLight(boolean lightState)
{
    // method to set state of digital out for light to on or off

    if (lightState == true) {
        try {
            System.out.println("LIGHT ON");
            digOut.setChannel(0);
            digOut.setState(true);

        } catch (PhidgetException e) {
            // TODO Auto-generated catch block
            e.printStackTrace();
        }
    } else {
        try {
            System.out.println("LIGHT OFF");
            digOut.setState(false);
            digOut.setChannel(0);

        } catch (PhidgetException e) {
            // TODO Auto-generated catch block
            e.printStackTrace();
        }
    }
}
```

Figure 11 - Phidget Kit API implementation

Figure 11 displays a short snippet of code that implements the phidgets kit API. The method called turnOnLight is a function that does not return a value. The data being

passed in the parameters is a Boolean, which means the data type can either be true or false. An If statement is then used to execute specific methods depending on the conditions. If the light State is true which is shown through the double == (lightState equals true) the following code will run. Within this a simple pre-defined method is called – System.out.println. This will allow the message to be printed in the console and will help clear any confusion for the developer. The setChannel method used will specify which channel to open, which in this case is 0. The setState(true) means the the dutyCycle will be overridden and the state will be set to true. This will all occur if the light state is true.

However, if the condition is false the else statement will be followed. This block of code is practically the opposite to the code above as the light state is now false. For example, the state is set to false.

1.26.2 NEUROSKY HEADSET

In order for the data to be passed and recorded into this system, further research had to be conducted to allow the ThinkGearConnector to carry out this function. After initially trying to implement this communication individually a ThinkGear Java socket was used. This consisted of a group of method for developers to use and miniplate, which is exactly what was done.

```
public class ThinkGearDemo extends PApplet
{
    public ThinkGearSocket neuroSocket;
    public int attention=0;
    public int meditation=0;
    public Object eegEventMethod = null;
    public Object rawEventMethod = null;

    public void setup()
    {
         ThinkGearSocket neuroSocket = new ThinkGearSocket(this);
          try {
            neuroSocket.start();
          }
          catch (Exception e)
          {
            println("Is ThinkGear running??");
          }
    }

    public static void main(String _args[])
    {
        PApplet.main(new String[] { thinkgeardemo.ThinkGearDemo.class.getName() });
    }

    public void attentionEvent(int attentionLevel)
    {
      println("Attention Level: " + attentionLevel);
      attention = attentionLevel;
    }
```

Figure 12 - ThinkGearDemo

This library allows the developer to use and communicate through a socket in JSON rather than the traditional method of using the serial port. This enable a lot of time to be saved as the java implementation has been created with core methods to communicate with the Neurosky Mindwave device. Another feature as to why this library was implemented is due to the target java IDE being Eclipse or processing. (Eclipse is the IDE used in this system). In terms of the code a setup method allows a connection to be started. Once this is done the data from the headset is returned to the console (The current attention level which is an integer will get passed and printed.)

1.26.3 NEUROSKY HEADSET COMMUNICATING WITH THE PHIDGETS KIT

The next step to progress this system further is to now combine the two main components, the headset and phidgets LED.

```
public void attentionEvent(int attentionLevel)
{
    System.out.println("Attention Level:" + attention);
    attention = attentionLevel;

    //If statement - depending on the unique condition which is altered
    //The main aspects is the condition is compared against the attention level
    if (attention >30 && attention <67)
    {
        //If the condition is true the method below is called
        //(Light turns on) - boolean is true
        turnOnLight(true);
    } else {
        //If the condition is false the method below is called
        //(Light turns off) - boolean is false
        turnOnLight(false);
    }
}
```

Figure 13 - Code snippet showing the attentionEvent

This method – attentionEvent is one of the main functions in this system. This passes the attetionLevel data which is an integer as is it one of the parameters in this method. The current attention value is then printed in the console. However, to now add in the Phidget kit condition, an if statement is carried out. Depending on the user's unique attention level a specific condition is compared against the value, if the condition is true the light state will be true as the method mention previously is called; however, if the condition is false the else statement will be invoked – turning the LED state off.

1.27 TRAINING PROGRAMME

Due to the agile development model being used in this system, sections were thoroughly tested in order to allow continuous improvement. Therefore, when the overall system was created, users tested and analysed it. Early customer feedback was given and when operating the system on different users, a serious of flaws in the foundation of the system was discovered. When carrying out the Blackbox testing the following issues arrised.

The issue was due to the core data being collected from the brain, which caused inconsistencies and major differences in the results to appear. This factor meant each system must be catered for every different individual, as no human being thinks the same. The complexity of the human is far beyond measuring the brain waves in order to return a numerical value, meaning the results are un reliable and not fully accurate. This hindered the SMART system as the design catered for more than just one individual, thus a solution had to be implemented to resolve the issue.

Another major issue that occurred is individuals found using the headset difficult, in terms of clearing their mind and focusing on an activity. The users stated the un-familiar device was a difficult concept to grasp, consequently a solution needed to be created.

The final problem was the Neurosky headset factored in all the 0's. At times the device would not pick up on all the signals the brain was sending which resulted in the numerical value being 0, this resulted in a false representation as to what the brain is thinking, however the device itself in terms of hardware was un able to process it. This meant that the system created had to overlook and ignore any 0's that were recorded.

Through researching and trying to think of a solution, one was finally reach that could resolve the dilemmas. A training programme would be ideal as this could allow and generate a unique numerical value specifically catered for the individual wearing the headset. The issue of tackling how to introduce and ease the user in with the headset device will be accomplished as a warm up brain activity will commence at the beginning of the system.

By understanding the clear aims of this training programme, the different components were split into 2 main sections.
Due to one of the aims of this system being user friendly the interface had to be simple therefore only one training programme will be developed to target the issues.

1.27.1 WARM UP BRAIN ACTIVITY

```
////////////////////(1)CALIBERATING READINGS - CALMING MIND DOWN(1)////////////////////
        System.out.println("Relax your mind and count backwards from 10");

        //For Loop implemented - i = 10 therefore if i is greater than 0 it will decrease by 1 each time
        for(int i = 10; i > 0; i--)
        {
          //Print out the value of i
          System.out.println(i);
          try {
            //Loop occurs after every 1 second
            TimeUnit.SECONDS.sleep(1);
            }
            catch (InterruptedException e) {
            // TODO Auto-generated catch block
            e.printStackTrace();
            }
        }

        /////RECALLING LIGHT ON AVERAGE READING/////
        System.out.println("Now think about turning a light ON ");

        try {
            //Allows the user to read instruction
            TimeUnit.SECONDS.sleep(3);
        } catch (InterruptedException e) {
            // TODO Auto-generated catch block
            e.printStackTrace();
        }

////////////////////////////////////////////////////////////////////////////////////////
```

Figure 14 - Training programme warm up activity

The code above shows the warm up activity. Taking into consideration the could be a users' first experience in using a device like this a simple activity takes place in this programme. The induvial will count backwards from 10, this is taking a familiar concept – like numbers and combining a new task like concentrating on a concept to clear the user mind together. Therefore, easing the process and decreasing the

confusion one may have when using this system. A live visual countdown is shown to the user which is incremented by 1 second which will help the user regulate and set the speed on the countdown. This activity will also help regulate the value being recorded when the activity to turn the light on/off is displayed as in previous versions of the system values may have been irregular due to the previous thoughts and actions of the user.

```
public static float findSum(ArrayList<Integer> array)
{
    //Float variable - decimal and whole integer
    float sum = 0;

    //i = 0
    //array.size allows me to find actual size in the array list

    for(int i = 0; i < array.size(); i++)
    {
        //Add the values and store in sum
        sum = sum + array.get(i);
    }

    //Divide sum by number of values (size of array)
    sum = sum/array.size();

    //Print out average value
    System.out.println("line 101: " + sum);

    return sum;
}
```

Figure 15 - Finding the average of the data

Initially the developer gathered a set of data from different users and from this calculated a general average range as to when the light value should be on and off. However due to the irregular results and individuals thinking differently this programme was implemented. The code above allows an average to be calculated using an array for each individual. The function is static as it means the method belongs to the class therefore can be easily called. Float was used due to the average sum could be a whole integer or a decimal, therefore will ensure the programme would not break due to the type of value.

```
public void attentionEvent(int attentionLevel)
{

System.out.println("Print and collect Attetnion data for 60 seconds");

  //Print out attention value
  println("Attention Level: " + attentionLevel);
  attention = attentionLevel;

  //Do not carry the method if the attention value is 0 - as this affects the average results
  if(attentionLevel != 0)
  {
      //pushes the attention value into the array list
      myArray.add(attentionLevel);

      //call method
      findSum(myArray);
  }

}
```

Figure 16 - attentionEvent average sum

This code aims to solve the issue of the value 0 appearing continuously affecting the result. The function of this method is to find the average of the attention level but ignore the value 0 as this influences the average sum data. By using an if statement before calling the previous method (findSum) is important and a simple condition can be placed to achieve this aim. By using !=0 , the value of 0 will not be added into the array and as a result to changing the outcome. Only when the value is NOT 0 the function will proceed, which will add the value into the array and then the average will be calculated.

Concluding that the training programme is successfully implemented within the system and helped achieve the issues raised during user testing.

1.27.2 MOBILE APPLICATION IMPLEMENTATION

This application includes 3 key elements for the application to be successful

- User friendly layout
- Mobile application can be used at any range
- Application allows you to switch the LED on or off

Therefore, if all these objectives are implemented correctly, the application will be an achievement.

USER INTERFACE

User interface is one of the most vital and crucial steps for a successful application. If the design layout is messy and confusing it will deter the audience away from the system as the research suggested in chapter 1.

Figure 17 - Neurosky LED application logo

Every aspect of this mobile application is designed with a justification which are as follows.

Firstly, the colour of the application and logo. The colour orange was specifically chosen as research suggests it is associated with “social communication”. It corresponds to “gut reaction” which is a similar concept to the SMART system as the reaction of the brain triggers the light to come on or off. (EmpoweredByColor)

Besides the psychoanalysis, the colour orange is also very vibrant consequently encouraging the individual to use it. The logo itself represents the system very clearly as the 2 main aspects of are integrated together. On one side the brain is shown while on the other the light bulb conveying the function of the SMART home system.

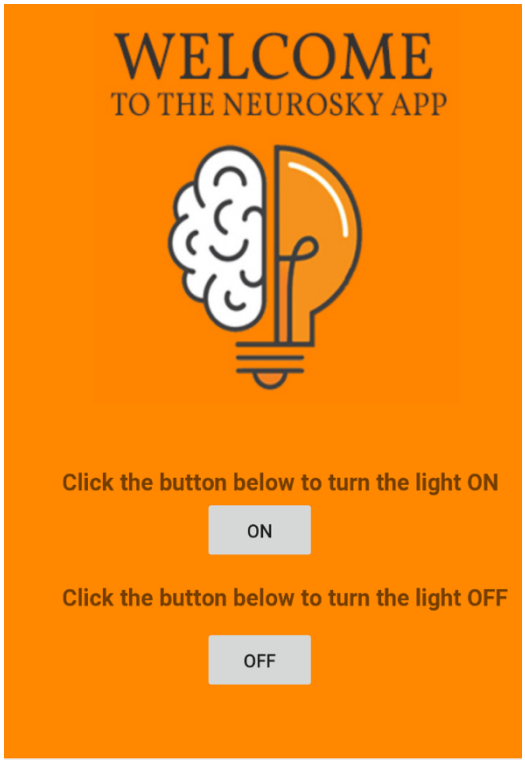


Figure 18 - Neurosky LED mobile application (final layout)

The application as shown in the design chapter is very similar, however the final outcome of the app the 2 main buttons are being used instead of the toggle switch. This is because by using 2 separate buttons the user is sure on what to press and where. The buttons are clearly labelled in capitals indicating to the user what function the button will invoke. There are also instructions on where to click to avoid any confusion. The main layout is overall very simple and straight to the point. No advanced and extra features were added as the overall system can be confusing for a customer who has not used a SMART system before therefore hoping the mobile application element will bring an easy alternative.

MQTT

MQTT is the protocal enforced into this application. The following shows how MQTT was implmented.

The first step was to create a topic that both devices were subscribed to.

As shown below this is how it was done.

```
String topicname = headsetid + "/" + sensorname;
public final String TOPIC_LED = headsetid +"/LED";
```

Figure 19 - MQTT Topic code in Android Studio

The topic name "/LED" will be used to send the message to turn the light on or off

```
//public static final String BROKER_URL = "tcp://iot.eclipse.org:1883";
public static final String BROKER_URL = "tcp://broker.mqttdashboard.com:1883";

public static final String light = "103"; // change this to be your student-id

public static final String TOPIC_LED = light + "/LED";
```

Figure 20 - MQTT Topic code in Eclispe

The broker is established here which will receive all the messages. The broker will also allow the messages to be further published across all devices who have subscribed to "/LED"

```
@Override
public void messageArrived(String topic, MqttMessage message) throws Exception //The code that gets executed everytime
{
    System.out.println("Message arrived. Topic: " + topic + "  Message: " + message.toString()); //Recieve this message string

    // Switch light to on if message is "on"
    if (message.toString().equals("on"))
    {
        l.turnOnLight(true);
    } else {
        //If the message is anything other than "on" - The method turnoffLight is called
        l.turnOffLight(false);
    }

    //send the sensor data object to the server
    if ((1+"/LWT").equals(topic))
    {
        System.err.println("Sensor gone!"); //In-case the sensor is disconnected - print sensor gone
    }
}
```

Figure 21 - MQTT message arrived

The code above is executed when the message arrives. If the message sent is "on" the light code which was previously shown switches the state on. Else if the message is something other than this, the state is turned to false.

To avoid the system crashing if the LED is not connected correctly, a message will be printed informing the user.

```
LEDOn.setOnClickListener(new View.OnClickListener()
{
    public void onClick(View v)
    {
        // Code here executes on main thread after user presses button
        System.out.println("PUBLISHING");
        runOnUiThread(new Runnable()
        {
            public void run()
            {
                try {
                        System.out.println("test on");
                        LightON("","on");
                        Toast.makeText(MainActivity.this, "The light has been activated", Toast.LENGTH_SHORT).show();
                    } catch (Exception e) {
                    e.printStackTrace();
                }
            }
        });
    }
});
```

Figure 22 - Button ON code

This code is written in Android studio – it is invoked when the induvial is using the mobile application and presses the on button. On the user interface side, a pop-up message will notify them the light on button was pressed. On the programming side the message is published to the MQTT broker.

1.27.3 API

An API was created which contained the core functions and methods used within the main system.
The code is as follows.

```
//Method called to connect to phidget RFID board and LED only
private static void open() throws PhidgetException
{
    // TODO Auto-generated method stub
    RFID phid = new RFID();
    DigitalOutput digOut = new DigitalOutput();
    digOut.setChannel(1);
    digOut.open();
    phid.open(5); // wait 5 seconds for device to respond
}

//Method called to connect to Neurosky Headset only
public static void connectNeuroskyHeadset()
{
    ThinkGearSocket neuroSocket = null;
    try {
        neuroSocket.start();
    } catch (ConnectException e) {
        // TODO Auto-generated catch block
        e.printStackTrace();
    }
}
```

Table 3 - API implementation

As you can see to open all the connections within the Phidget kit is included under one method, the same applies to the Neurosky Headset.

1.28 SUMMARY

This chapter contributed to the final design as all the design concepts that were talked about was actually implemented. The main result that affected the development of the product was discovering the in accuracy of the ECG Neurosky head set. The functionality is not limited as the training programme was designed and incorporated to help overcome this issue.

5. TESTING

This chapter entails all the testing methods done throughout the process of developing the SMART system which clarified the main functionality was working correctly. When discussing what testing method was conducted, the data collated from the tests will be included alongside a detailed description on any relationships portrayed.

1.29 TESTING AND RESULTS

Initial testing was conducted on myself as checking if the system worked correctly and smoothly was important before expanding and making other users test a broken system. Eventually this progressed and the testing expanded on to a series of different people.

1.30 BLACKBOX TESTING

This is a method used to test software, by not informing the subject about any of the systems structure. This technique was chosen as it allows the system to be critiqued by the target audiences point of view. The result gained from this testing are shown in table 3. When evaluating the results, the data is very irregular. This fault was indicated and resolved by developing a training programme. Therefore, Blackbox testing was a major factor as to why the prototype became successful. It allowed the developer to understand the amount of work still needed to be carried out as the users were firstly, confused on how the system ran and secondly found the headset difficult to use.

	5 seconds after the activity was called out					
	1	**2**	**3**	**4**	**5**	**AVG**
Activity	**Attention**	**Attention**	**Attention**	**Attention**	**Attention**	**Attention**
Switch light ON	60	47	41	44	50	48.4
	17	15	11	17	35	19
	21	20	20	20	24	21
Switch light OFF	**Attention**	**Attention**	**Attention**	**Attention**	**Attention**	**Attention**
	84	77	83	84	70	79.6
	61	41	48	48	48	49.2
	43	38	40	40	42	40.6

Table 4 - Blackbox testing results

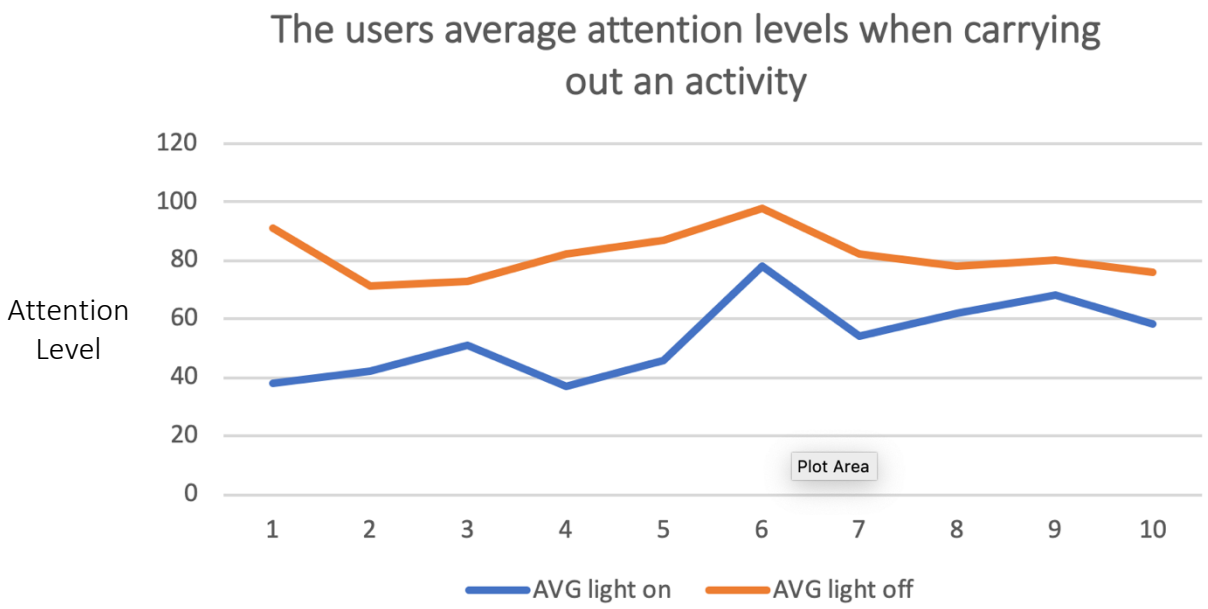
1.31 WHITEBOX TESTING

On the contrary to black box testing, white box testing is essentially the opposite. This means the system is tested and checked by someone who understands all aspects of the project. This technique will benefit the system as the user understands the background knowledge as to the project hence any issues can be highlighted earlier on. Whitebox testing was conducted after the final prototype was developed as this meant the official results could be analysed and evaluated. The participants were briefed in depth on the project background, aims and most importantly guided on how the SMART system works.

Attention Levels	
AVG light on	AVG light off
38	91
42	71
51	73
37	82
46	87
78	98
54	82
62	78
68	80
58	76

Table 5 - Whitebox testing

In total 10 participants were able to test the system. The results noted down were primarily what the average attention level value was recorded by the training programme and if the users were able to turn the light on and off using their brain. 100% of the participants achieved this outcome which can be later shown via the questionnaire that was carried out after the white box testing was done.



In order to visually display the results collated – a graph was drawn to show the relationship between the activity and the attention level. As you can see the attention levels are much higher when thinking to turn the light off compared to the user thinking to turn the light on. The data is also much more consistent and smother for switching the light off as when comparing it to on, the attention levels differ randomly. This emphasises the concept of how complex the human brain is. This huge difference also suggests a unique system is required and the attention level must be altered to cater that individual.

1.32 QUESTIONNAIRE

Another technique conducted for testing the system was using a questionnaire. A questionnaire is a perfect route to take to gain feedback from potential buyers of the SMART home system. It also allows you to collect important data very quickly and easily as a wide range of people can answer the questionnaire.
Another advantage found when using the questionnaire is the results can be analysed and interpreted much easier and can be transformed into a visual format. The participants used for testing included a range of people – not just the targeted population. This would allow the system to be evaluated by all users, expanding the number of individuals who can use the system.

1.32.1 QUESTIONS

The questions included are as follows;

1) How old are you?
2) Have you used a SMART system before today?
3) Have you used a Neurosky Headset before?
4) Rate from 1-5 how responsive this system was?
5) Did you manage to turn the light on AND off using your brain?
6) Do you think it achieved the aim of the system?
7) Do you think this system was suitable for a disabled individual?
8) In terms of the Mobile application - Was it user friendly?
9) Did you like the design of the mobile application?
10) What improvements could be made in the future?

1.32.2 RESULTS

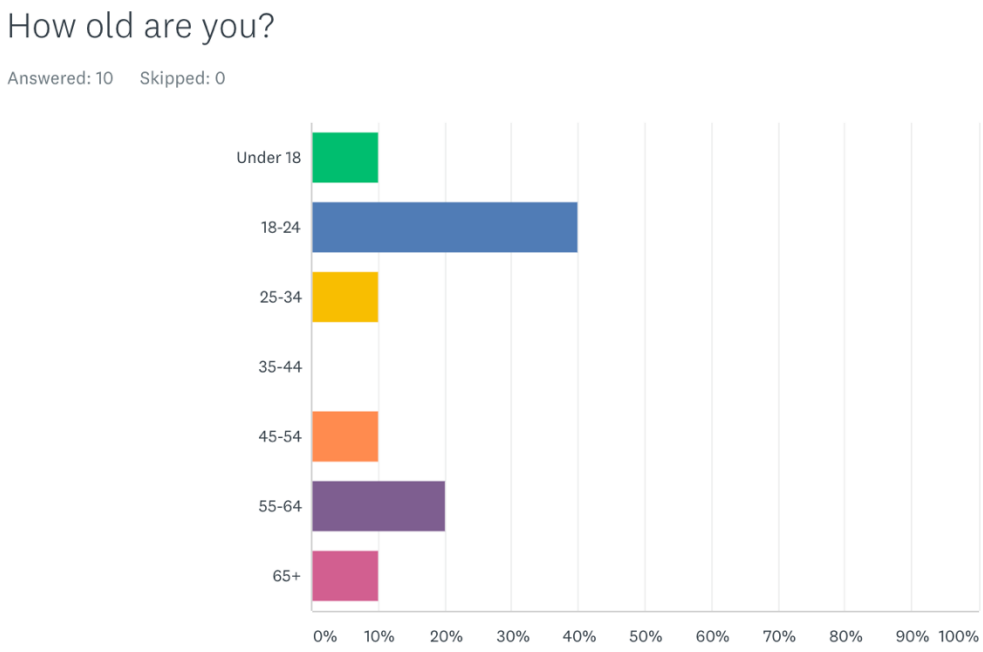


Figure 23- Q1 result

The first question asked the user how old they are as this establishes weather the system was suitable for all ages. The result collated indicates the majority was tested by 18-24-year olds. 20% of the users were the target audience of this system, ideally this age category would have been bigger however due to lack of time it was limited.

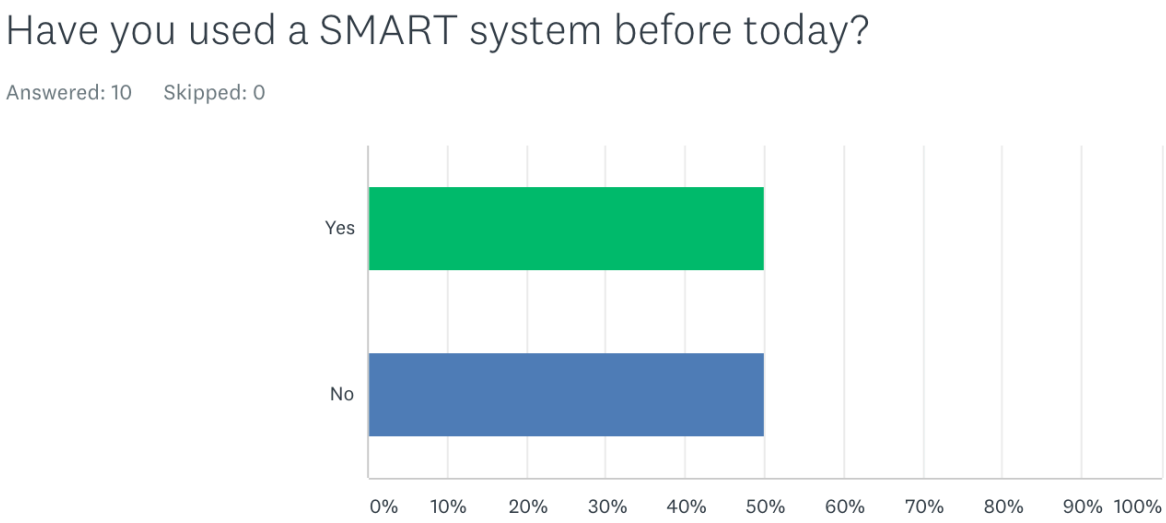


Figure 24 - Q2 result

Figure 26 shows the how familiar the user is with using a SMART system. This question was important to ask as in enabled the developer to understand if the system can be used with all users, from individuals who have prior background on SMART devices to users who may not know anything about this concept. As you can see it was a 50% split which benefits the results as it gives a mixture (range) of different people.

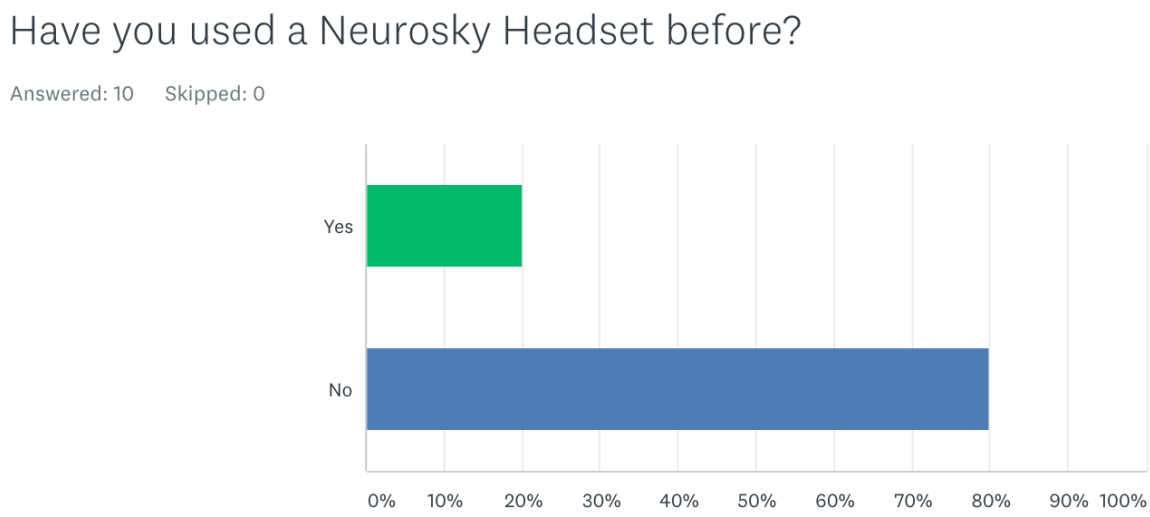


Figure 25 - Q3 result

This question was essential to ask as individuals who may be familiar with this device could find the system more responsive and easier to understand due to the familiarity, therefore allows the developer to ensure this system can be integrated in a SMART home where no training or extra information is given before using the system.

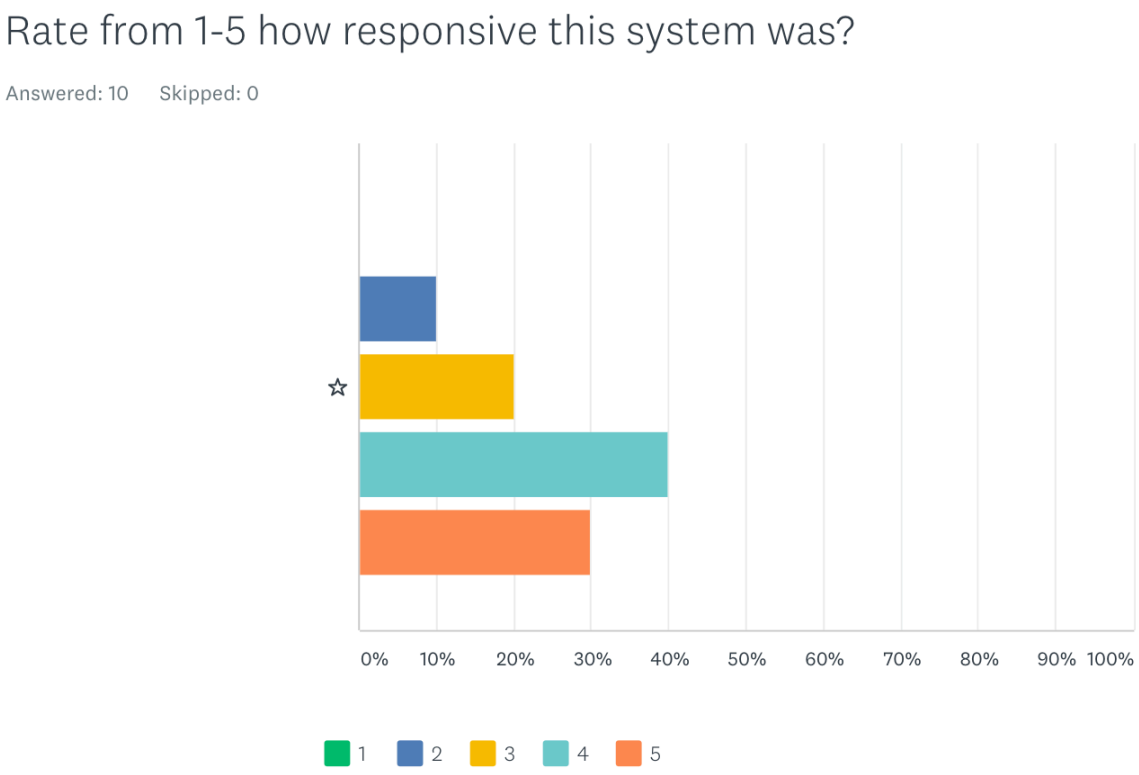


Figure 26 - Q4 result

Figure 28 displays question 4 which asks the user how responsive the overall system was. This is rated from 1 – 5 and as you can see the majority of the results rate this 4. This suggests the prototype was extremely successful as not only did 30% rate 5/5, but ensured the developer successfully achieved one of the aims as the system reacted quickly and positively.

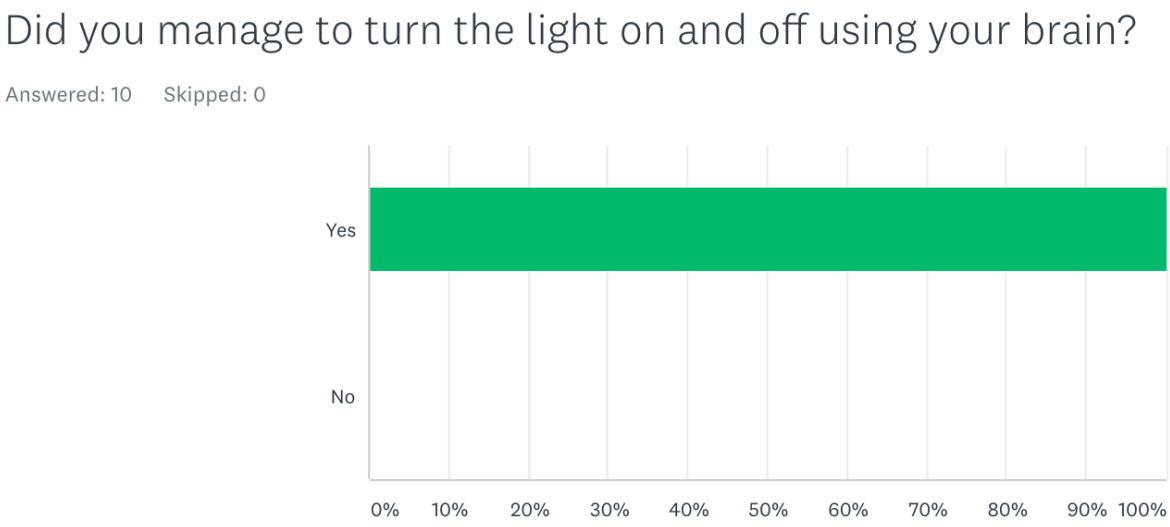


Figure 27- Q5 result

100% answered yes in question 5 which stated if the user was able to turn the light on and off using their brain. This means from all the scenarios the main essential aim of the system, which is to turn the light on and off using their brain was achieved. The achievement therefore ensures the prototype is a success.

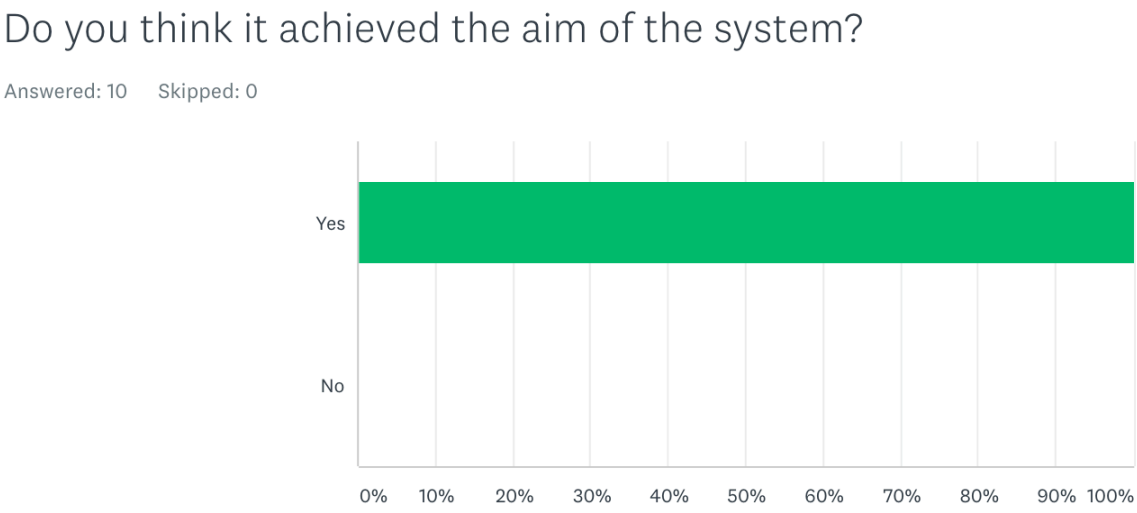


Figure 28 - Q6 result

Due to the question above gaining a percentage of 100, this follow up question also received full marks. This is because the user was asked if the aim of the system was achieved. The subject was briefed on the project, aims, outcomes in order to answer this question therefore reinforces the success of this project.

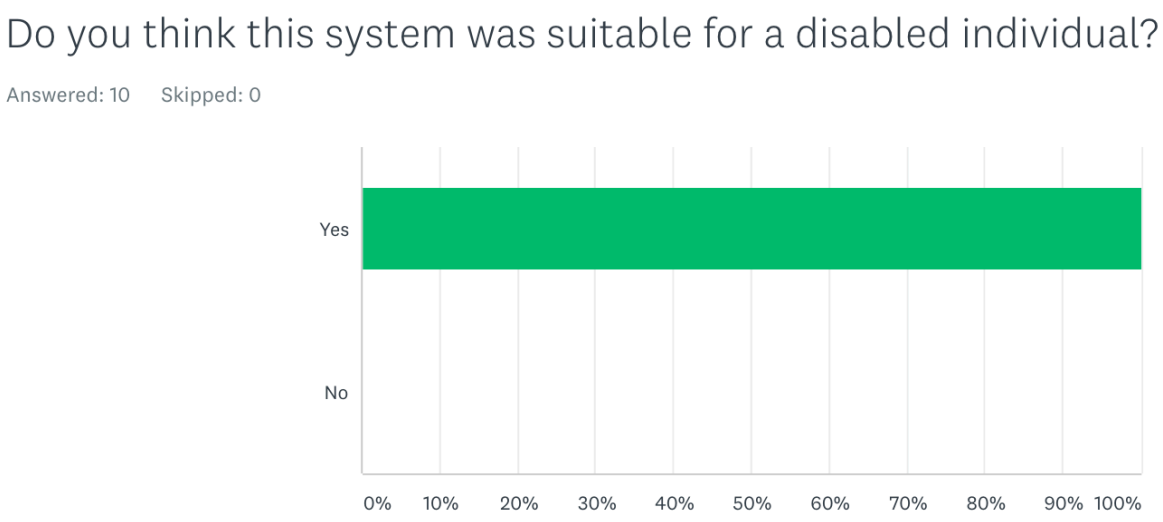


Figure 29- Q7 result

Two of the users who took part in this questionnaire were disabled, however the rest were a range of different ages. Question 4 was designed to allow the developer to understand how the subject tester feels when using the system. This is important as it means not only did the target market believe this system was catered for them, but also non-disabled users understood the concept and adapted their experience to see if this would be practical for a disabled person. The result was interesting to see that 100% believed the system was suitable and catered to disabled people.

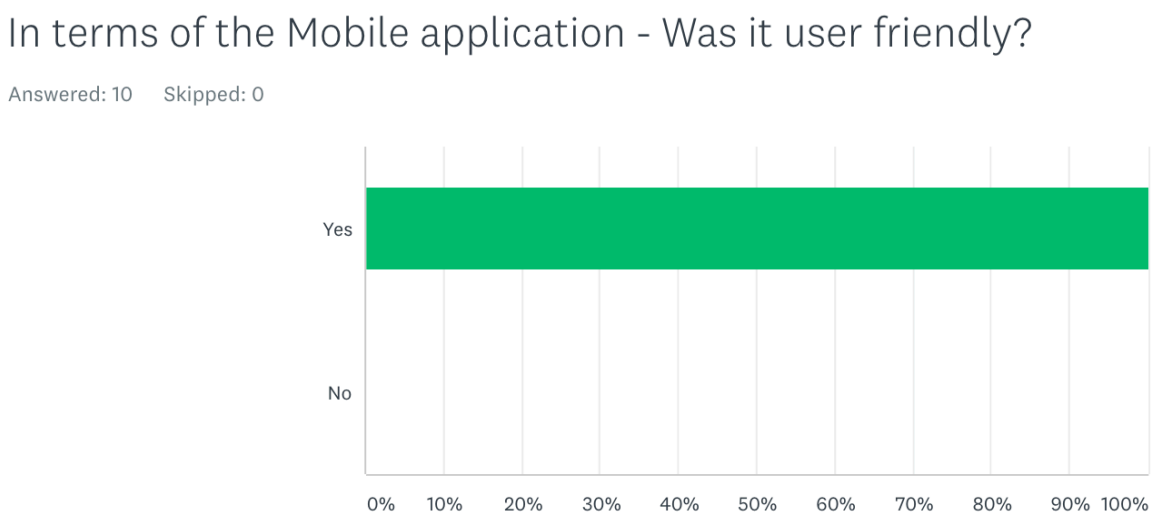


Figure 30 - Q8 result

Now moving on to the other section of the system – the mobile application. Figure 32-Q8 result shows the audience enjoying the app, as 100% believed it was user friendly. This was yet again another aim of the system that has been successfully achieved.

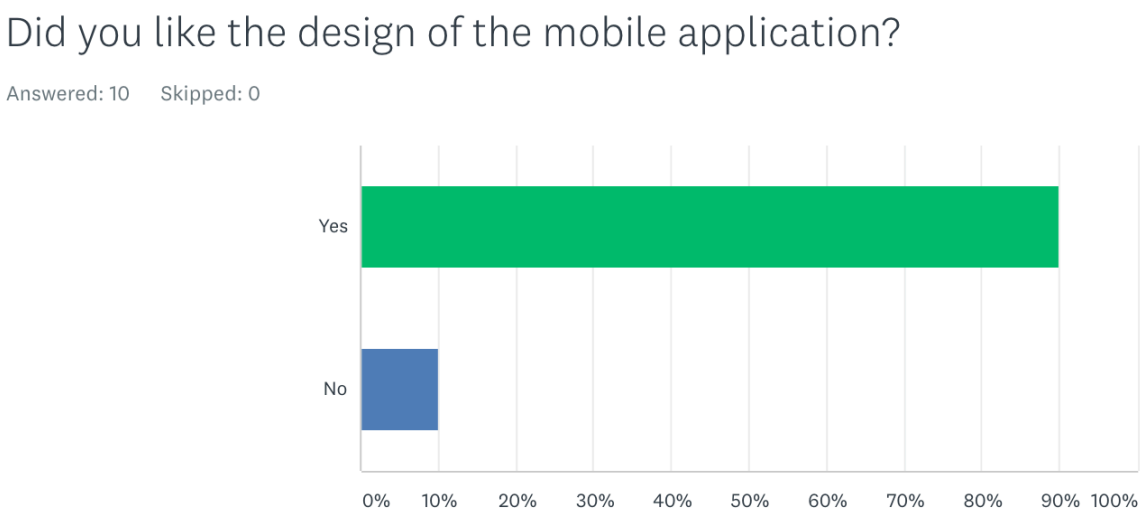


Figure 31 - Q9 result

Although 100% believed the application was user friendly, only 90% liked the design aspect of the app. This is personal preference therefore as majority liked the design this can be overlooked and suggests the porotype app design worked well as more people enjoyed the design aspect.

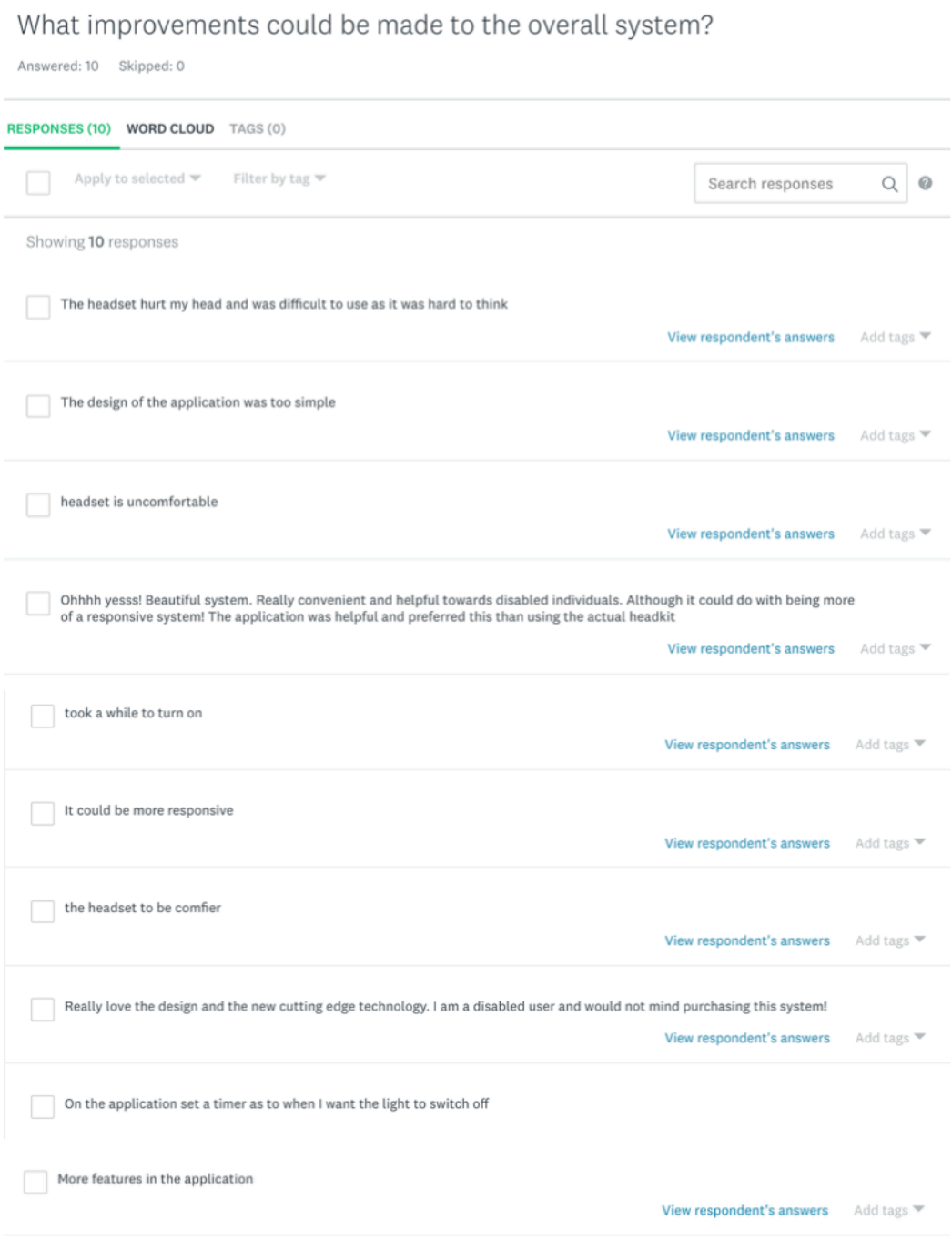


Figure 32 - Q10 result

The final question consisted of asking the user what improvement could be made. The feedback provided was interesting to see as the responses given were very different, however there was one common main feedback reported. 3 comments all included how the Neurosky headset was uncomfortable. The testing process approximately took 15 minutes which included a briefing and testing the system and the application. Another common area was users, in particular the younger people suggesting adding more advances features within the application. This is understandable as the youth are very familiar to the idea of applications and can understand how to use one, on the contrary the older people enjoyed using the application due to the simplicity as the questions written before this shows how satisfied they were. The other main response to improve the system was making the system more responsive. Some people who may have not used this technology could have found clearing their minds and thinking about turning a light on difficult. What is essential in this design is making sure the thought process is the same when using the training programme and then the actual programme. If the thinking is diffident, the value will then be altered hindering the responsiveness of the system. Therefore, an explanation as to why some individuals felt the responsiveness lacked.

1.33 SUMMARY

In regard to how the testing element contributed to the final system, it impacted on the final outcome dramatically. This is because it indicated any issues within the system that could be either tackled or noted for future development. The final questionnaire conducted towards the end of the project was the. Most interesting and effective method. This allowed me to find out the opinions of other different individuals and how they felt after using the system. Analytical feedback was also given which enabled me to gain an understanding of what future areas need to be further researched and altered.

6. EVALUATION

This chapter consists of an in-depth analysis of the SMART system final product. It will include scrutinizing the steps taken to achieve the outcome and discussing how well the systems aims and objective that were stated from the beginning were achieved. This section will also delve into any obstacles that were encountered throughout the development of the SMART system.

1.34 OUTCOMES ACHIEVED

The aims and objectives were repeatedly referred to when creating this system, from when designing the prototype to the end stage of testing the product. This guaranteed the project followed and achieved the main goals of the system.

The main purpose of this entire project stems down to the title which was to develop a software to enhance control for physically challenged individuals in a SMART home environment. Results and user feedback can provide evidence of this outcome being achieved, as from the questionnaire 100% of participants stated the system was suitable for disabled induvial, and the outcome of the system was achieved.

Furthermore, this means the SMART system was fully implemented successfully as it is suitable for disabled individuals and allows the user to take control of the light feature in a SMART home.

1.34.1 AIMS FOR THE SYSTEM

User does not have to physically move to switch on/off the light

When using the system, participants were immobile This was proceeded to create a similar scenario as to an individual who is physically unable to move. This provided an insight on how practical the system was and also allowed the developer to adapt the situation into a real-life setting.

Concluding that the overall system requires no movement once the set-up has been completed. 2 options were created for the user due to personal preference (Mobile application and the overall system), both of which again does not need movement.

System is able to communicate with the light system and an ECG headset

In order for this aim to be achieved APIs were used to allow the data transmission between the phidgets LED and the ECG headset. The connection between the 2 devices are stable as long as the Bluetooth is working which is dependent on the internet router. This aim can be shown by the 100% results feedback on how successful the system was, as in all scenarios the participants were able to switch the light on and off using brain data.

System is expandable for further development and enhancement

An API was created to allow developers use the existing prototype and prevent someone from taking the process perused when figuring out how to communicate the two devices together.

Methods that are incorporated within the final API design included critical basic functions that are needed to set up. It allows that developer to establish the connections between the different devices that are used within the design.

1.34.2 AIMS FOR THE MOBILE APPLICATION

An easy, friendly user experience

From feedback received by participants testing the system, 100% claimed the application was user friendly. The design element helped assist this aim by making sure the layout was simple, clean and straight to the point. Thus, an achievement within this system.

Ensure the user is able to communicate at any range and the data is kept secure

This was done by using MQTT, the protocol allows all users who are subscribed to the specific topic to communicate with the LED no matter how distant you may be from your SMART home system. MQTT is robust which corresponds to the feasibility where the objective was to build a robust, secure system by using messaging techniques. MQTT is a method used to communicate and pass data which is encrypted and secure therefore effectively achieving the aims.

1.34.3 AIMS FOR THE API

Easy to read and use even with no documentation

The API is inevitably a group of important methods used in the SMART system hence the aim was achieved as an API was developed and can be used by 3rd party for future improvements.

1.35 STRENGTHS AND WEAKNESSES OF THE OVERALL SYSTEM

Strengths	Weakness
2 separate components were created widening the options the user has to turn the light on or off. This is a good feature of the system and from the feedback given many users enjoyed using the application alongside.	Neurosky Headset is not reliable or accurate – This means the data collected is just an average which hider the system responsiveness.
The system is robust as the code style used has factored in any errors that could occur. If else statements are incorporated to avoid the system from crashing. This strengthens the system because it increases the responsiveness and provides a smooth interface.	The training programme fails to implement the unique attention level value into the main system automatically. This is done manually however once the set-up is done the value should not change but can be very inconvenient for the user.
Training programme implemented which is an extra advanced feature acts as a fundamental function within the system.	The headset is limited in range as the device required and passes data using Bluetooth.
Adequate testing was carried out including using the target audience as participants which therefore ensured the results were valid to the target population.	The headset requires batteries – not a charging aspect. This is a limitation of the system as it means the user will inevitably change batteries every 3 hours.
The overall system created is unique - There is no established, existing software then enables users to incorporate a SMART system in their homes to turn the light on and off.	The API could provide more methods for the developers to use

Table 6 - Strengths and weaknesses of the overall system

1.36 COMPLICATIONS ENCOUNTERED

Many complications arrised when developing this SMART system. The main issues stemmed from the Neurosky headset. This device is extremely problematic to use and connect if the individual is not familiar with it.
Some of the main issues that occurred was the initial headset given was an older model that was not compatible with all devices, hence a new updated model had to be ordered. Upon arrival the setup was easy yet the connectively caused immense distresses, after a while of attempting to solve the issue Neurosky support suggested using a fresh alkaline battery (carbon zinc battery) as this will cause an increase in connectivity. At last the issue was solved and the headset was able to connect to laptop device.

In addition to this the Neurosky headset required immense power so much so this effected the battery usage and drained the power extremely fast (3 hours were the maximum usage gained)

Another area of the headset which again caused compilations was the accuracy of the data recorded from the Neurosky Headset. The device can repeatedly be jammed on measuring the attention value of 0. This was later resolved as a training programme was implanted which factored out the 0's, this was necessary as 0 implied no brain data was being passed which caused no action of the LED.

1.37 FUTURE IMPROVEMENTS TO THE SYSTEM

If additional implantation was to occur external developers who look at this system could insert in these future development plans. This includes:

- Use a configuration file to store the unique average attention level which will then be placed into the main systems conditions.
  This is important as for the system to progress further the fundamentals need to be correctly working.
- Further developing the API would be recommended as there are some many factors that can improve this API. Before publication of this API to be used by developers the API design needs to be looked into in depth.
- The next addition of the mobile application would include adding more features, some users stated the application was simple therefore to enhance the application set features could be added. For example, incorporating a time feature where the user can pre-set up a fixed time as to when the light will be switched on or off. More security features should be added to before publishing this app, like a log in page that is password protected.
- In terms of the overall system the logical feature to implement next is controlling more than one light – due to this being a SMART home system, there are many lights included in a home. Having them all be controlled via your brain and mobile app would be revolutionary, as there is no existing established system that is able to turn multiple lights using brain activity.

7. CONCLUSION

The following will aim to summarise the Neurosky LED SMART system. A general overview will be included to clarify the main functions that helped the structure be successful. Any complications that occurred within the development of the process will be discussed and how, if doing the whole process again would be attempted differently. Lastly suggestions will be made for potential future enhancement.

The aspiration of this project was to investigate into existing SMART systems and build a prototype for a disabled induvial to use. This system would allow the user to take control of house hold appliances like the lights system and minimised the movement needed to invoke the action. The strength of this report lies within the results and feedback of the system and shows how successful the porotype was. The final data outcome is very valid as the sample of the participants included disabled, old, young, physically able individuals. This means the results can be extrapolated and generalised, suggesting the final product that aimed to satisfy disabled users' needs were achieved.

The substantial amount of the complications that arrised within the project was due to the Neurosky headset which caused a lot of frustration, however eventually the main errors were solved and arear where the project was affected by this was the accuracy of the measurement. Due to the attention levels not being precise it provoked the responsiveness of the programme to lack. However, taken this into consideration, the methodology used provides structure to the project and avoided other problems that could have occurred.

Acknowledging the limitations of this system is crucial as it will allow further progression to improve the functionally of the prototype. From the 3 main areas of the system overview, the most work is needed to execute on the API. The current api designed lacks complexity and flexibility within the methods when comparing against well-established APIs. The training programme also requires extra work as the sum average attention level calculated is unable to be stored and passed to the main system. This is a key feature to be implanted within the training programme as it will increase the efficiency and practicality of the system. Moving on to the main programme, the responsiveness could be improved and altered as many users found the existing system took a while to eventually invoke the light on or off, this is not practical for a real-life system and therefore a crucial function to target. Identifying the limitation is important as in

order to make this prototype at a publishing stage for users to potentially buy, and use in their home, the industry standards require the design to be flawless.

If the process was to be carried out again, key factors that restricted the final outcome would be illuminated. For example, not using the Neurosky headset. This headset is merely a gimmick for buyers to experiment and have fun with, trying to incorporate this product to a SMART system was difficult as the data is the core foundation needed to develop the system. Another area that would be approached differently is not underestimating the complexity behind making an API. This was a stage that was overlooked and rushed. Advanced prior research should have been conducted, which includes how to make a successful API and critically evaluating existing ones; to adopt their main functions.

Upon reflection the final product developed was a success and entailed all the features a SMART automated system should include. Future development is needed to enhance the prototype beyond the means of basic functionality and allow the individual to access more advanced features within the system.

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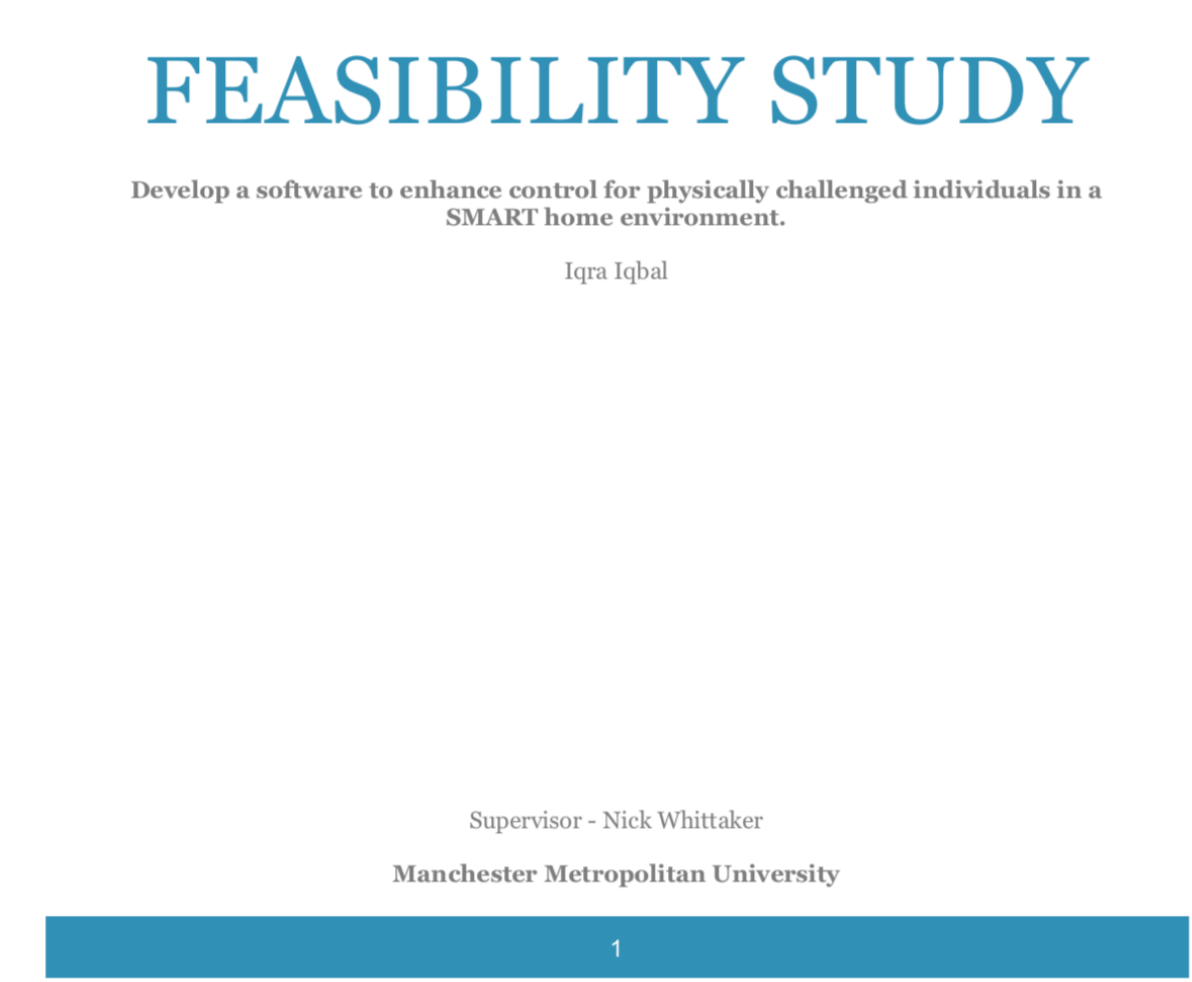
APPENDICES



FEASIBILITY STUDY

Develop a software to enhance control for physically challenged individuals in a SMART home environment.

Iqra Iqbal

Supervisor - Nick Whittaker

Manchester Metropolitan University

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Figure 33 - Feasibility Study

Iqra Iqbal - 16024003

TABLE OF CONTENTS

Figure 34 - Feasibility Study

Iqra Iqbal - 16024003

TITLE

- Develop a software to enhance control for physically challenged individuals in a SMART home environment.

COURSE-SPECIFIC LEARNING OUTCOMES

- Demonstrate an understanding of the principles of object orientation in the context of analysis and design;
- Apply project management techniques in order to plan, monitor and control a project;
- Explain and utilise fundamental object orientation concepts such as classes, encapsulation, inheritance and polymorphism and relate them to their practical situations including library and graphical user interface (GUI) development;
- Utilise in-depth, practical experience of the types of software tools that can support an object-oriented software lifecycle and develop this through practical experience;
- Utilise and understand methods and appropriate software tools for software development, including Software Testing Tools, Version Control and Project Management
- Demonstrate an understanding of the fundamental, basic issues of software testing;
- Evaluate and apply design patterns for the development of high-quality, object-oriented software systems;
- Build robust, secure distributed systems using techniques such as messaging, persistent storage, remote methods and components;
- Have a range of programming skills to apply in the software engineering environment;
- Demonstrate that they can participate in and complete a substantial project, involving research, planning, specifying, designing, building and testing software, integrating knowledge gained from the core units on the award.

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Figure 35 - Feasibility Study

Iqra Iqbal - 16024003

PROJECT BACKGROUND

Smart environment is rapidly evolving. So much so that owning a smart device in your home has now become a norm, due to the significant number of brands releasing devices as low as £30; Hence increasing the audience and accessibility. From voice activated devices to applications on your mobile, smart technology is a huge field which is constantly expanding. It is suggested by 2020, 20.6 billion devices will be connected, therefore it is an intriguing field to explore. **[1]**

A SMART (Self-Monitoring Analysis and Reporting Technology) object is a device which communicates to other drivers via Bluetooth, Wi-Fi, NFC etc. The Internet of Things (IoT) comes under this term of referring to objects that are connected via the internet, which can communicate between devices or systems. From this communication it allows you to collect information to analyse and use. This data can then aid with a particular task, for example DHL's IoT Tracking and Monitoring System. DHL is a huge company sending 1,282,000,000 parcels every year to over 220 countries, this is all possible due to SMART technology making transactions more efficient. **[2]**

Figure 36 - Feasibility Study

Iqra Iqbal - 16024003

Another aspect of SMART technology is Wearable Devices. Big companies such as Samsung and Apple have invested a lot of money in this sector; and introduced wearable technology like Apple watches which can track health, fitness and other convenient data. Small sensors are able to collect information about the user which can then be collected and displayed in a visual form via the internet.

Despite many other real-life examples of IoT, SMART homes are by far the most popular. The thought of living in the comfort of your home and being able to monitor and control devices without the effort required behind it, is one of the main reasons as to why this branch is expanding significantly. SMART home devices consist of Amazon Echo, Home kits (A framework that contains a variety of different smart apps that can be controlled via smartphone) Fridges, TV, Lights, Security etc.

Consequently, SMART technology can dramatically impact on a person who is physically unable to carry out certain tasks, therefore completely transforming their lifestyle – making them feel more independent as they gain control over their actions again. It could be as little as allowing people who have memory loss issues to be reminded about what tasks need to be done daily; or in a more severe situation, aiding a disabled person who is unable to move to turn off the lights, lock the door, open the blinds, all of which can be accomplished by a simple motion gesture sensor or an instinctual thought.

AIMS

The main aims of this project are:

- To introduce a smart home device for a disabled person, enabling them to take control of their household devices. Hence minimising the difficulties of their daily household struggles and enhancing their day to day environment - allowing them to become autonomous.
- Targeting a selected disability to ensure the software efficiently manages the task and prevents any difficulties. Also making sure the sensor used best fits the scenario however, at the same time using something other than voice activation control or a mobile application as there are many existing SMART models in this field already.

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Figure 37- Feasibility Study

- Develop an API (Application programming interface) to allow future development from third party businesses, thus leading to enhancements being made and improving the final outcome.

OBJECTIVES

1. **Research**
   a. Identify which type of disability this project will aim to target and what kind scenario to control
   b. Identify data input from an appropriate and best sensor, to target the selected disability effectively. This will be done by looking at the range of possibilities in the current field. (e.g. Neurosky/LEAP motion gesture sensor).
   c. Finding out if any current or similar models exist in this market already. If so, seeing if an API is accessible to use allowing me to build on this foundation instead of starting from the beginning to prevent wasting time.
   d. Identifying which language program options to use to communicate between devices, that are also suitable for a mac operation system.
   e. Explore and familiarise with the Phidgets development kit as this is one of the main components of the project.
2. **Plan and Design**
   Planning and designing are a crucial step which will allow the project to be monitored clearly, ensuring there is a clear structure in creating the software smoothly.
   a. Plan the basic fundamentals of how to connect the device with the Phidgets kit. This could be done by building a conceptual model entailing what component this system will have, how the system devices will connect to each other and what programming languages to use to communicate with the devices.
   b. Create a use case diagram (UCD) to visually represent the overview relationships of the user and the whole system in different scenarios.
   c. Design an overall systems design.

Figure 38- Feasibility Study

Iqra Iqbal - 16024003

3. **Develop and Implementation**
   a. Program the software that will connect the two devices.
   b. Implement the system.
   c. Develop an API for my system of the basic usability (A library of routines)
4. **Results and Check**

   There are a variety of testing procedures;
   a. Check using formal software engineering testing methods. For example
      I. Black Box Testing
      II. White Box Testing
      III. Checked by unknown testers
      IV. Stress testing
      V. Different individuals test the system – No personal data is recorded, and the questionnaire carried out is kept anonymous.
      VI. Test if the program effectively works with different scenarios and situations
5. **Evaluate**
   a. Any improvements which could enhance the existing system
   b. Read feedback given from testers
   c. Look at the results from all the tests as a whole to make final conclusions of the SMART device
   d. Produce a final report summarizing the whole project

PROBLEMS

Some difficulties that may occur are connectivity issues as various software could only support selected operating systems. Also set systems may be more compatible and work better on specific devices. Another big issue I could encounter is my code not working or being fixated on a problem, therefore preventing me from progressing and meeting my final outcome and aims.

REQUIRED RESOURCES

- Neurosky headset sensor/ LEAP motion gesture
- Phidgets development kit sensors – Lights/Motors
- PC/Laptop

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Figure 39 - Feasibility Study

Figure 40 - Slideshow presentation for showcase