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An Evaluation of the Impact of Macular Degeneration on Hazard Perception using Virtual Reality

RESEARCH PROPOSAL
SAMUEL WITHERS

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1. Introduction

In this introduction, the type of project that is going to be undertaken is outlined and the motivation for the project determined.

The title for the research project is *An Evaluation of the Impact of Macular Degeneration on Hazard Perception using Virtual Reality*.

There are many people who are visually impaired yet undiagnosed [1], as many visual impairments develop gradually over time, meaning people will not go to an optician to get their eyesight checked as they have not noticed any perceivable deterioration in their eyesight. According to the National Eye Institute, in the USA in 2010, nearly 37 million adults have some form of vision impairment [2]. A significant percentage of these adults are likely undiagnosed.

Adults with undiagnosed eyesight conditions are likely to still hold a valid driving license, as most eyesight conditions develop later in life, likely after the person has secured their driving license. This means there are likely many drivers on the road with undiagnosed eyesight conditions [3]. These conditions may not be severe and may have no impact on their driving ability, however, in some cases there may be a significant impact on their driving ability, and they won't realise this until it's too late.

Macular Degeneration is a prime example of this, as it is a condition that typically develops later in life, and normally develops slowly. As it causes blurring of the central vision, it could easily have a significant impact on reaction times to stimuli in the centre of vision, therefore having an effect on driving ability [4].

If it were possible to determine the impact Macular Degeneration has on driving ability, then it would mean that it's possible to determine at which stage it becomes unsafe to drive with the condition. Also, modelling the condition allows drivers with perfect eyesight to better understand what other road users might be seeing and therefore be better informed to make better decisions whilst driving. The overarching goal of this project is to make driving on the roads safer and to make more people aware of the eyesight conditions some people may have without even realising it and the impact this has on driving ability.

Virtual Reality is the perfect technology to investigate this with, as it allows drivers to become fully immersed in an environment without the danger of having to drive on the road to perform these tests. It is a technology that has relatively recently lowered in cost enough to be used by typical consumers and has quickly found its place in many industries as a learning tool, making it perfect for this use case.

The setting for the research conducted is a combination of University of Wales Trinity St David, Swansea and the DVLA (Driver and Vehicle Licensing Agency), Swansea. The University provides higher education courses to Swansea and the surrounding area and the DVLA are part of the Department for Transport which hold the driver and vehicle records for the United Kingdom.

2. Background to the Proposed Research

In this section the current literature on the subject area is reviewed and the background of both Macular Degeneration and Virtual Reality technologies discussed.

2.1 Macular Degeneration

Macular degeneration (MD), also known as age-related macular degeneration (AMD), is a condition effecting eyesight which can result in impaired vision in the centre of vision. The condition is most common in people aged 60 or over, however factors such as family history, genetics and smoking can play a role in the development of the condition [4].

The macula is a small part of the retina at the back of the eye. It is a small patch about 5mm across responsible for all our central vision and a large part of our colour vision. The macula has a higher concentration of photoreceptor cells than the rest of the retina (cells that detect light and send electrical signals to the brain based on the light detected).

As it is responsible for all our central vision, therefore macular degeneration causes blind spots in the centre of vision and not the extremities. In the UK alone macular degeneration affects over 600,000 people and 6.2 million worldwide [5].

MD can cause everyday activities such as reading, recognising faces and driving to become difficult.

MD is typically diagnosed by an optometrist performing an eye exam. The severity is categorised into early, intermediate and late types depending on the severity of the damage.

The current approach to diagnose and determine the severity of MD is to have the subject look at an Amsler grid (a grid with dots in specific places on it, designed for identifying MD) and the subject describe what they can see at certain points on the grid. Some lines may

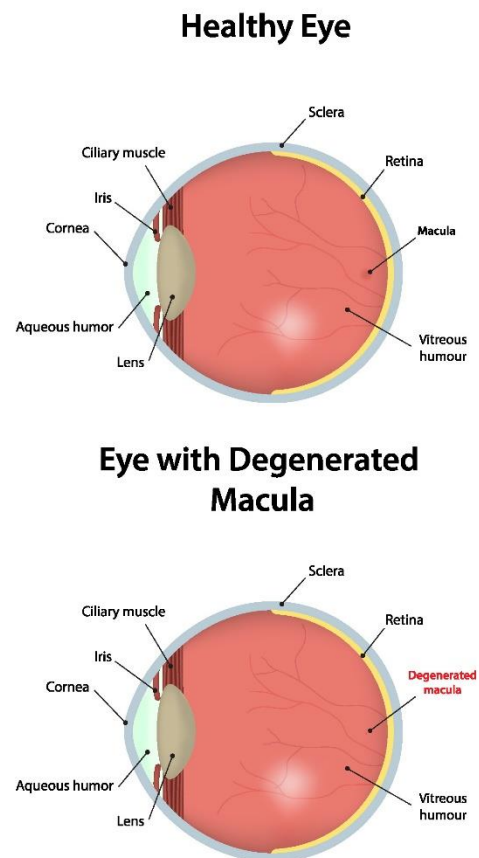
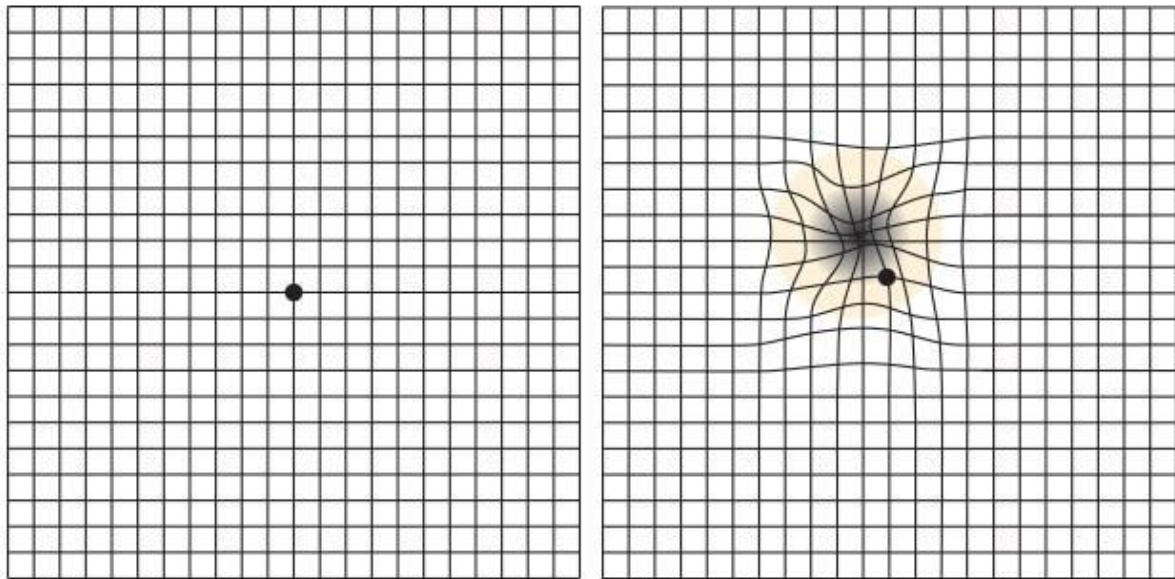


Figure 1: Healthy eye compared with an eye with degenerated macula, illustrating just how small yet important the macula is [14]

appear wavy black spots may be seen. The doctor conducting the test analyses the results and uses these to determine whether the subject has MD and the severity of it if so [6].



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Figure 2: Amsler grid as seen with perfect vision (left) and how it may look with an advanced stage of MD (right) [6]

2.2 Virtual Reality

Virtual Reality (VR) essentially means 'near-reality', in terms of technology, VR is a specific type of reality emulation. VR technologies typically use a headset with video and audio to simulate a three-dimensional environment we can move through and interact with; however, some go further and provide forms of haptic feedback to add to the immersion factor [7].

The origin of the concept of VR headsets or 'goggles' is often thought to be Stanley Weinbaum's 'Pygmalion's Spectacles', a science fiction book from 1935. In the book, the main character wears a pair of goggles that transport him to a fictional world [8].

The first physical VR machine was introduced in 1962 and called 'Sensorama'. Sensorama was a device used to simulate a motorcycle ride through New York, it used a combination of colour display, fans, odour emitters, stereo sound and a motion chair to achieve this effect. Sensorama was introduced by Morton Heilig and is considered the earliest VR system, nowadays it is thought that the machine was ahead of its time and this ultimately lead to its commercial failure [9]. Heilig details many potential uses for the machine in his patent application, including helping students train to fly a jet before stepping into one. Unfortunately, investors were not interested and Sensorama failed to secure enough investment for development to continue [10].



Figure 3: Sensorama Simulator from 1962 [13]

More recently VR has started to become a more consumer friendly, mainstream technology, with companies such as Oculus, HTC and Sony producing various headsets for consumers to use. The predominant use of VR today is for entertainment purposes, be that consuming video content or playing games. VR headsets command a larger market share than they ever have in the past previously, and with more and more headsets coming out for a variety of uses, the future of VR as a mainstream technology looks bright.

Whilst the predominant use of VR is for entertainment, it has also found great use in education, industry and medicine. Applications such as Google Earth VR can be used to visit locations and look around them without ever leaving the living room. Medical professionals can use VR headsets to look through three-dimensional images of CT and MRI scans to help pinpoint the exact area they need to study and examine it from every angle possible [11]. VR has been used for workplace training, it allows for people to experience high-risk, dangerous situations first-hand before experiencing them in real life, giving them a level of first-hand knowledge about the situation that would have otherwise not been possible.

Looking at these applications of VR, I believe it is possible to determine the impact eyesight has on driving ability/awareness without this having to be tested on the road. This hugely increases safety as the impact a person's vision has on their driving could be investigated without putting anyone at risk. There is also the potential to assess the impact different eyesight conditions would have on driving without ever having to go on the road.

3. Aims & Objectives

The aim of the project is to determine whether VR technologies can be used to make the roads safer by accurately modelling the affect visual impairment can have on driving ability. Specifically, the affect macular degeneration can have on driving ability and whether it makes for unsafe driving.

This aim will be achieved with the use of several objectives. The first objective is to determine which VR technology is best suited for the purpose of simulating the experience of driving without the need to drive a real car on a real road.

The second objective will be to develop an environment that can be used for simulating driving a real car.

The third will be to alter the environment produced in the second objective to achieve the affect macular degeneration has on eyesight. This may involve developing a program to achieve this affect or editing the video being played through the headset

The fourth will be to develop a method of quantifying a driver's ability. Most likely their ability to spot hazards and other road users accurately. The way to do this will likely be like the current hazard perception test, which measures a participant's reaction time to hazards appearing on screen and the accuracy with which they identify what a hazard is. This will most likely involve developing a program to conduct this test and produce a score at the end based on these factors.

The fifth and final objective needed to achieve the overarching aim will be to conduct a study using the method developed in the objective above. The study will compare the results of participants using an accurate. Using these results, it should be possible to say whether macular degeneration has a noticeable affect on driving ability. Statistical analysis will be performed on the results of the study to truly determine the result.

4. Considerations

There are currently many headsets available that could potentially fit the needs of the study. The main considerations when choosing a headset will be resolution, refresh rate, latency and cost.

The resolution of the headset must be high enough to accurately show an image/video at close to real world standard, if a user cannot correctly identify and registration plate due to a low pixel density then there would be an impact on the results due to different reasons to those being studied.

The refresh rate and latency are tied together. The refresh rate on a VR headset must be high enough and consistent enough not to induce any motion sickness in a participant due to low and inconsistent refresh rates. It must feel as smooth as real life to produce the best simulation possible.

The cost of headsets varies greatly ranging from the Google Cardboard which is a cheap cardboard casing with lenses that uses your phone for the display for about £20, to the Valve Index with built in high resolution and refresh rate displays and highly accurate six degrees of freedom tracking for around £800.

There are multiple ways to create an environment to simulate driving a car using a VR headset. This may involve recording 360-degree video footage and displaying that through a VR headset so the participant can freely look around the car they are in. Another solution may be to design a 3D environment for the participant to move around freely or use pre-existing software to accomplish the same affect.

5. Research Methods

In this section, the research methodology that will be followed is outlined and the philosophy, strategy and approaches behind the methodology discussed. The risks and limitations of the research will be discussed and steps that can be taken to prevent them presented. Finally, we will consider how to evaluate the data collected and analysed through the research to determine whether the aim and objectives have been achieved.

5.1 Philosophy

The first step before beginning research is to decide on a research philosophy to follow. A research philosophy is important as it outlines a way in which data should be collected and analysed. The two major philosophies are positivist and interpretivist.

As this research project will attempt to quantify driving ability and compare results quantitatively with others, the philosophy used will be positivism. Positivism is highly structured and is a system stating that research is based on information derived from sensory experience which can produce quantifiable data. If necessary, the quantifiable data can be supplemented with qualitative data, however, conclusions cannot be drawn from the qualitative data alone.

5.2 Approach

The next step after choosing an appropriate research philosophy is to identify an appropriate research approach. The two to choose from are inductive and deductive.

The deductive approach is typically paired with the positivism philosophy as it generally involves developing a hypothesis and then designing a research strategy to test that hypothesis. The deductive approach gives us the ability to measure concepts in a quantitative way.

The inductive approach is typically paired with the interpretivist philosophy as it involves searching for patterns in the observations made during research. This means not starting out with a hypothesis to investigate and searching for patterns and meaning in the data during the process. This approach typically requires a large time investment so is suitable for research where time constraints are not a large factor.

As this research will have a well-defined hypothesis to investigate and will be following the positivism research philosophy, the approach chosen will be deductive. We know the amount of time allocated to perform the research project and deductive research allows us to plan accordingly. The deductive approach is typically low risk as a hypothesis will

generally be proven or disproven with very little room for middle ground, meaning the research is almost guaranteed an outcome in the limited time frame.

5.3 Strategy

Research strategies are important as they tell us how we are going to conduct our research and therefore how we are going to collect data.

5.3.1 Experiment

The first strategy used will be an experiment. This is because an experiment can be designed to investigate a single hypothesis and provide an answer with the results collected. A well-designed experiment would allow us to quantitatively say whether we can determine the impact Macular Degeneration has on driving ability.

5.3.2 Quantitative Research Strategy

The experiment is used to collect data. This data will be statistically analysed to determine results and draw conclusions. In quantitative research, the researcher can change variables for the desired outcome, allowing for multiple sets of results to be collected and analysed.

5.3.3 Software development

Software development will likely be a significant part of the project as a program to help conduct the experiment will eliminate human error in the collection of results and allow for more iterations of the experiment to be conducted. A program could also be developed to automatically analyse results of the experiment and produce appropriate visual aids, again saving time in the long run.

Software development methodologies to be used will be discussed in section 5.

5.4 Risks & Limitations

There is always inherent risk and limitation in any piece of research. Certain steps can be taken to minimise risks and overcome limitations however, and this section discusses those.

As the participants of any experiment ran in this research will be human, there will always be an element of human error present. To combat this, the experiment should be repeated

and ran with as many people as possible to average out any human error that causes bias to the results.

Time is obviously a constraint with the project needing to be finished by January, however with proper time management it should be possible to overcome this time constraint. Tools such as Gantt charts can be used to plan out timeboxes for each task needed. This can help as having a clear outline of what needs to be done and how long it should take before starting allows us to tell if a task is taking longer than it should do and adjust ourselves accordingly. Beginning the experiment in the project as early as is reasonably possible should help with time management also, as this gives us more time to collect and analyse results and more importantly, time to reiterate and repeat the experiment if needed.

Another potential limitation is not having the skills or knowledge to develop a program for the VR headset of choice. Over time it may be possible to gain the skills and knowledge needed to build complex programs for it, however, keeping in mind the time constraint mentioned above, it is likely best to start off with the simplest program possible and build on top of this if time allows.

5.5 Data Evaluation

If the experiment and program used to collect data are designed correctly, there should be two main sets of data to analyse. In order to draw meaningful conclusions from the data collected, statistical analysis of the data will need to be performed. This will be done with the intent of statistically proving a null hypothesis to be false, thus accepting an alternative hypothesis allowing us to draw a meaningful and statistically accurate conclusion from our data.

Software testing will also need to be present to ensure that any program developed is working correctly and with the same intent it was designed for. Testing will also allow to identify any issues so that they can be resolved in a timely manner and not affect the workflow further along in the project.

6. Development Methods

There is likely to be a software development component to this project, and software development has many different methods available for many different use cases.

Waterfall is the traditional software development methodology where progress typically flows in one direction 'down the waterfall', moving through requirements, design, implementation and testing phases before having a complete product. There are many others to choose from that fit many different situations. As this is a solo project, we need a methodology that can work for a solo developer.

6.1 Software Development Methodology

The software development methodology that will be used during this project is Kanban, as Kanban allows for an extremely effective way to visualise the work that needs to be done, and the flow of that work throughout the project. Kanban has many elements that can apply to a single developer working on a project, and even has certain variations set up specifically for a solo developer, such as Personal Kanban [12].

The main element of Kanban that will be highly useful during this project, is the use of a Kanban board to easily visualise and plan exactly what work needs to be done and which work is of the highest priority.

7. Resources & Planning

In this section, the resources that will be required for the project are listed and how they will be used outlined. A Gantt chart is used for project planning and management, showing the proposed timescales for each of the tasks required to complete the project.

7.1 Resources Required

The following resources will be required for the successful completion of the project.

- Virtual Reality headset – to be used for the driving simulation
- PC/Laptop – to be used for software development
- Participants – to take part in the experiment
- Books and papers on the subject area – to further research Macular Degeneration
- Camera with the ability to film 360 degree footage

7.2 Gantt Chart

A Gantt chart is a very useful tool for planning on a high level all the tasks that must be undertaken and an estimated time frame for each task is shown.

The tasks are split into four main groups representing the main sections of work to be undertaken. The resources, planning and difficulty of work to be undertaken are all considered when estimating the time each task will take.

TASK NAME	START DATE	DAY OF MONTH*	END DATE	DURATION* (WORK DAYS)	DAYS COMPLETE*	DAYS REMAINING*	PERCENT COMPLETE
Requirements and specification							
Research macular degeneration further	6/7	7	6/13	7	0	7	0%
Decide which VR headset is appropriate	6/14	14	6/20	7	0	7	0%
Record 360 degree footage	6/21	21	6/27	7	0	7	0%
Trial 360 degree video through headset	6/28	28	7/4	7	0	7	0%
Research programming for headset	7/5	5	7/18	14	0	14	0%
Design driving ability program							
Write user stories	7/19	19	7/25	7	0	7	0%
Design first iteration	7/26	26	8/22	28	0	28	0%
Test first iteration	8/23	23	8/29	7	0	7	0%
Rewrite user stories and repeat	8/30	30	9/19	21	0	21	0%
Perform experiment							
Choose location and set up	9/20	20	9/26	7	0	7	0%
Participants take part and record results	9/27	27	10/31	35	0	35	0%
Analyse results							
Write scripts to analyse results	11/1	1	11/7	7	0	7	0%
Sanity check results and write up initial outcome	11/8	8	11/14	7	0	7	0%
Write up full report	11/15	15	1/2	49	0	49	0%
Hand in report	1/2	2	1/3	2	0	2	0%

Figure 4: Gantt chart showing the tasks to be undertaken. Credit for template [15]

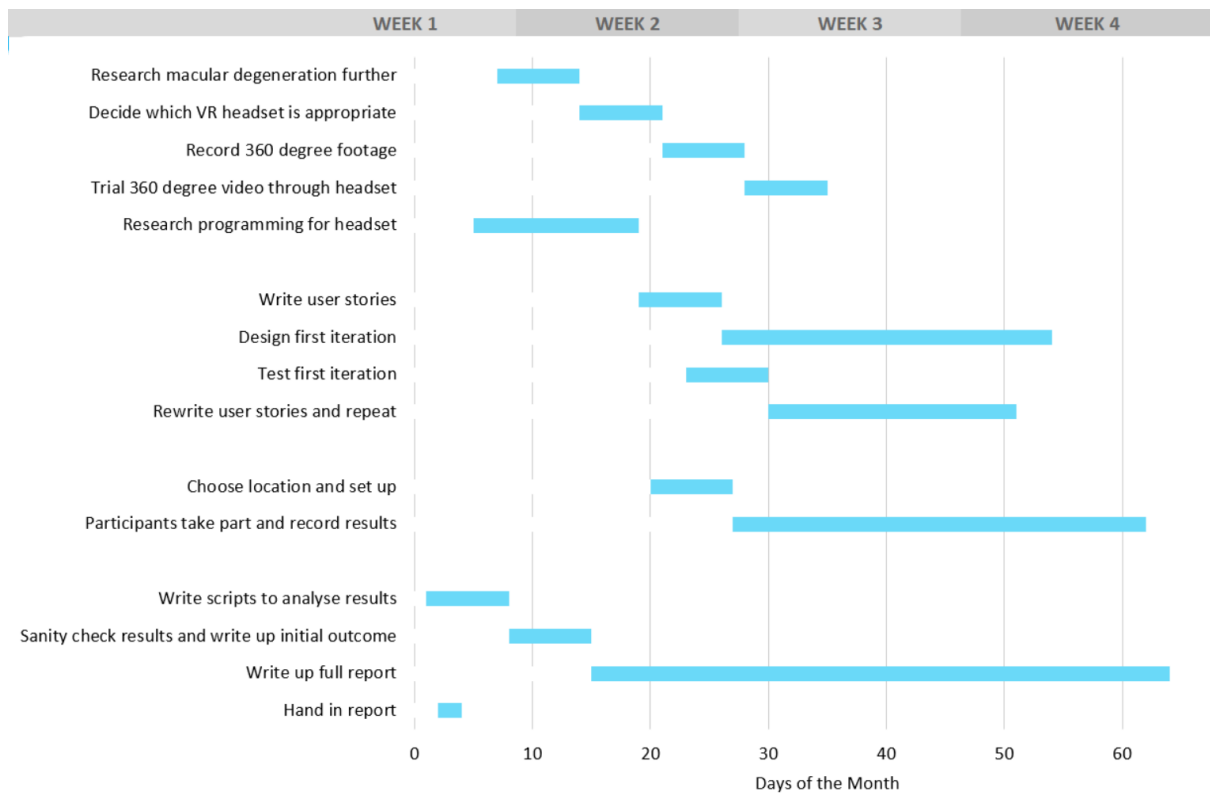


Figure 5: Gantt chart showing graphically how long each task takes. Credit for template [15]

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