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DIGITISING THE 20 METRE VISION TEST USING 3D IMAGE SCALING AND SPEECH RECOGNITION SOFTWARE FOR USER INPUT

by

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Project submitted as part of the requirements for the
award of MSc Software Engineering (Web
Development)

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i. Declaration

I, Edward Prasad declare that I am the sole author of this project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

Signed Edward Prasad

Date 24/01/2020

ii. Form of Consent

I, Edward Prasad hereby consent that my project, submitted in candidature for the BEng Computer Systems and Electronics degree, if successful, may be made available for inter-library loan or photocopying (subject to the law of copyright), and that the title and abstract may be made available to outside organisations.

Signed Edward Prasad

Date 24/01/2020

iii. Acknowledgements

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iv. Abstract

The overall aim of this project is to evaluate the effectiveness of recreating the minimum eyesight distance test for UK drivers using 3D image scaling and transformation and speech recognition software. The 3D application created was done so using the modelling software Unity and the speech recognition software used was accessed via an API provided by IBM Watson. This project used a phenomenological and inductive approach to research to gather both qualitative and quantitative data from questionnaires within experiments with randomly selected participants. In each experiment the participants were presented with various pieces of software that recreated the minimum eyesight distance test; the 3D application created for this project, a test created by Britannia Driving School and another called SeeDrive from EyeLab.

The results gained from the questionnaires and experiments found that a very small number of failures were recorded which mirrored the real values provided by the Driver and Vehicle Standards Agency and those presented by other researchers. The results of a Chi-square test proved the null hypothesis of “there is no relationship between age and preference of software” to be true. Each of the participants in the final experiments gave their responses to the question of whether or not speech recognition made the test easier in a Likert scale. The scores from the Likert scale showed that the majority of participants agreed or strongly agreed that speech recognition made the test easier to perform. The results lead to the conclusion that the 3D application created would be a suitable software to replace the physical minimum eyesight distance test compared to the Britannia Driving School and SeeDrive tests.

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1. Introduction

The first section of this document introduces the project and explains the reasoning why this project is being conducted. It also introduces the company that is working with this project.

The title of this project is “Digitising The 20 Metre Vision Test Using 3D Image Scaling and Speech Recognition Software for User Input” and was conducted in conjunction with the Driver and Vehicle Licencing Agency (DLVA). The DVLA holds over 80 million records relating to drivers and vehicles and are responsible for the licencing and registration of both drivers and vehicles in the United Kingdom [1]. The aim of this project is to evaluate the effectiveness of a digital version of the minimum eyesight distance test against the current physical test and currently available online tests.

The conclusion of this project was derived from various studies performed with the United Kingdom general public. These studies gathered information regarding the view the public had about the current available digital versions compared to the physical test and later the difference between the physical test and the version created during the development of this project.

Before a full driving licence can be issued, there are a variety of tests that the DVLA can require drivers to perform ranging from the common driving theory test to visual acuity tests for drivers of heavy goods vehicles and public service vehicles [2]. However, there is one test that must be passed by all who wish to drive a vehicle in the United Kingdom, that is the minimum eyesight distance test [2].

Also known as the 20-metre test and the number plate test, the minimum eyesight distance test is a visual readability test where the user is asked to read a UK number plate of standard printing from 20 metres away [3], [4]. Standard printing of number plates in the UK changed with the redesign on September 1st, 2001 making the number plates easier to read by decreasing the width on all characters from 57mm to 50mm [5], [6].

The minimum eyesight distance test must be performed at a driving test centre before a practical driving test. However, most drivers will only complete this test once during their driving lifetime [7]. A study conducted in South Wales in 2007 performed the minimum eyesight distance test with a sample size of 301 random motorists concluded that raising the awareness of regular eyesight checks is a crucial necessity. The authors coordinated with local police to safely conduct the study who confirmed that while breathalyser checks are common when a vehicle is pulled over, eyesight checks are not mandatory. Five of the 301 randomly selected drivers failed the test and were deemed not fit to drive and were therefore advised to seek an optometrist immediately for a full eyesight examination. The study also stated that the vast majority of the participants agree with the notion of introducing mandatory eyesight checks. This project will aim to build on this by providing a piece of software that allows any user to perform the minimum eyesight distance test at any time, therefore reducing the number of people that are potentially driving illegally.

The only requirements set by the government for people learning to drive are that they hold a valid provisional driving licence and are accompanied by a licenced driving instructor or a competent driver who is aged 21 years or older [8]. There is also a recommendation that learners familiarise themselves with the highway code [9] and when completing the form to apply for a provisional licence it states that the learner must be able to pass the minimum eyesight distance test [10]. However, there is no physical check and the government trust that people complete the form correctly and accurately. This means that there is a period of time where someone can be driving on the road with a provisional driving licence without having first officially completed the minimum eyesight distance test.

1.1. Aims and Objectives

The overall aim of this project is to evaluate the effectiveness of recreating the minimum eyesight distance test for UK drivers using 3D image scaling and transformation and speech recognition software.

The objectives of the project are as follows:

- To provide a system that allows any user to perform the minimum eyesight distance test as to ensure that every driver on the road is legally fit to drive with regards to eyesight distance readability.
- To gather user responses via studies and questionnaires with respect to the effectiveness of digital versus physical implementations of the minimum eyesight distance test.
- To use 3D modelling software to render and scale a number plate based on the user's screen resolution so the number plate appears 20 metres away.
- To analyse the results of the studies and questionnaires to determine if speech recognition is a usable method of input for the minimum eyesight distance test.
- To understand if there is a relationship between age and preference of software to complete the minimum eyesight distance test on a computer.

This section has been an introduction to the project by way of detailing the minimum eyesight distance test, introducing the company this project is working in conjunction with and explaining the overall aims and objectives of the project. The remainder of this paper is as follows. Section 2 contains the literature review where previous work with regards to the minimum eyesight distance test and speech recognition software is discussed. Section 3 details the various aspects of the research and development methodologies that were used, including risks and limitations and a description of how the experiments were conducted. Section 4 describes the design and implementation process used for the software development, while also

describing the design of the questionnaires. Section 5 discusses and analyses the results gathered from the experiments and questionnaires. Finally, section 6 provides a conclusion to this paper and section 7 presents a personal reflection of this project.

2. Literature Review

The previous section provided an introduction to this project. This section provides a detailed analysis of previous work in the areas of this project such as the minimum eyesight distance test and speech recognition software. The analysis performed in this section will bring to light the areas of the field in which this project can thrive.

2.1. Snellen Chart and Visual Acuity

Visual acuity is a fraction or decimal value given to represent eyesight distance [11] and is usually measured via the use of a Snellen chart [12].

The Snellen chart, designed by Dr Herman Snellen in 1862 [13], is the medical test used by optometrists to give a numerical value to a person's visual acuity [12]. When the Snellen chart is used by optometrists, a patient must read aloud a series of letters set out in rows where each row increases in the number of letters but decreases the size of the letters. The patient will be situated six metres away from the chart with one eye will be covered and will be asked to speak aloud any letters they are able to read, starting from the top of the chart [14]. The value obtained from this test is represented as a fraction such as 6/12. The numerator of the fraction represents the distance between the chart and the patient, while the denominator represents the distance at which a normal eye (an eye with a visual acuity of 6/6) can read the line of the chart at which the patient failed [15]. For example, a person with poor vision could have a visual acuity rating of 6/24 meaning that they can read from six metres what normal visual acuity would be able to read from 24 metres. The minimum eyesight standards set out by DVLA states that to be legally fit to drive any person must have a visual acuity of at least 6/12 [2].

2.2. Minimum Eyesight Distance Test

In the United Kingdom, every driver on the road must pass a series of tests before being issued a full driving licence. It is common knowledge that any potential driver must first pass a driving theory examination before successfully completing a practical exam. However, there is one

more test that every driver must pass to be legally allowed to drive which may have less renown in the public eye. This is the minimum eyesight distance test.

As described in law in “Amendment to disabilities prescribed in respect of Group 1 licences” all drivers must, in good daylight and wearing corrective lenses if needed, be able to read a number plate from 20-metres away [16]. There are two types of number plates that can be used in the minimum eyesight distance test: number plates that were created before 2001 and those printed after. For those printed prior to 2001 the characters are 79 millimetres high and 57 millimetres wide and must be read at 20.5 metres, while after 2001 the printing was changed so that the width was decreased to 50 millimetres and must be read at 20 metres [3], [16].

The minimum eyesight distance test is typically conducted at the beginning of the practical test. However, this is typically this only time the test is performed, even though it is a requirement for the entire time a person is operating a vehicle [7]. As this test is only completed once during a practical driving test, the onus is on the driver to inform the DVLA of any changing or detrimental eye conditions [2].

Therefore, there is a potential that a number of drivers on the road may not be fit to drive but are not aware. In addition to this there is a potential that learner drivers may not have good enough vision to be able to drive while they hold a provisional licence.

2.3. Previous Studies and Reports

2.3.1. Previous Work Regarding Eyesight within the General Public

There are a large number of people in the UK who are not aware that they are living with poor eyesight that could also affect their driving capabilities. A study conducted by YouGov in May 2011 found that of 2042 participants, ranging in ages from 18 to 55+, 25% said that, if all the presented options were the same price, they would prefer to pay for an eyesight test over other options, such as a spa treatment (25%) or a home teeth whitening kit (11%) [17]. However, when asked how often they perform an eyesight test only 21% answered once a year or more

and 36% said at least every two years. 33% stating at least once between every 4 and 10 years and alarmingly a full 10% stated they do not go for eyesight tests. In another question 10% stated they would feel safer driving if their eyesight was improved [17].

In July 2016 the Royal National Institute of Blind People (RNIB) and Specsavers commissioned YouGov to perform an online survey where the participants were asked various questions about their perception of eyesight [18]. Over ten thousand participants, aged 18 and above, completed the survey, providing the authors with a considerable sample size of the UK population. This allowed the authors to extrapolate the data to represent the entire population of adults in the UK. Similar to the findings in the previous eyesight survey conducted by YouGov in 2011, the survey conducted by RNIB and Specsavers found that a startling 21% of the population had not had an eyesight test within the previous two years of participating in the study. However, in comparison to this statistic, the authors found that 93% of participants concurred a person's eyesight could be improved with frequent tests [18]. This shows that while people understand the importance of eyesight and eyesight tests and will advocate others check their eyesight, the individual is reluctant to go to an optician and perform a formal eyesight test themselves.

A study conducted in a report published in The College of Optometrists interviewed a sample of the UK population consisting of 4352 adults who were asked various questions about their eyesight and their view on the importance of eyesight tests [19]. To further build upon the conclusions made in the previous reports, this report found that 52% of the participants stated that they view eyesight tests as 'very important' however 8% of the participants stated that they had not had an eyesight test in at least 10 years and a further 3% had never received an eyesight test. This is even further evidence of the need to increase the awareness of eyesight tests and this also shows how there is a large section of the general public of UK drivers who may be driving with subpar eyesight.

2.3.2. Minimum Eyesight Distance Test Studies

As these reports and surveys concluded that a greater awareness, and more frequent practices, of eyesight tests were needed with regards to driving the DVLA responded by launching a campaign to encourage drivers to take the minimum eyesight distance test [20]. The campaign created by the DVLA that implored drivers to take the minimum eyesight distance test to ensure they are legally fit to drive was launched in 2018 [21]. The campaign provides a number of techniques to measure the correct distance from five car lengths, eight parking bays or 26 steps for a man and 33 steps for a woman. As part of the release a survey was conducted and it was found that only 5% of the participants would use a tape measure, or equivalent, to measure the distance while the majority would use car lengths and paces. However, there is a clear flaw with measuring the distance without the use of a precise measuring apparatus as car lengths, parking bays and human strides can vary wildly. As vision and eyesight is such an important factor of driving it is important that the governing bodies remain focused on ensuring all drivers meet the standards to work towards safer roads. To this end, Dr Wyn Parry, a senior doctor at DVLA, said “The number plate test is a simple and effective way for people to check their eyesight meets the standards for driving ... having good eyesight is essential for driving so it’s really important for drivers to have regular eye tests”[20]. This is echoed by a post made by Dr Cathy Armstrong, the Vision Panel Secretary for Drivers Medical Group in DVLA, where she states that the DVLA advocate drivers undergo an eye examination every two years [22].

A study conducted by Anuradha et al. [23], in a layby off a primary A-road in Abergavenny, selected 301 drivers at random with help from the local police, and asked them to perform an impromptu minimum eyesight distance test. Drivers were asked to read a series of number plates at varying distances, but the authors specifically focused on the results of the number plate placed 20 metres away. Out of 301 drivers that were selected, 298 complied and performed the test. From the 298 participants, it was found that five individuals could not

correctly read the number plate that was 20 metres away therefore failing the minimum eyesight distance test and giving the study a failure rate of 1.68%. The authors extrapolated the data and found the five failures equated to 20,000 drivers in Wales and over 500,000 in the UK. Of the drivers that failed the test, three were aware they had to wear corrective lenses when driving, though two did not wear them for the test as they didn't normally wear them while driving; and the other two drivers were not aware that their eyesight failed the minimum eyesight requirement. From this study, the authors concluded that there is a lack of knowledge the general public has about minimum eyesight requirements for driving and therefore concluded that there needs to be a rise in awareness of these requirements and suggested that mandatory eyesight tests should be issued more frequently [23]. The results from this study correlate with the findings in the previous studies discussed therefore showing there is a gap of knowledge in the general public with regards to eyesight requirements when driving. In addition to the findings of the study conducted by Anuradha et al., the previously discussed studies have shown that the general public needs a more readily available minimum eyesight distance test to ensure they are fit to drive and do not have their licence revoked.

As part of a Freedom of Information (FOI) request made to the DVLA by FeelGood Contacts, it was revealed that in 2014 508 people failed the minimum eyesight distance test and this grew by 17% to 599 failures in 2017 [7]. In the same FOI request, it was found that over a five-year period from 2013 to 2017 inclusively, over 40 thousand driving licenses were revoked due to poor eyesight. While this data includes any and all eyesight related issues, including glaucoma and poor visual fields, it is representative of how prevalent eyesight issues are and the importance of frequent visits to an optician.

The minimum eyesight distance test is not only used to check if a driver has satisfactory vision before obtaining a licence, it can also be used to revoke a licence of any driver currently on the road. In 2013 the DVLA issued a new process, named Cassie's Law, that allows police officers

to issue an immediate minimum eyesight distance test when interacting with a driver after an incident such as a road collision or a driver being pulled over [24]. Cassie's Law states that if a driver does not pass the minimum eyesight test issued by a police officer then the officer has the authority to immediately notify the DVLA via email, rather than by writing or fax as previously, that the driver should have their licence revoked on grounds of poor vision [25].

While driving licences can be revoked due to poor eyesight, it is not always the case that visual acuity alone is the cause for a licence revocation. Over the years, a number of studies have been performed to determine if there is a link between visual acuity and driver safety. The following studies have all concluded that there is either a significant but weak relationship between visual acuity and traffic collisions or no relationship at all. Hofstetter performed a study where the visual acuity of 13,786 drivers was tested [26]; Rubin et al. questioned 1,801 drivers who were involved in collisions in Britain to determine what potential impairment caused the crash [27]; and Cross et al. gathered data with respect to visual impairments from 3,158 drivers across three states in the USA [28].

However, as reading road signs, interpreting other cars' movements and understanding the environment are very important while driving, it is still very important to test a person's visual acuity before a licence is issued [29], [30].

2.4. Minimum Requirements Outside UK

2.4.1. Europe

While the minimum eyesight distance test is the current standard in the UK there are other tests that other countries in the EU implement when a person obtains their licence. In a 2017 consensus paper produced by the European Council of Optometry and Optics, it was found that only Cyprus, France, the Netherlands and Norway have the same requirement of the minimum eyesight distance test as the UK. However, a number of countries, including but not limited to Austria, Ireland, Italy and Portugal require drivers to pass both a visual acuity and visual field

test. Belgium and Bulgaria require additional tests above the visual acuity and field tests, where the former requires a twilight vision test and the latter requires a colour vision test [31].

2.4.2. Rest of the World

Visual acuity is considered one of the most important factors when determining if a person is fit to drive in many countries even outside Europe. A study performed by Bron et al. revealed that in every state within the United States a visual acuity score of at least 6/12 is required to drive. However, there was found to be discrepancy with three states, namely California, New York and Iowa. California requires drivers to have a visual acuity score of 6/12 with both eyes open as is the case when driving, while New York and Iowa both require a minimum visual acuity rating of at least 6/12 in at least one eye [32]. Further to this, a report by Colenbrander and De Laey stated that the minimum requirements for a driving licence in Australia is the same as the UK in that the driver must have a visual acuity of at least 6/12 in both eyes, while in India the only requirement is for drivers to have a visual acuity of at least 6/18 [33].

2.5. Current Online Digital Minimum Eyesight Distance Tests

While there are a number of online tests that can simulate a Snellen test or other eyesight related tests that an optician would normally perform, there are currently only two tests online that attempt to emulate the UK's minimum eyesight distance test. One is hosted by Britannia Driving School [34] and the other is called SeeDrive [35] and was created by the vision research company EyeLab [36]. Both tests display a number plate on the screen and require the user to position themselves a certain distance away from the screen in an attempt to emulate 20 metres. The Britannia Driving School test is based on screen size and instructs the user to measure the width of their screen in centimetres (cm) and position themselves twice that distance away from the screen, for example if the width of the screen is 30cm then the user is positioned 60cm away from the screen. The SeeDrive test on the other hand, presents the user with a yellow line and requests the user measure the length of the line in centimetres and then for the user to sit

100 times further away, for example if the line is measured at 2cm then the user is positioned 200cm, or 2 metres, away from the screen. To input a response, a text box is made available to the user for the Britannia Driving School test, while there is no way to input a response in the SeeDrive test.

While these tests both provide a potential solution to digitising the physical 20-metre eyesight distance test, both have a multitude of problems. The immediate problem is that of ensuring the distance the user is positioned from the screen is correct. Unless a user has access to a tape measure, ruler or equivalent then there is no way to ensure that they are positioned correctly, which has major consequences for the validity and reliability of these tests. Additionally, for SeeDrive, if a user is located in a small room or has limited physical space around them then they might not be able to position themselves far enough away.

Another issue both tests face is how users input a response. As mentioned, the SeeDrive test does not have any way for a user to enter a response and as such whether the user passes the test or not is solely on the user to decide. This again lowers the validity of the test as a user could misinterpret some letters of the number plate but believe they passed the test.

As for the Britannia Driving School test, while it does provide a text box for input it obviously requires a user to enter their response via a keyboard. While there are many ways of entering data into a computer, particularly with regards to accessibility, the typical user will use a standard keyboard. The greatest issue with this is that if the number plate is not clear for a user when they are positioned correctly but is clear when they are closer to the screen, they may only be able to read the number plate correctly when inputting their response. If this is the case, then their response could provide a false positive where they believe they pass the test but would in actuality fail the physical test.

Furthermore, the Britannia Driving School test has an additional critical flaw due to the fact that the test requires Adobe Flash to be enabled to run. This is problematic since most major web browsers have Flash either not installed or disabled by default and Adobe will stop supporting Flash at the end of 2020 [37]–[41]. While some users will have the knowledge to enable Flash, many will not, and this limitation means that many users will not be able to load the test in their browser therefore decreasing usability and reliability.

2.6. Speech Recognition Software

When performing the current online minimum eyesight vision tests, users can be positioned from the screen such that they cannot reach the keyboard to input a response. As such, speech recognition software will be implemented to allow users to give a response when they cannot reach a keyboard.

2.6.1. History and Relevance

Speech recognition is the technique of identifying and interpreting components of spoken language, coupled with the analysis of the acoustic signals produced [42]. Speech recognition has been a large topic of research and development for a number of decades, with early iterations consisting of: the Shoebox from IBM in the early 1960s, which was able to interpret numbers between zero and nine inclusively [43], [44]; and the initial incarnation of the Dragon system in the 1970s [45], which has progressed into a globally used speech recognition software.

In recent history, the field has grown rapidly to become a common component of everyday life for a large portion of the population with the integration into cars [46], mobile devices and home automation, with virtual personal assistants such as Apple Siri, Microsoft Cortana, Google Home and Amazon Alexa [47], [48].

There are a many different methods by which speech recognition software has been created with the most common being the hidden Markov model (HMM) and more recently large vocabulary continuous speech recognition (LVCSR) [49].

2.6.2. Hidden Markov Models

The hidden Markov model is a statistical, probabilistic model that produces a sequence of symbols that can be used to interpret a stationary process such as continuous speech [50]. HMMs are based on the Markov process which states that given a known state, the probability of a future state is unaffected by any previous knowledge of the history of the system [51]. HMMs are used for speech recognition as a model can be trained, via a set of known states (previous words or phrases), to predict and interpret the best possible outcome of a future hidden state [52].

To predict the next state in a sequence, HMMs assign a weighting or score to each potential state, from which an algorithm can derive the most probable future state [53]. Providing a weight for each potential future state can be a computationally demanding task, therefore speech recognition software that utilises HMMs must find solutions to overcome this. One of the most frequently used voice recognition software technologies that utilises HMMs is the Dragon system by Nuance [45], [54], [55]. To combat the computational requirements of weighting every possible outcome, the Dragon system was designed with two data structures that hold all the knowledge of the system. One structure holds knowledge about the transitions within the system and the other stores the probabilities of the transitions of hidden states based on the known states [45].

Another solution to the computational requirements for speech recognition using HMMs is to create multiple HMMs for varying words or phonemes (elements of speech that combine to form words [56]) and concatenate them together creating a large matrix of the possible future

states [50], [57], [58]. An algorithm can then process each HMM separately while also transitioning between different models when needed [59].

2.6.3. Neural Networks and Deep Learning

The vast majority of early speech recognition applications made use of HMMs, though as the requirements of the applications grew, so too did the complexity. Initially, neural networks were implemented due to how quickly they can be trained with a vocabulary set and their ability to compute functions in parallel [60]. Neural networks can compute functions in parallel by clustering and categorising information within a hidden layer situated between input and output layers. With the faster processing power, neural networks produce a higher confidence layer than HMMs when used to predict future states as with speech recognition [61], [62].

However, a drawback of using neural networks for speech recognition is the fact that the system has to be retrained with a new set of phonemes and words when a new speaker is introduced, due to the nuances between different people's speech [63]. This is especially impractical for any speech recognition software that is designed to be used by more than a single person [64].

As the constant re-training of systems was unfeasible for large scale speech recognition systems, neural networks were made more complex and evolved into deep learning machines. Deep learning is the process where multiple hidden layers are added between the input and output layers of a neural network [61]. The output of one layer becomes the input of the next until the output layer is reached [65]. This communication allows an algorithm to produce an output with a higher confidence level than a neural network [62].

Although the actual implementation differs between software, the typical practice for deep learning speech recognition is as follows: as a user speaks, the phonemes of the utterance are passed into the model; each layer attempts to interpret what letter or word those phonemes correspond to; the output of each layer is then used as the input of the next, until the final output layer is reached; then a confidence score is provided alongside the final prediction [65].

The continuous interpreting at each layer allows speech recognition algorithms that utilise deep learning to produce an output with a higher confidence level than those produced via HMMs or individual neural networks. However, the recognition can still falter when attempting to interpret a pronunciation with multiple meanings [66]. The solution to this issue is to use semantic analysis [66].

2.6.4. Semantic Analysis and Large Vocabulary Continuous Speech Recognition

Semantic analysis is the process of utilising previous words or sentences in speech to predict what will follow or to understand which usage of a pronunciation is being used [67].

While listening to a sentence, humans implicitly perform semantic analysis as they can understand which definition of a pronunciation is intended [68]. For example, the words ‘their’, ‘they’re’ and ‘there’ are commonly pronounced similarly but have different meanings and usages which must be inferred by the listener.

While this is inherently performed by people, an algorithm or model must be trained to perform semantic analysis [69], [70]. Training a model to perform semantic analysis can be an arduous task due to the need to recognise spoken words and then combine them to determine the most appropriate usage of a pronunciation [71]. However, owing to their multi-layer structure, deep learning models can allocate certain layers dedicated to performing semantic analysis based on the recognised words provided by previous layers [72].

This use of semantic analysis is the gateway to large vocabulary continuous speech recognition (LVCSR). The premise of LVCSR is that a speech recognition program will be able to interpret speech of any length and of any inflection or accent and predict the most probable words with a high degree of accuracy [73]. LVCSR allows speech recognition systems to be implemented and deployed on a large scale as with Amazon Alexa, Apple Siri, Google Assistant, IBM Watson and Microsoft Cortana [48], [55].

As LVCSR is built upon previous speech recognition technologies – HMMs, neural networks and deep learning machines – it has a similar processing power requirement when being run on a single machine [74].

When the powerhouses of the technological industry, such as Amazon, Apple and Google, were creating LVCSR applications to compete with each other, they each solved the problem of needing excessive computational power by deploying their applications as cloud-based services [75], [76].

Implementing an LVCSR software in this way enables large-scale distribution as any individual could access the service at any time, with the only dependency being a stable internet connection [77]. This distribution can be observed in the real world as many homes worldwide utilise Amazon Alexa and Google Assistant, while Apple's Siri is pre-installed on all Apple products by default [78].

For these cloud-based applications to function, the background code that performs the interpreting and semantic analysis is hosted on a server and an application programming interface (API) is used to receive incoming data via the internet and return the result [79]. This opens the possibility of the system accessing more processing power as more machines, memory or processors can be added flexibly, therefore further increasing the complexity the system can handle [80]. This extra complexity handling allows LVCSR systems to interpret multiple languages together with multiple accents within those languages [81].

While this type of implementation allows for global distribution of software, there is a substantial drawback where the device must have an internet connection to send the recorded speech input to the service's API. This is a drawback that many large companies have conceded to accepting as the benefit of flexibly adding or removing processing power outweighs the potential that some users may not have access to the service at certain times.

As a device must be connected to the internet to access the relevant API there will always be a slight delay between the utterance and the response from the service [82]. While this delay can be minimised with faster and more consistent internet speeds as well as less complex utterances, it can also be increased to unacceptable levels with complex utterances. For most common uses of speech recognition, such as home automation or personal assistance, any delay will not have that big an impact.

However, when speech recognition is used for real-time instances, ranging from conversational algorithms in customer care to medical applications even to video game input, any delay could be costly and vastly decrease the user experience of a product [83]. This drawback is magnified and moves beyond user satisfaction when speech recognition is used for extremely time sensitive situations, such as to aid pilots with command and control in military aviation [84]–[86].

Opposing the notion of needing a cloud-based architecture to implement an LVCSR system Ivanov et al. found there is a possibility of running an LVCSR system on a single machine with the correct hardware [82]. The hardware the authors used was NVIDIA's Tegra K1 embedded system-on-a-chip, which is commonly used in high-end Android smartphones and tablets [82], [87]. The authors tested their implementation against an online speech recognition tool, the Kaldi online2-wav-nnet2-letgen-faster decoder [88], providing both with the LibriSpeech library [89]. The authors concluded that their implementation had both a lower latency response time and an accuracy of similar levels to the Kaldi online tool [82].

2.7. Conclusion

The purpose of this literature review was to understand the conclusions of studies performed based around the minimum eyesight distance test, discuss different aspects of speech recognition to rightfully use the most appropriate tool in the development and to review the currently available online versions of the minimum eyesight distance test. The review found

that substantial amounts of people have not checked their eyesight in a number of years or even since passing their practical driving test. There is a clear lack of knowledge in the general public with regards to the minimum eyesight requirements. This review discussed the currently available online tests that attempt to simulate the minimum eyesight distance test. It was found that the both tests require the user to physically position themselves away from the device and therefore could produce false positive results if the user leant forward to input their response. This review discussed the practices involved with speech recognition and evaluated how to best implement a speech recognition software. The research found that using a cloud based LVCSR tool would be the most beneficial as the detection accuracy was the highest and the time delay would be acceptable. The next section describes the various methodologies that were used in this project including both research and developmental methodologies.

3. Methodology

This chapter will discuss the various methodologies used for the research and development portions of this project. This section includes detail on the research philosophy, strategy and approaches that were used, in addition to stating the risks and limitations before discussing the validity, reliability and generalisability of this project. Data evaluation and collection are discussed here, as well as the development methodologies and resources that were followed and required.

3.1. Research Methodology

3.1.1. Philosophy

The philosophy used in this project was a phenomenological approach as phenomenology is the study of the phenomena, or events, that occur in the real world [90], [91]. Focusing on first person interactions and lived experiences within the real world, phenomenology lends itself to working with qualitative data [92].

An advantage to using a phenomenological approach is the ability to gain knowledge of an individual person's thoughts of a phenomenon presented before them [93]. This insight can then inform the direction of further research or development. Further to this, phenomenological research can allow for studies and interviews to be driven by a specific purpose from the researcher and then adjusted for further studies – initial studies being broader in scope while later studies are more specific and detailed [94], [95]. These advantages aided the creation and execution of multiple studies while also providing the ability to record both the immediate thoughts of the participants through both closed and open-ended questions.

While this approach provides flexibility with regards to the number of studies and interviews that can be performed, and the types of questions proposed within them, there are however some drawbacks. A common disadvantage is that users may provide misinformation or intentionally give false results, while another related disadvantage is that users are not

interested in the study in which they are asked to participate [96]. This project worked around these disadvantages by ensuring the participants were briefed before conducting the study, to ensure they are interested in the concept, and that they were supervised so as to not as easily provide purposefully incorrect responses.

A limitation of phenomenological research is time as any study that is to be conducted with this philosophy will take time to perform each phase, from gathering participants, performing the surveys and then analysing the data [94]. The limitations around time usage were taken into consideration in this project and as such the initial studies were performed before the development had commenced so the results could then also aid the development. To combat the limitation around difficulty in finding correlations and themes in the data, multiple studies were conducted with a number of participants throughout the project therefore gaining a larger sample size and wider array of responses.

The first study conducted questioned participants on their experience using the online minimum eyesight distance test from Britannia Driving School. The second focused on the comparison between the Britannia Driving School and SeeDrive tests, while the third compared the software developed for this project against SeeDrive.

3.1.2. Strategy

The research strategy this project employed was inductive, as studies with qualitative data responses needed to be conducted early on in the process [97]. Inductive research enables studies to be performed to gather qualitative responses which then inform a more general theory or hypothesis [98]. An advantage to an inductive approach is that the qualitative studies will provide varying responses therefore allowing for more potential theories to be scrutinised [99]. This advantage was used during this project as each study that was performed presented differing responses that allowed for greater depth in the analysis.

A drawback to an inductive strategy is that the conclusions drawn from the results can be vulnerable when extrapolating a generalisation from a sample to the whole population. It can only be assumed that a generalisation applies to a population rather than proven undoubtedly [99]. To manage this disadvantage, a wide variety of participants were chosen for the studies to facilitate having enough responses to more comfortably infer a conclusion for the population in general.

3.1.3. Approaches

3.1.3.1. *Literature Review*

The main approach to conducting the research in this project is the literature review. The literature review delves into the previous work carried out by others in the relevant areas, namely the relationship between eyesight and driving, the minimum eyesight distance test and speech recognition. The approach of a literature review was chosen as it provides insight into the fields of this project while also displaying any gaps in those fields that this project could fill.

3.1.3.2. *Software Development*

The aim of the software development was the creation of a digitisation of the minimum eyesight distance test in a 3D environment that incorporated speech recognition and screen resolution detection. The direction the development of the software undertook was informed by the findings of the literature review and the created software was then used to support the experiments and studies. The specific methodologies that were used, along with their benefits and drawbacks are discussed in section 3.2.

3.1.3.3. *Experiment*

This project utilised questionnaires within experiments to gather responses from users regarding the usability and viability of the created software in comparison with the currently available online minimum eyesight distance tests.

The experiments were initially used to gain understanding of participants views on the physical test against the currently available tests, namely those created by EyeLab and Britannia Driving School [34], [35]. The results gained from the initial surveys were analysed and the analysis supported the development section of the project.

Further experiments were performed throughout the project which compared the minimum eyesight distance test by EyeLab to the software created within the software development section of this project and another between Britannia Driving School and the created software. The results of each survey are analysed in more detail in Section 5.

3.1.4. Risks & Limitation

There are certain risks that are associated with this project that were recognised during initial research and were therefore avoided during the data gathering and development sections. Though there were however some limitations that presented themselves throughout the course of the project that were not foreseen.

As this project gathered qualitative data through experiments and questionnaires, there is always a risk related to human interaction, that any given participant could have negative personal or environmental effects that affect their responses therefore providing less reliable results. To avoid this risk, multiple experiments were performed at each relevant stage rather than just one. This allowed the results to contain a greater number, and a greater variety, of responses.

A very real risk to this project was the consistency of the experimental setup. As certain tests within the experiments required participants to sit at a specific distance away from the device, the anticipated risk was that there could be inconsistent performances between participants if they were not positioned at the same distance or using the same device. Therefore, when performing the experiments, the same Apple MacBook Pro was used to display the tests and

the same tape measure was used to measure the distance between the device and the participant's eyes.

A limitation within this project was based in the hardware and software that were used. This project was developed on an Apple MacBook Pro which limited the use of certain features that were originally planned to be utilised. The main risk was that the Microsoft speech recognition system provided through the chosen 3D modelling software, Unity, was only available on Windows operating systems [100]. This risk was not discovered during the planning of the project but rather was presented during development. To manage this limitation, research was conducted into other potential speech recognition software, including those provided by Google Cloud and IBM Watson [101], [102].

As qualitative data is based on human interaction and can be influenced by emotion, a general limitation is that it can be difficult to draw conclusions and patterns from the results. To work around this limitation, multiple experiments were conducted with multiple participants to gain as much data as possible to therefore have a higher chance of discovering patterns in the results.

As the data collection method in this project is a qualitative, phenomenological approach there are some associated limitations. The first limitations being time; each experiment must be conducted in person with a number of participants and if not carefully planned could cause major disruption to the rest of the project [94]. Another limitation is that which is associated with qualitative data, whereby the data collected needs to be interpreted in some way and conclusions drawn. As each individual person has different personal experiences, the responses can range wildly and so it can be difficult to find correlations and common themes when analysing the data [103]. This limitation can be minimized by increasing the sample size of the population partaking in the studies and interviews which then in turn increases the time needed before completion.

3.1.5. Validity, Reliability & Generalisability

3.1.5.1. *Validity*

Validity is used to determine if the data collection methods and instruments of a project do in fact collect the data the project intended to collect. Smith states “validity is defined as the degree to which the researcher has measured what it is designed to measure” [104, p. 167], while Babbie states “validity refers to the extent to which an empirical measure adequately reflects the real meaning of the concept under consideration” [105, p. 153].

The questionnaires used in this project aimed to understand which of two applications the participant’s preferred and why. During each experiment the participants were asked to answer preliminary questions of a questionnaire before performing the tests, after which further questions relating to the tests were answered. The questions that were based around the practical tests and the option for extra comments show strong validity as they are directly linked to the tests the participants performed.

It could be argued that as the participants perform one eyesight distance test before the other in each of the tests, then they are better equipped for the second, therefore decreasing the validity of the research. However, this line of reasoning does not hold much merit as an individual’s eyesight will not change between the tests, particularly when one is performed immediately after the other.

3.1.5.2. *Reliability*

Reliability is the concept of whether the results would be the same if the project was carried out by a different researcher but using the same methods [106].

The reliability of results throughout the course of the experiments was maintained as each experiment was repeated on different days and by focusing on the general ideas of the participants’ responses. This was done to counter the effects of subject error.

Subject error is where the same individual gives different results on different days depending on how they are feeling. Subject error of the individual can be extrapolated to encompass the wider sample of participants where any given person's experience on the day of testing could be positively or negatively affected therefore giving differing results [93], [106], [107].

Another aspect of reliability that can be scrutinised is observer error and bias. This is where the results are interpreted in a certain way because the researcher expects to see certain results. Therefore, different researchers on different days could expect different results, thus causing the results to be unreliable [107].

If this project were to be repeated, the researchers will have to take subject error and observer bias into account. They would have to ensure the tests are performed on different days and ensure the participants are comfortable and in a good state of mind before beginning the experiments, while remaining impartial when analysis the results.

3.1.5.3. Generalisability

Generalisability can apply to two different concepts in research; can the data be extrapolated to create a statement about the larger population, and can the results be applied to a different field or to solve a different problem [108].

Though the results of this project were gathered from a sample of the population, the sample contained wide ranges of age and visual impairments, and as such, the results could be analysed to devise a general statement about the population at large. The details of the results are analysed in full in section 7, but in general, the majority of the participants preferred the use of speech recognition to give their response. Therefore, a generalisation could be made that states, the majority of the population prefer speech recognition rather than the use of a keyboard to provide a response when performing the minimum eyesight distance test whilst stationed at a computer.

In terms of being able to apply the results to other fields or problems, the very fact that this project incorporates eyesight, the results lend themselves to the medical field. While the data gathered relates to the minimum eyesight distance test, the results could potentially be used as part of research into eyesight in general or, more specifically, into how different eyesight impairments affect reading from a screen.

3.1.6. Data Evaluation Methods

3.1.6.1. *Data Collection*

The data collected in this project was both qualitative and quantitative. Through the use of questionnaires, both fixed and open-ended questions were asked. The fixed questions lend themselves to quantitative data as the responses can be measured and analysed through the use of equations to give numerical values that can be compared, while the thoughts and sentiments of the open-ended questions are compared to each other for qualitative analysis.

Due to time constraints of the project and the need to complete two experiments before the development could begin, the initial sample sizes contained only ten participants each. For the experiments that were conducted after the completion of the development larger sample sizes were used as to achieve as wide a range of responses as possible. The participants for each experiment were chosen at random from the university campus as well as work colleagues. Each experiment was performed over multiple days allowing for enough participants to be gathered, and performing multiple experiments allowed for the qualitative data to be robust.

3.1.6.2. *Data Evaluation*

To evaluate and analyse the quantitative data collected via questionnaires, a chi-squared test was performed on the user's age and preference of test to determine if age affects preference of using voice recognition to input a response for the minimum eyesight distance test. A binomial test was also conducted to understand how many participants completed each

individual eyesight test. Graphs and tables represent the data gathered and are accompanied by a detailed discussion and analysis in section 5.

3.2. Development Methodology

3.2.1. Feature Driven Development

The software development methodology used for this project was the agile implementation of feature driven development (FDD). FDD was chosen as it provides the ability to focus on a specific feature of the project, ensures a given feature is fully implemented before moving onto another and it intrinsically provides milestones which can be used to measure progress and provide intermediate deadlines [109].

An advantage that FDD offers is the ability to easily separate a large problem into smaller, more manageable problems. As FDD requires a list of features which can be worked on individually, the problem at large is naturally separated thus easing workflow [110]. Separating features in this way additionally provides simple points at which milestones can be set, for this project the milestones were chosen to be set at the completion of each feature, though they could have been set at the completion of a group of features.

One of the main concepts of FDD is that when a milestone is achieved there is a version of the product that can be interacted with and showcased [110]. This tangibility was a key factor in deciding upon the methodology as it allowed for testing to be completed with a working version of the product even when certain features had not been implemented.

FDD is typically used as a development methodology for a team comprised of multiple developers and testers and as such provides the advantage of allowing for testing to be performed alongside development [109]. However, as this project was completed individually this advantage was not realised and the testing aspect of the development process took on a more traditional form.

3.2.2. Waterfall Methodology

While FDD was the main development methodology of this project, the more traditional waterfall was used during the implementation of each feature. The waterfall model states that each section of the software development lifecycle should be completed in its entirety before progress begins on the next section, that is, all development work must be completed before any testing can begin. It is that such sentiment of the waterfall methodology that was used during this project [111], [112].

Rather than following the waterfall methodology to complete every aspect of the development before testing began, it was followed within each feature set out by FDD. The FDD methodology allows for testing to be performed alongside the development but as this project was completed by an individual this was not feasible, alongside the fact that most of the features had to be completed in full before they could be tested.

3.3. Resources

3.3.1. Hardware Resources

Section 5 will discuss in greater detail how the hardware was used during the experimental setup, in this section however, the hardware that was used will be discussed and reasoned.

The development was conducted on an Apple MacBook pro that was provided by DVLA and the same laptop was used to perform each of the experiments therefore ensuring each participant had the same conditions when performing the tests. The inbuilt microphone of the laptop was used with the implementation of the speech recognition, no external microphone was used.

To test the scaling by screen recognition a number of different monitors were required; the Apple MacBook 15.4-inch built-in display with a resolution of 2880 x 1800, an ASUS MX239 24-inch display with a resolution of 1920 x 1080, a dell P2417H 23.5-inch display with a resolution of 1920 x 1080 and an Acer 23-inch display with a resolution of 1920 x 1080.

3.3.2. Software Resources

The 3D modelling software used in this project was Unity and for consistency, the version was kept at 2019.1.10f1 [113] and Visual Studio for Mac community edition version 8.3.5 was used to create the C# scripts [114].

3.3.3. Human Resources

This project needed to conduct a number of experiments with members of the general public. For two of the studies that were performed ten subjects were needed who were selected at random from the UWTSD campus. Another experiment conducted towards the end of the project required 20 participants who were selected at random from the UWTSD campus as well as colleagues from DVLA.

This section has detailed the various methodologies used in this project. This project employed a phenomenological philosophy and inductive approach to the research in conjunction with experiments and questionnaires to gather qualitative data. A literature review, development of a piece of software and experiments were all used to support the research conducted with regards to eyesight, the minimum eyesight distance test and speech recognition. This section also detailed the risks and limitations presented while also discussing the validity, reliability and generalisability within this project. Finally, data collection and evaluation techniques were described alongside any and all resources this project required. The next section will describe the process of the development, including design and implementation of the software. The next section will also discuss the design of the questionnaires and the manner in which they were conducted.

4. Development and Questionnaires

This section will detail various aspects of the software development and questionnaires. The design and implementation of the development will be discussed along with the software and technologies used. This section will also discuss the questionnaires that were conducted prior to, during and after completion of the development.

4.1. Development

4.1.1. Design

The aim of this project is to evaluate the effectiveness of recreating the minimum eyesight distance test for UK drivers using 3D image scaling and transformation and speech recognition software. Therefore, a piece of software was created that fulfilled the following high-level requirements; display a number plate 20 metres away, allow user to give a response verbally, inform the user if their response was correct and change the image size based on screen resolution.

To create a 3D scene that displayed a number plate 20 metres away, the 3D modelling software Unity was used. Unity was selected because it provides the ability to place objects in the scene with real world distances and measurements, therefore allowing the origin of the number plate to always be set at 20 metres. The main other software that was considered for this project was Unreal Engine as it also allows for real world measurements and 3D modelling. The major difference between the two pieces of software is the programming language they use to create custom scripts; Unreal Engine uses C++ while Unity uses C#. Thus, Unity was selected for the familiarity of the programming language as the timescale for the development did not allow sufficient time to learn the complexities of C++.

To display the number plate on the screen, the scene as a whole had to be thought out before implementation could begin. This involved deciding on how to display the number plate and the main question that arose here was: how much scenery should be put into the scene? The

answer to this question was revealed when the development was initially planned, and the timescale devised. The amount of time that would be needed to understand and learn the intricacies of creating large scenes in Unity was too great for the time available for the implementation, given that surveys were to be performed before and after the implementation. Ultimately, it was decided that the number plate would simply be displayed on a vehicle with a terrain underneath to add realism, as seen in Figure 1.

Then came decisions based around the user interface (UI) and how best to display instructions and messages to the user. This raised the problem of how the UI would be affected by different screen resolutions. Ultimately, the design favoured a simple UI display to the left of the vehicle allowing enough room for messages as well as the vehicle on any device or screen resolution.

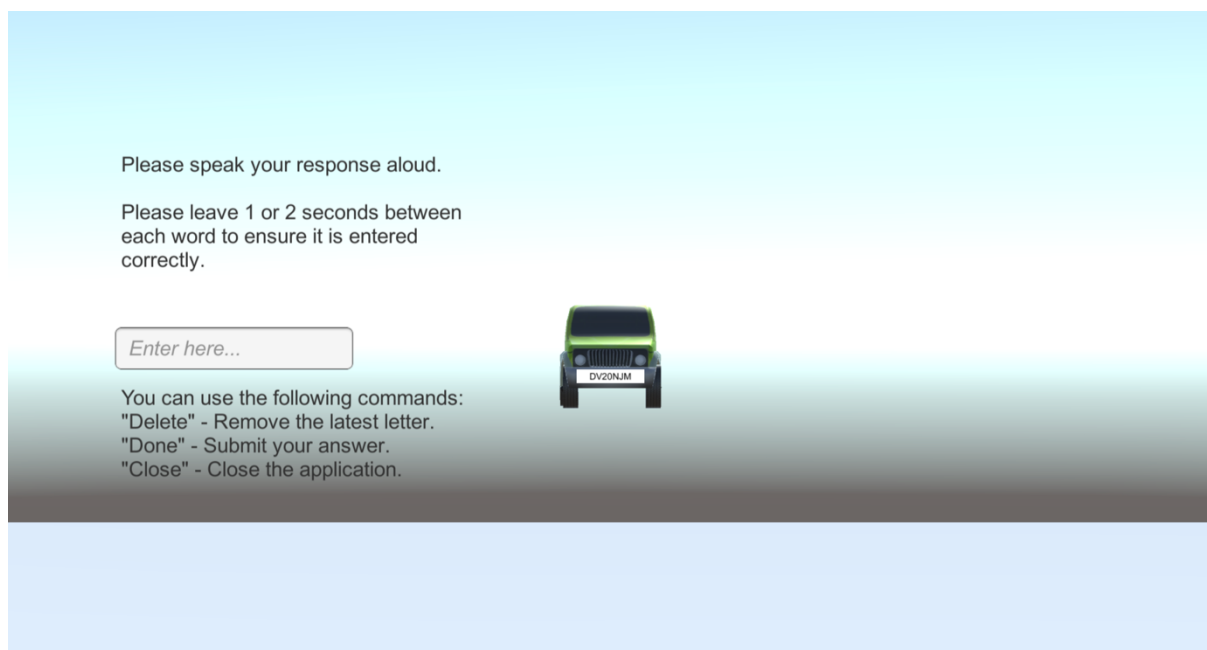


Figure 1 - 3D Application Full Scene

With regards to speech recognition, the design was based around how the words would be captured and in turn what happens when the words are interpreted. The initial design isolated certain words to be used as commands for the user to proceed through the system, such as 'done' to submit the response and 'close' to quit the application on completion. As it was thought to increase the usability of the system, the initial design of the system stated that the

user would use the NATO phonetic alphabet to enter the letter of the number plate they were reading (i.e. ‘Alfa’, ‘Bravo’, ‘Charlie’, ‘Delta’) [115].

4.1.2. Implementation

Once the modelling software was chosen, the decision was made to display the number plate on a vehicle to give the scene context and to increase user experience. The model used for the vehicle was a free model of a Jeep Renegade from the Unity Asset Store [116]. This was resized and scaled to emulate the actual dimensions of the vehicle and as such the number plate, once sized correctly, was added to the front of the vehicle increasing the realism of the scene.

The number plate itself was created in Blender; a software tool used to create 3D models which can then be imported into 3D scenes. The reasoning behind using Blender to create the number plate object rather than within Unity directly is due to the fact that Blender can isolate a single object ensuring no other objects in the Unity scene are affected. As each object in a scene in Unity has its own scale (its raw size) as well as the world scale (which dictates an object’s size relative to others) the isolation Blender offered was a great benefit as it ensured that no other objects within the scene were affected by the precise dimensions needed for the number plate. To ensure accuracy was maintained, the number plate was required to be the exact same size as the physical plate as stated by the DVLA, 520 millimetres in width and 111 millimetres in height. The text on the number plate was randomly generated with two random letters that excluded ‘I’, ‘Q’ and ‘Z’, a random series code (i.e. 19, 20, 68, 69) and three more random characters that excluded ‘I’ and ‘Q’. The exclusion of the certain letters was used to ensure that the DVLA rules for the creation physical number plates were followed [6].

When implementing the speech recognition, the initial planning and research was focused on using the speech recognition software built into Unity. However, when attempting to implement this, it was found that the software was only supported by Windows 10 so as this project was developed on an Apple MacBook Pro, a new speech recognition software was

needed. The simplest solution was to use a public speech recognition API, and the two major systems that were considered were Google Cloud and IBM Watson.

IBM Watson was chosen as the API to use as the implementation was less arduous and a large amount of code was provided through GitHub to allow for more customisation. Once configured in Unity, the source code listened to speech from a user, sent the data to the API and returned with the interpretation. Access to the source code allowed for the response to be intercepted and passed into custom methods to then perform relevant actions.

The implementation for speech recognition deviated from the design slightly as the decision was made to use the first letter of a spoken word as the input for a number plate letter rather than the NATO alphabet equivalent. This was done for a number of reasons: first, the code was more efficient; second, not all users would know the NATO alphabet; and finally displaying the NATO alphabet in the UI would clutter the screen potentially obscuring the vehicle.

Once the speech had been interpreted and returned by the API it was examined so the relevant steps could be followed. If a number was returned, then the number as a whole was added to the response; if the command 'delete' was returned, then the last character of the response was deleted; if the command 'done' was returned, then the full user response was checked for correctness; if the command 'close' was returned, then the application will close; and finally, if the response did not contain a number or a command then, the first letter of the string was added as the users response, even if the string contained multiple words.

An interesting problem that occurred during the implementation was how to correctly interpret spoken numbers when a user is reading the series code of the number plate. When a number was uttered, the API would predominantly return the numerical value, however, some numbers would not return their numerical value when uttered alone as there was no context for the program to decipher which implementation to use. In this case the response would include the

string of a different word with the same pronunciation. For example, the utterance of ‘one’ would occasionally return the string ‘won’, and ‘two’ would more often than not return ‘to’ or ‘too’. To solve this issue, each number from zero to nine was tested and those that consistently returned a string rather than the numerical value were added to an array. Zero to nine were the only numbers treated in this manner as any number above ten spoken in its full pronunciation would always return the numerical value.

If the user’s response was correct, then a successful message was displayed and the number plate was updated and if it was incorrect, then an unsuccessful message was displayed, and they were allowed another attempt at the same number plate.

4.1.3. Questionnaire

There were a number of questionnaires that were used in this project to gather data and inform the direction of the development. The questionnaire that was to be created for the first experiment was initially designed to gather participants’ opinions on the SeeDrive test, however, this was disrupted by the fact that the SeeDrive test was temporarily taken offline. This setback required a new questionnaire to be created which just focused on the Britannia Driving School test, as seen in Appendix A.

Once the first experiment had been concluded it was found that SeeDrive had once again become publicly available. This allowed a second experiment to be conducted which utilised the initial questionnaire where the participants were asked to perform the SeeDrive test followed by the Britannia Driving School test. The questionnaire used for this experiment can be found in Appendix B. This test improved on the lessons learnt from the preliminary test as this test recorded more information, such as whether or not the participant passed each test on two separate attempts.

Two more questionnaires were created for use in two separate experiments where the first compared the software developed for this project against the Britannia Driving School test and

the second against SeeDrive, these can be seen in Appendix C and D respectively. These experiments were performed separately as to gather the largest sample size possible and to ensure the experiment remained a reasonable length as to safeguard against the participants losing focus [117], [118].

For each sample of the population used in each experiment the participants ranged in age from 17 to over 61 and were chosen at random with the aim of creating a sample that represented the population as a whole in both age and eyesight limitations. During each experiment the participants completed various initial questions that were used to record their age and any eyesight impairments while also understanding their experience with the physical minimum eyesight distance test.

After this, the participants were presented with the relevant minimum eyesight distance test software for that experiment before moving onto the second. The first experiment saw the participants use the Britannia Driving School test in isolation, the second presented Britannia Driving School then SeeDrive. The final two experiments both started with the 3D application followed by SeeDrive in the third, and Britannia Driving School in the fourth. Once the participants had performed the tests, they were presented with closed and open-ended follow-up questions that can be seen in the appendices A through D.

This section has described the various stages of the design and implementation of the software development as well the design of the various questionnaires that were used in the experiments. The initial requirements that were to be completed and preliminary thoughts and plans are outlined in this section along with how the implementation proceeded with details on how and why the development deviated from the design. The design of the questionnaires is also discussed in this section which includes the reasoning behind multiple questionnaires being

used across different experiments. The next section will analyse the results gathered from the experiments and will discuss the implications.

5. Results and Discussion

This section discusses the results of the questionnaires and experiments by first analysing the success and failure rate of each experiment using the Binomial theorem. Afterwards, a chi-square test is performed to discover if there is a relationship between age and preference of minimum eyesight distance software finally followed by a discussion regarding Likert scale responses with regards to speech recognition software.

The findings of each analysis are examined in particular with their reference to the aims and objectives set out by this project. In this section the term ‘3D Application’ refers to the software application created for this project as described in section 4.

5.1. Pass/Failure Rate

During the experiments, the passes and failures of each participant were recorded both with and without glasses or corrective lenses where appropriate. Unfortunately, while four experiments were performed, no pass or fails were recorded in the first experiment. This oversight has resulted in a lower overall sample size for this analysis than originally anticipated. However, this setback is not as impactful as it may have potentially been due to the fact the first experiment only focused on the Britannia Driving School test which participants carried out in two other experiments.

The below tables (1, 2 and 3) show the number of passes and failures for each experiment, where participants wore their glasses they use for driving if needed, though they were not tested without their glasses. To gain a greater understanding of these results, while also increasing the sample size, the results for each software were combined and are displayed in Table 4, Table 5 and Table 6.

Table 1 - Pass/Fail Scores for Britannia & SeeDrive from Second Experiment

Britannia Driving School					SeeDrive				
Without Glasses		With Glasses			Without Glasses		With Glasses		
Pass	Fail	Pass	Fail	Total	Pass	Fail	Pass	Fail	Total
6	2	10	2	20	5	3	9	3	20

Table 2 - Pass/Fail Scores for 3D Application & SeeDrive from Third Experiment

3D Application					SeeDrive				
Without Glasses		With Glasses			Without Glasses		With Glasses		
Pass	Fail	Pass	Fail	Total	Pass	Fail	Pass	Fail	Total
5	1	14	0	20	4	2	14	0	20

Table 3 - Pass/Fail Scores for 3D Application & Britannia from Fourth Experiment

3D Application					Britannia Driving School				
Without Glasses		With Glasses			Without Glasses		With Glasses		
Pass	Fail	Pass	Fail	Total	Pass	Fail	Pass	Fail	Total
6	0	13	1	20	5	1	13	1	20

Table 4 - Total Pass/Fail Scores for Britannia Driving School

	Britannia Driving School				
	Without Glasses		With Glasses		
	Pass	Fail	Pass	Fail	Total
	11	3	23	3	40
Percentage	78.57%	21.43%	88.46%	11.54%	

Table 5 - Total Pass/Fail Scores for SeeDrive

	SeeDrive				
	Without Glasses		With Glasses		
	Pass	Fail	Pass	Fail	Total
	9	5	23	3	40
Percentage	64.29%	35.71%	88.46%	11.54%	

Table 6 - Total Pass/Fail Scores for 3D Application

	3D Application				
	Without Glasses		With Glasses		
	Pass	Fail	Pass	Fail	Total
	11	1	27	1	40
Percentage	91.66%	8.33%	96.43%	3.57%	

The total scores give a more explicit picture with regards to the success rate of each software. As can clearly be seen from the above tables, the 3D application created for this project had the highest pass success rate out of the three pieces of software both from participants who wear glasses and those that do not. The failures recorded for the 3D Application were recorded by different participants while both Britannia Driving School and SeeDrive saw certain participants fail consistently therefore contributing to the higher failure rates. The higher failure rates of the Britannia Driving School and SeeDrive tests could be influenced to the fact that the participants had to position themselves certain distances away from the screen therefore potentially not being at the correct distance.

To give more context to these results the binomial theorem can be used to find the probability of actually getting these results. The binomial theorem requires the following: that there are a fixed number of tests, each test is independent of any others, there are only two possible outcomes and the probability of each outcome remains the same between each test [119], [120]. Each of the conducted experiments met these requirements as: each experiment had exactly ten participants, who each performed the tests of each software twice; each experiment was conducted in isolation so could not be affected by any previous participant's responses; the only possible outcomes of the tests are pass or fail; and the probability of a pass or fail for each test in the experiments is always 50% or 0.5 probability.

The binomial theorem equation is as follows:

$$P(x) = \frac{n!}{(n-x)!x!} p^x q^{n-x}$$

Where:

- n is the sample size,
- p is the probability of a pass,
- q is the probability of a fail ($1 - p$),
- x is the current value.

Performing this equation multiple times from $x = 0$ to $x = n$ will create a binomial distribution graph. The binomial distribution graph for 40 participants with an outcome probability of 0.5 can be seen below in Figure 2.

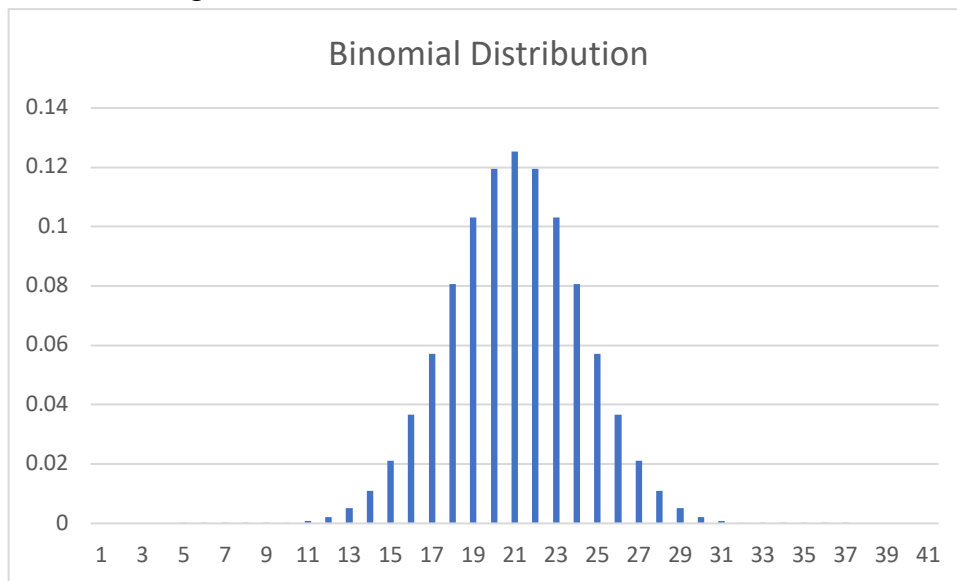


Figure 2 - Binomial Distribution for 40 tests with probability of 0.5

This graph can be used to find the probability of achieving the pass or failure scores from the above tables. The total number of failures for the 3D Application of participants, both with and without glasses, numbers only two which is an incredibly low probability, as shown by Figure 2. Using $x = 2$ in the above equation, the actual probability is 7.09406E-10.

To add some relevance to this probability, as found in the literature review, in 2017 a total of 599 individuals failed their practical driving test because they failed the minimum eyesight

distance test [7]. As the Driver and Vehicle Standards Agency (DVSA) publish how many theoretical and practical driving examinations are performed each year, the percentage of failures can be found. In 2017 1,965,972 practical tests were performed [121]–[124], therefore the 599 failures due to failing the minimum eyesight distance test is a miniscule 0.03%.

To get even remotely close to this percentage, the experiments performed in this project would need sample sizes in the tens of thousands. Therefore, it can be concluded that the 3D application is an accurate representation of the physical test based on the number, and probability, of failures.

5.2. Age vs Preference of Software

One objective this project set out to understand is whether there is a relationship between age and a preference of software used to perform the minimum eyesight distance test on a computer.

To achieve this, each participant was asked which software they preferred once they had performed the tests of each software. The second, third and fourth experiments were used for this analysis as they each compare two different minimum eyesight distance test software, whereas the first experiment was only concerned with the Britannia Driving School software.

The tables detailing the age distribution against preference of software can be found in Appendix E. Table E-1 shows age against Britannia Driving School test and SeeDrive, Table E-2 shows age against the 3D application and SeeDrive and finally Table E-3 shows age against the 3D application and Britannia Driving School. Table 7 below shows the total scores for each participant's preferred software distributed against the age range of which they were a member, Figure 5 is a visual representation of the same data.

Table 7 - Total Observed Values of Age Against Software Preference

Age	Britannia	SeeDrive	3D	Total
17-20	0	0	2	2
21-30	3	3	4	10

31-40	2	2	2	6
41-50	2	0	2	4
51-60	3	0	5	8
61+	0	0	0	0
Total	10	5	15	30

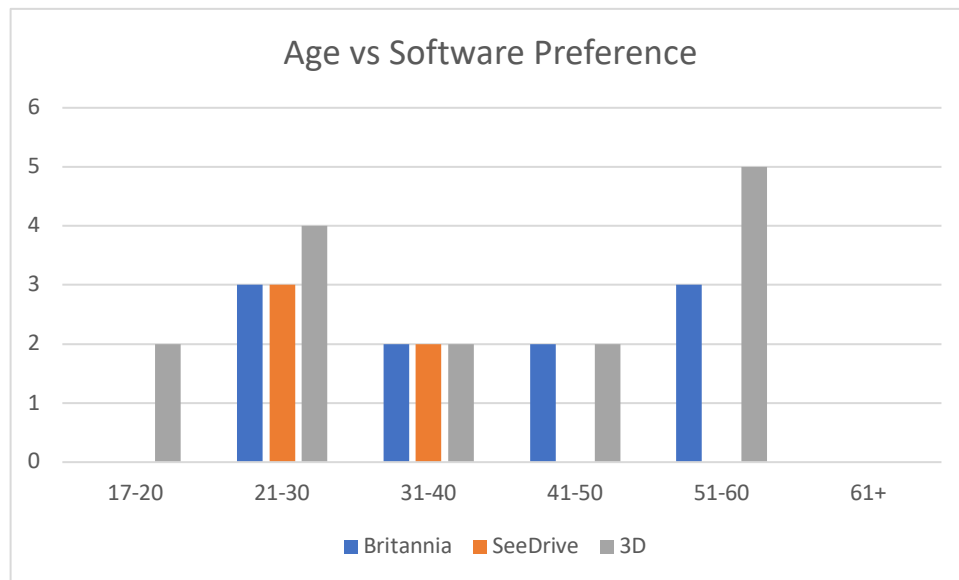


Figure 3 - Age vs Software Preference

This table can be used to perform a Chi-squared (χ^2) test of independence. This test is used to determine whether there is a relationship between certain variables. The Chi-squared equation is the sum of the square of the difference between the observed and the expected values divided by the expected values, and is as follows:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where:

- O_i is the current observed value,
- E_i is the current expected value.

This equation provides a Chi-square statistic that can be used to find a probability (p) value that can be used to determine whether to accept or reject a hypothesis. There are two hypotheses that must be created to allow this equation to perform correctly: the null hypothesis (H_0), which

assumes no relationship or association between the variables; and the alternative hypothesis (H_a), which assumes there is a relationship or association.

To determine whether to accept or reject the null hypothesis, an alpha (α) value must be selected; this a percentage that the Chi-square statistic is compared against representing the confidence level of the hypothesis and is typically either 0.1 (10%), 0.05 (5%) or 0.001 (1%). Once the chi-squared statistic has been found, it is compared against a Chi-squared critical value table at the chosen alpha level at a certain degree of freedom (df). The degree of freedom is found by multiplying the number of rows minus one by the number of columns minus one, $df = (r - 1)(c - 1)$. The table is typically very large and so the first ten rows are shown in Table F-1 in Appendix F.

If the Chi-squared statistic at the degree of freedom and alpha level is higher than the number in the corresponding cell then the null hypothesis can be accepted, conversely the null hypothesis can be rejected if the Chi-squared statistic is the lower of the two. The actual p-value can be found and then compared against the alpha level directly, however, this is a difficult calculation, so tools have been created to simplify this process, such as Microsoft Excel. If the actual p-value is used then the null hypothesis is rejected if the p-value is lower than the alpha value, and by extension it is accepted if the p-value is greater.

To apply this to the data in Table 7, a null and alternative hypothesis must be devised and are as follows:

H_0 = There is no association between age and preference of software to perform the
minimum eyesight distance test digitally.

H_a = There is an association between age and preference of software to perform the
minimum eyesight distance test digitally.

The degree of freedom for Table 7 is eight – $(5 - 1)(3 - 1) = 4 \times 2 = 8$ – and the alpha level is set at 0.05. Using the Chi-square equation for Table 7, the Chi-square value is 7.2583333. The critical table in Appendix F with eight degrees of freedom and a 0.05 alpha level gives 15.51. As 7.2583 is less than 15.51 the null hypothesis is accepted, therefore it can be concluded that there is no relationship between age and software preference to perform the minimum eyesight distance test.

As this shows there is no relationship between age and preference of software with which to perform the minimum eyesight distance test, it can be concluded that the 3D application would be a viable software for the wider population of drivers to use to ensure they meet the minimum eyesight requirements for driving. This conclusion also meets the objective set out at the beginning of this project that states “To understand if there is a relationship between age and preference of software to complete the minimum eyesight distance test on a computer”.

5.3. Speech Recognition Before and After Implementation

During the experiments that were performed before the implementation of the 3D application, the participants were asked how strongly they agreed with the statement that speech recognition could be used to make the software better and easier to use. As for the tests after the implementation, because the participants had used speech recognition while performing the 3D application, they were asked if they preferred speech recognition compared to the input capabilities of the other software they used.

The participants were presented with a Likert scale to supply their responses. A Likert scale is a tool used in questionnaires where a certain number of fields are presented that represent a scale without tangible values. The Likert scale is most commonly represented as ‘Strongly Agree’, ‘Agree’, ‘No Response’, ‘Disagree’ and ‘Strongly Disagree’. The scale is used to give the user a comfortable range with which they associate their experience, however, there is a drawback to the Likert scale where a user believes themselves to be between two answers. To

combat this drawback an open-ended section can be provided where participants are able to provide extra detail if they desire. This implementation of the Likert scale can be seen in the questionnaires in Appendix A – D.

The results of the Likert scales were compiled and are shown in Table 8 and Table 9 below and are visualised in Figure 3 and Figure 4.

Table 8 - Speech Recognition Likert Scores Prior to Implementation of 3D Application

Likert Value	Score
Strongly Agree	3
Agree	11
No Response	4
Disagree	1
Strongly Disagree	1
Total	20

Table 9 - Speech Recognition Likert Scores After Implementation of 3D Application

Likert Value	Score
Strongly Agree	6
Agree	8
No Response	2
Disagree	3
Strongly Disagree	1
Total	20

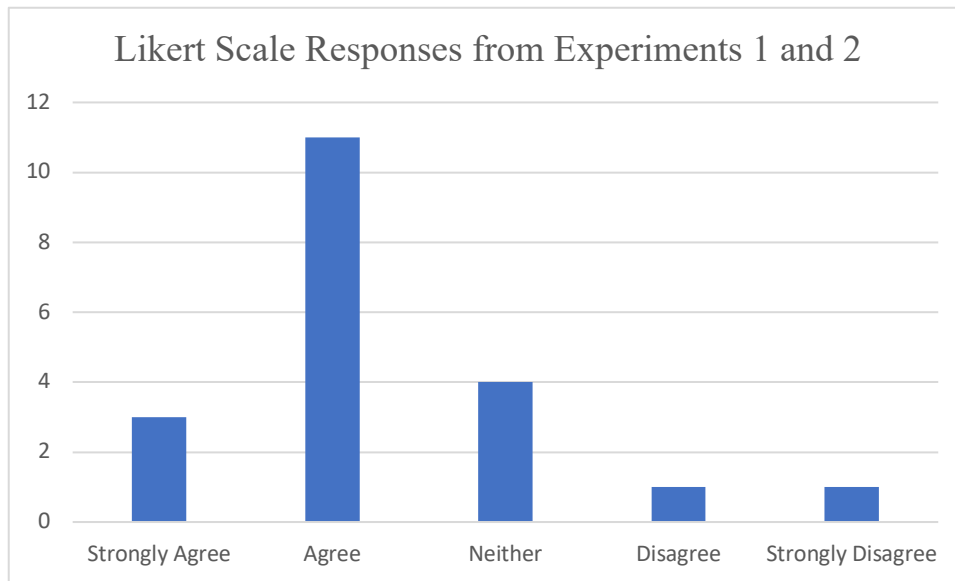


Figure 4 - Likert Scale Responses to "Would Speech Recognition be Beneficial?"

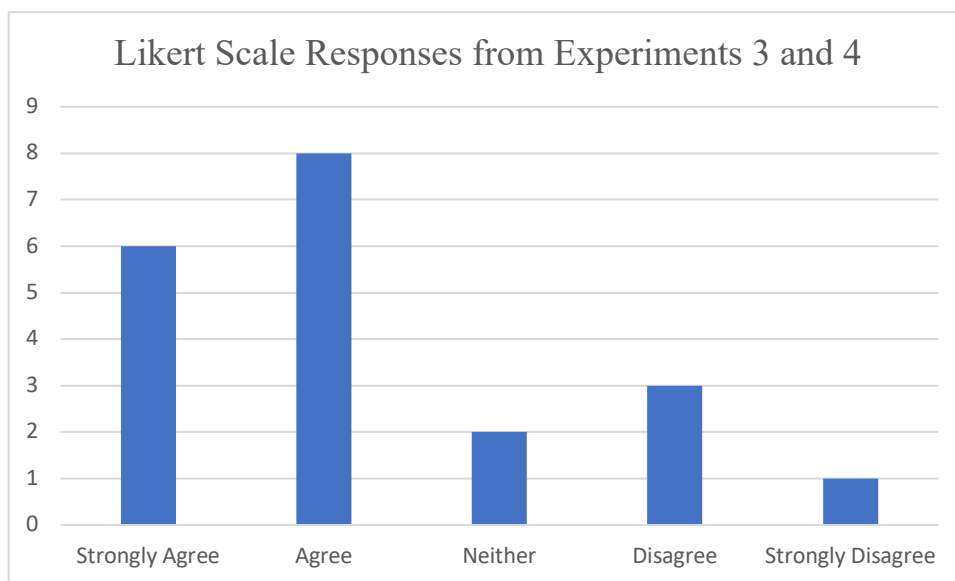


Figure 5 - Likert Scale Responses to "Did Speech Recognition Make the Test Easier?"

These results show that 70% of participants, without using any speech recognition, agreed or strongly agreed that they would prefer the minimum eyesight test to implement a speech recognition option. While 20% had no preference and 10% disagreed or strongly disagreed. Similarly, 70% of participants who used speech recognition software agreed or strongly agreed that speech recognition made the minimum eyesight distance test easier to perform than the

tests that did not employ such software. Moreover, 10% had no preference while 20% disagreed or strongly disagreed.

This shows that the participants' preferences were well founded, and speech recognition software is a viable tool to increase usability and user experience of a digitised version of the minimum eyesight distance test. However, the results also show that using speech recognition software in reality is more polarising than just a thought experiment as more participants found the speech recognition not as helpful than the first sample speculated. This is expounded upon by the responses left by those such participants, with one stating they were unsure if the software was recognising "background noise" as "it kept picking up different letters than what I was saying." and another expressed discontent as they "had to say delete a number of times".

5.4. Conclusion

This section has been an analysis of the results gathered via questionnaires within multiple experiments. The binomial theorem was used to deduce the probability of achieving the results the experiments produced which was then compared against the values discussed in the literature review. It was found that the probability of achieving the observed number of failures was comparable to the 599 failures of 1.97 million practical tests that occurred in 2017. A Chi-square test was then performed between age and the participants' preference of software. This test found that there was no statistical relationship between age and software preference within the sample. Finally, the Likert scale responses to questions regarding speech recognition between participants who did not use such software against those that did was analysed. It was found that the majority of participants who did not use speech recognition software agreed that it would be a beneficial addition, and the majority of participants who did in fact use the software agreed that it made the minimum eyesight distance test easier to perform.

From the analysis of the results it can be concluded that the 3D application software created for this project is a viable, accurate and usable implementation of a digitised version of the

minimum eyesight distance test. The next section is the final conclusion of this document that will summarise each section and concisely reiterate the results described in this section and the conclusions to which they led.

6. Conclusion and Recommendations

6.1. Conclusion

This section is a final conclusion to the paper as a whole and will summarise each of the previous section while reiterating the conclusions drawn from the results of the experiments and will discuss how the objectives of this project were realised.

Section 1 introduced this project by introducing the DVLA as the company this project worked alongside and stated that the aim of this project was to evaluate the effectiveness of recreating the minimum eyesight distance test for UK drivers using 3D image scaling and transformation and speech recognition software. Section 2 provided a review of the literature surrounding this project including speech recognition software and experiments surrounding the current minimum eyesight distance test. Section 3 described the methodologies that this project employed, including feature driven development and the potential to utilise both qualitative and quantitative data. Section 4 described the design and implementation of the software while also discussing the questionnaires used within the experiments. Section 5 analysed the results gathered from the experiments by performing a binomial theorem test and a Chi-squared test.

The development of the 3D application was conducted within Unity and used speech recognition software made available through IBM cloud. The development was then compared against the online minimum eyesight distance tests from Britannia Driving School and SeeDrive. This allowed experiments to be performed where participants were asked which software they preferred and whether they felt speech recognition was a beneficial tool.

The results of these experiments were analysed first by using the binomial theorem test that showed the 3D application has a similar probability of users failing the minimum eyesight distance test as the physical test based on the number of test failures in 2017. Secondly, the Chi-squared test established that there was no relationship between age and preference of software and concluding that the 3D application would be viable to allow the whole population

of drivers to use the software, regardless of age. The final piece of analysis focused on speech recognition; whether participants believed it would be a beneficial addition to the test, and whether it was beneficial after using speech recognition software. These tests were used to arrive at the conclusion that the 3D application created in this project is a suitable and user-friendly software that can be used to replace the physical minimum eyesight distance test.

6.2. Recommendations

If this project were to be performed again in the future by different researchers, it is advised that a greater number of experiments should be performed each with larger sample sizes. This would allow for more robust hypothesis testing and stronger comparisons between each software and the literature. Another recommendation would be for the researchers to create multiple versions of the 3D application rather than just the single version. Multiple versions, created within different 3D modelling applications alongside different speech recognition programs, and combinations of each, would allow for greater diversity in what the public is exposed to therefore opening the potential to find the perfect software.

This section has been a conclusion to the project as a whole and has provided certain recommendations should the project be conducted for a second time. The next section is a personal reflection of the experiences this project provided.

7. Reflection

This section is a personal reflection on the project and will discuss the experiences gained, challenges faced, and lessons learned while undertaking this project.

The conception of this project came from the DVLA when they produced a list of project ideas that would be of value to them as a company and the one that interested me was ‘drivers medical vision test’. This was a vague title that was open to interpretation and initial thoughts considered the visual field test that tests a user’s peripheral vision. However, after some discussions with DVLA technical leads as well as doctors within Drivers Medical, it was decided that the project would aim to create a digital version of the minimum eyesight distance test.

One of the first major challenges that I faced during this project was when planning the first experiment which focused on the SeeDrive test by EyeLab. As mentioned in section 4.1.3, the challenge came when I discovered that the SeeDrive was no longer available. This forced me to change my original plan and quickly find another online eyesight test, namely the Britannia Driving School test which was the only other minimum eyesight distance test I could find.

The development section of this project challenged me to rapidly learn multiple new technologies such as Unity and C#. I welcomed the challenge of using C# as it is not too dissimilar to Java, which is a programming language I am comfortable with using. However, learning Unity was a more daunting task as I had never used a software like it before. Similarly, implementing the speech recognition software that is offered from IBM Watson was a technology I had not used before. I believe pushing myself to learn these different technologies and pieces of software allowed me to grow as a programmer and I became more confident in applying them the further the development progressed.

Perhaps the greatest test this project proposed revolved around time management. Establishing a balance between performing my job at the DVLA and working on this project was a difficult

task throughout the course of the project. Certain weeks I would be focused more on DVLA responsibilities taking time away from the project and vice versa. This challenged me to develop my time management capabilities; and towards the latter end of the project my time management was much improved as there was a comfortable balance between DVLA and project work.

In summary, this project challenged me and improved my skills in varying ways including time management, individual learning of new technologies and problem solving when plans went awry.

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9. Appendix

9.1. Appendix A – Questionnaire 1

20 Metre Eyesight Distance Questionnaire

This questionnaire is anonymous, therefore sensitive data such as names and addresses will not be recorded.

This questionnaire will be used to record your responses to using an online version of the 20 metre eyesight distance test, created by Britannia Driving School.

You will need to perform the test at the link below once you have completed the first section. Please have available a ruler and/or tape measure to perform the test.

1. Before Taking the Test

Background

How old are you?

Age: _____

Do you have any visual impairments, such as long or short sightedness?

Yes ☐ No ☐

If yes, please state: _____

Driving History

Do you have a full UK driving licence?

Yes ☐ No ☐ Provisional Only: ☐

When was the last time you performed the 20 metre eyesight distance test?

Never ☐

Less than one month ago ☐

Less than one year ago ☐

Between one and five years ago ☐

Five or more years ago ☐

Ten or more years ago ☐

Do you wear glasses or corrective lenses while driving?

Yes ☐ No ☐ Occasionally: ☐

If occasionally, please state why: _____

Now perform the test here: <https://www.britannia-driving-school.com/eye-test-simulator/>.

If you wear corrective lenses or glasses while driving you should wear them during the test.

2. After Completing the Test

Response

Please select only one option for each of the following questions.

Do you agree that measuring the correct distance to sit from the screen was easy?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Once at the correct distance, do you think that the image replicated 20 metres accurately?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Do you agree that this test is a suitable replacement for the physical test?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Improvements

If a user cannot reach the keyboard while positioned at the correct distance, they may have to move closer to input their response. How do you think this could affect the results of the test?

No change for anyone ☐

No change for people with perfect eyesight ☐

False results for people with perfect eyesight ☐

False results for people with poor eyesight ☐

Would you prefer that this test provided you with a method to enter your response other than keyboard input, such as voice recognition?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Would you prefer that the image was scaled for you, rather than requiring you to move away from the screen?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Any Other Comments/Notes

9.2. Appendix B – Questionnaire 2

20 Metre Eyesight Distance Questionnaire

This questionnaire is anonymous, therefore sensitive data such as names and addresses will not be recorded.

This questionnaire will be used to record your responses to using two different online versions of the 20-metre eyesight distance test, one created by Britannia Driving School and the other by EyeLab.

Once you have completed Section 1 below, you will need to complete the tests by following each of the links provided at the end of Section 1.

1. Before Taking the Test

Background

How old are you?

Age: _____

Do you have any visual impairments, such as long or short sightedness?

Yes ☐ No ☐

If yes, please state: _____

Driving History

Do you have a full UK driving licence?

Yes ☐ No ☐ Provisional Only: ☐

When was the last time you performed the 20 metre eyesight distance test?

Never ☐

Less than one month ago ☐

Less than one year ago ☐

Between one and five years ago ☐

Between five and ten years ago ☐

Ten or more years ago ☐

Do you wear glasses or corrective lenses while driving?

Yes ☐ No ☐ Occasionally: ☐

If occasionally, please state why: _____

Now perform the tests:

If you wear corrective lenses or glasses while driving, you should wear them during each of the tests.

First, perform the test by Britannia Driving School here: <https://www.britannia-driving-school.com/eye-test-simulator/>.

Once you have completed the above test, please complete the SeeDrive test by EyeLab here: <https://www.eyelab.co.uk/seedrive/index-seedrive.htm>

2. After Completing the Test

Response

Please select only one option for each of the following questions.

Which test did you prefer overall?

Britannia Driving School ☐ SeeDrive ☐ Neither ☐

Which test did you prefer with regards to measuring the correct distance?

Britannia Driving School ☐ SeeDrive ☐ Neither ☐

Why? _____

Which test do you think replicated 20 metres accurately?

Britannia Driving School ☐ SeeDrive ☐ Neither ☐

Why? _____

Do you agree that either of these tests could be a suitable replacement for the physical test?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

If you agree, please state which is a more suitable?

Britannia Driving School ☐ SeeDrive ☐ Neither ☐

Why? _____

Improvements

If a user cannot reach the keyboard while positioned at the correct distance, they may have to move closer to input their response. How do you think this could affect the results of the test?

No change for anyone ☐

No change for people with perfect eyesight ☐

False results for people with perfect eyesight ☐

False results for people with poor eyesight ☐

Would you prefer that these tests provided you with a method to enter your response other than keyboard input, such as voice recognition?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Would you prefer that the images in the tests were scaled for you, rather than requiring you to move away from the screen?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Any Other Comments/Notes

3. Pass Completion

3.1. Britannia Driving School

Attempt 1:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

Attempt 2:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

3.2. See Drive

Attempt 1:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

Attempt 2:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

9.3. Appendix C – Questionnaire 3

20 Metre Eyesight Distance Questionnaire

This questionnaire is anonymous, therefore sensitive data such as names and addresses will not be recorded.

This questionnaire will be used to record your responses to using an application that replicates the 20-metre eyesight distance test in a 3D environment and an online version created by EyeLab.

Once you have completed Section 1 below, you will need to complete the tests by following each of the links provided at the end of Section 1.

1. Before Taking the Test

Background

How old are you?

17 – 20	☐	21 – 30	☐	31 – 40	☐
41 – 50	☐	51 – 60	☐	61 +	☐

Do you have any visual impairments, such as long or short sightedness?

Yes ☐ No ☐

If yes, please state: _____

Driving History

Do you have a full UK driving licence?

Yes ☐ No ☐ Provisional Only: ☐

When was the last time you performed the physical 20 metre eyesight distance test?

Never	☐
Less than one month ago	☐
Less than one year ago	☐
Between one and five years ago	☐
Between five and ten years ago	☐
Ten or more years ago	☐

Do you wear glasses or corrective lenses while driving?

Yes ☐ No ☐ Occasionally: ☐

If occasionally, please state why: _____

Now perform the tests:

If you wear corrective lenses or glasses while driving, you should wear them during each of the tests.

First, perform the test within the 3D environment. Once completed, please complete the SeeDrive test by EyeLab found here: <https://www.eyelab.co.uk/seedrive/index-seedrive.htm>

2. After Completing the Test

Response

Please select only one option for each of the following questions.

Which test did you prefer overall?

3D ☐ SeeDrive ☐ Neither ☐

Why? _____

Do you agree that the voice recognition made it easier to ensure your response was correct?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Why? _____

Which test do you think replicated 20 metres accurately?

3D ☐ SeeDrive ☐ Neither ☐

Why? _____

Do you agree that either of these tests could be a suitable replacement for the physical test?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Please state which you believe is a more suitable test?

3D ☐ SeeDrive ☐ Neither ☐

Why? _____

Any Other Comments/Notes

3. Pass Completion

3.1. 3D Application

Attempt 1:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

Attempt 2:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

3.2. See Drive

Attempt 1:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

Attempt 2:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

9.4. Appendix D – Questionnaire 4

20 Metre Eyesight Distance Questionnaire

This questionnaire is anonymous, therefore sensitive data such as names and addresses will not be recorded.

This questionnaire will be used to record your responses to using an application that replicates the 20-metre eyesight distance test in a 3D environment and an online version hosted by Britannia Driving School.

Once you have completed Section 1 below, you will need to complete the tests by following each of the links provided at the end of Section 1.

1. Before Taking the Test

Background

How old are you?

17 – 20	☐	21 – 30	☐	31 – 40	☐
41 – 50	☐	51 – 60	☐	61 +	☐

Do you have any visual impairments, such as long or short sightedness?

Yes ☐ No ☐

If yes, please state: _____

Driving History

Do you have a full UK driving licence?

Yes ☐ No ☐ Provisional Only: ☐

When was the last time you performed the physical 20 metre eyesight distance test?

Never	☐
Less than one month ago	☐
Less than one year ago	☐
Between one and five years ago	☐
Between five and ten years ago	☐
Ten or more years ago	☐

Do you wear glasses or corrective lenses while driving?

Yes ☐ No ☐ Occasionally: ☐

If occasionally, please state why: _____

Now perform the tests:

If you wear corrective lenses or glasses while driving, you should wear them during each of the tests.

First, perform the test within the 3D environment. Once completed, please complete the SeeDrive test by Britannia Driving School test found here: <https://www.britannia-driving-school.com/eye-test-simulator/>

2. After Completing the Test

Response

Please select only one option for each of the following questions.

Which test did you prefer overall?

3D ☐ Britannia Driving School ☐ Neither ☐

Why? _____

Do you agree that the voice recognition made it easier to ensure your response was correct?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Why? _____

Which test do you think replicated 20 metres accurately?

3D ☐ Britannia Driving School ☐ Neither ☐

Why? _____

Do you agree that either of these tests could be a suitable replacement for the physical test?

Strongly Agree ☐ Agree ☐ Neither ☐ Disagree ☐ Strongly Disagree ☐

Please state which you believe is a more suitable test?

3D ☐ Britannia Driving School ☐ Neither ☐

Why? _____

Any Other Comments/Notes

3. Pass Completion

3.1. 3D Application

Attempt 1:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

Attempt 2:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

3.2. Britannia Driving School

Attempt 1:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

Attempt 2:

Pass without glasses.

Yes ☐ No ☐

Pass with glasses

Yes ☐ No ☐ N/A ☐

9.5. Appendix E – Tables for Age Against Preference of Software

Table E - 1 - Britannia Driving School vs SeeDrive Preference

Age	Britannia Driving School	SeeDrive	Total
17-20	0	0	0
21-30	2	2	4
31-40	1	1	2
41-50	2	0	2
51-60	2	0	2

Table E - 2 - 3D Application vs SeeDrive Preference

Age	3D Application	SeeDrive	Total
17-20	1	0	1
21-30	2	1	3
31-40	1	1	2
41-50	1	0	1
51-60	3	0	3

Table E - 3 - 3D Application vs Britannia Driving School Preference

Age	3D Application	Britannia Driving School	Total
17-20	1	0	1
21-30	2	1	3
31-40	1	1	2
41-50	1	0	1
51-60	2	1	3

9.6. Appendix F – Chi-Square Critical Value Table

Table F - 1 - Chi-Square Critical Value Table [125]

df	P=0.05	P=0.01
1	3.84	6.64
2	5.99	9.21
3	7.82	11.35
4	9.49	13.28
5	11.07	15.09
6	12.59	16.81
7	14.07	18.48

8	15.51	20.09
9	16.92	21.67
10	18.31	23.21