Can Virtual Reality be Used to Accurately Perceive Depth Perception?

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Abstract.
The project investigates into whether depth perception be can accurately perceived within virtual reality. This is observed by participants completing a catching exercise within a real-life scenario and a virtual reality scenario. The distance from the centre of the hand to the centre of the ball in both scenarios is measured. It is theorized that there should be no significant difference between these results if depth perception can be accurately perceived within virtual reality. The results gathered show that the majority (3 of 5) of five throws between participants show no significant difference between the measurements gathered in both scenarios. However, it is concluded that due to a small sample size, high confidence intervals, limitations, and no absolute majority that the results remain inconclusive. The project provides several improvements of the design undertaken where a new procedure can address encountered limitations to determine if depth perception can be accurately perceived within virtual reality.

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1 Introduction

The intentions of this project were to examine whether virtual reality could be used to accurately perceive depth perception. The data gained could be used to examine whether a participant has poorer depth perception, further, providing a basis for testing for dyslexia or dyspraxia. It is estimated that 10% of people have dyslexia (NHS, 2018) or dyspraxia (Foundation for People with Learning Disabilities, undated). Such conditions are of importance to be diagnosed so that appropriate support can be given to minimize any disadvantage. One example of support is speech recognition software which helps the users with writing and spelling (cache, 2018). These support frameworks would not be given without a diagnosis. The papers “Dyspraxia or developmental coordination disorder? Unravelling the enigma” (Gibbs et al., 2007) and “Persistent Deficits in Motor Skill of Children with Dyslexia” (Fawcett and Nicolson, 1995) show the relation between these conditions and impacted motor skills. Participants with dyslexia or dyspraxia scored a significant amount lower against participants without the mentioned conditions. In addition to this, existing research involving depth perception in virtual reality strictly involves examining data observed in virtual reality against existing static data. For example, in the paper “Size and Distance Estimation in Virtual Reality” (Lammi et al, 2019) participants were asked to estimate the distance and height of objects within virtual reality. These estimations were compared against the actual values.

The project undertaken compares a participant’s results against their own in two scenarios: virtual reality and real-life. This allows the results to be examined against the participants’ existing skill, furthermore it removes the subjectivity of asking a participant for their opinion. It will investigate into whether depth perception can be perceived accurately within virtual reality. A thorough literature review will be undertaken to improve on existing research and highlight any potential limitations which should aim to be controlled.

2 Literature Review

2.1 Background

One of the objectives (objective 1) of this project is improve on the existing research by accounting for unforeseen shortfalls and gathering more useful metrics with extra functionality. This can only be done by first understanding how real-life actions can be translated within virtual reality. Furthermore, it is important to research into and mitigate against the potential for virtual reality elements in the form of virtual reality sickness influencing any results. This also includes controlling variables which affect how participants perceive what is happening within the scenarios. This will be done by examining how people catch balls, what controllable factors influence depth perception, and how virtual reality sickness can be lessened or avoided.

2.2 Related Literature

Catching a Ball

The fundamental aim of the project is recreating a catching scenario from real-life into virtual reality. It is therefore imperative to understand how people catch balls and what could affect the person catching the ball in virtual reality compared to real-life.

Results gathered were compared against the skill of catching a ball in real-life and virtual reality. “Catching a flying ball involves bringing the hand to the aimed interception point at the right time.” (Cesqui et al., 2016). Cesqui et al. assessed this by characterizing grasping and wrist movement kinematics amongst 11 participants. These participants attempted to catch a ball of varying arrival heights and flight durations. Cesqui et al. concluded that one characteristic influencing performance was the “alignment of the peak of the hand closing speed to the impact event”. This interception can be predicted and guided by visual information (Cesqui et al., 2012), which is impacted by the participant’s depth perception. Cesqui et al. identified multiple “kinematic features, such as wrist trajectory, velocity profile, timing and spatial distribution of the impact point, body postures and submovement decomposition structures”. This was observed by throwing balls using a ball launching machine controlling the different height and flight conditions. How participants caught and reacted to the balls was then noted. Subsequently, the ability to see where the thrower is aiming before they throw is also important. The catcher is allowed more time for adjustments allowing them to catch the ball more comfortably, (Moliner et al., 2010). Moliner et al. tested this by occluding the catcher’s sight at different times. Participants could catch most balls when sight was occluded randomly for 250ms and suffered difficulties when sight was occluded for the throw until the last 200ms. However, Moliner et al. concluded “in general, having more visual information is better.” To recreate this visual information in virtual reality a red cylinder shows where the ball is being thrown from.

Visual information shapes how a participant tries to catch a ball. It is important that the same (or as close as possible) visual information used by participants in the real-life scenario is recreated inside the virtual environment.

Influencing Depth Perception

It is important to account for anything which could limit or impact the participant's depth perception. Where they are found they should be controlled to allow both scenarios to be as similar as possible. Real-life scenarios should also aim to be as close to each other as possible for all participants.

Visual and perceived information can be improved by following the procedure from the paper "Walking through a virtual environment improves perceived size within and beyond the walked space" (Siegel and Kelly, 2017). This describes a method for improving distance and size perception. The procedure describes that participants were given a blind walking task to a perceived location and then back to a starting point. This could be replicated by participants observing where the thrower resides in the scene for five seconds, which then disappears. They will then be asked to walk to the perceived location, after which they will then be guided back to the starting position. Carrying this out would improve the judgement of size and distance (Siegel and Kelly, 2017). This was unfeasible within the current environment as participant's had to undertake the experiment within their home. The procedure requires a large area to be carried out within, such space was not available to all participants. Therefore, this could have produced inconsistencies in the results, where some participants could carry the out procedure and others could not.

Another aspect of importance is size perception. The size of an object influences the speed of perception (Park et al., 2005). Park et al. had six participants who were shown two scenes with 2D objects. Objects in the two scenes differed by size, speed, and distance. Even though, the research was conducted with 2D objects it could be theorized that the same relationship could be seen with 3D objects, therefore it was best to remove this potential for bias. To remove this bias, participants were preferably asked to use a standard tennis ball for throwing and catching. "Modern tennis balls must conform to certain criteria for size, weight, deformation and bounce" (Wikipedia, 2021). When catching the concern was for the same size and weight of the ball thrown and caught by participants.

By controlling the size of the tennis ball within the real-life scenario it will allow participants, who underwent the scenario in different settings, to experience the same speed perception in relation to the size of the thrown object.

Virtual Reality Sickness

Some senses cannot be recreated within virtual reality. This disconnect can cause virtual reality sickness. Furthermore, aspects of the virtual reality environment could also cause sickness and should be avoided and designed against.

Biases can be introduced within the virtual reality scenario itself. Care must be taken to ensure the user is as comfortable as possible within the scene; the user interface plays a large role in this. Poor UI can make the experience uncomfortable and cause neck strain (Unity, 2020). This can be avoided by using high quality components which are not pixelated and fit within the camera's frustrum, residing 2-5 metres from the player (the comfort zone), (Unity, 2020). Any world or post processing effects were also avoided. Effects such as depth-of-field blur have been seen to cause some slight but not significant disadvantage (Hillaire et al., 2009). Hillaire et al. explain that this effect blurs "the pixels of objects in front of or behind the focus point. The focus point is associated with a focal distance (fd)—the distance between the eyes (or camera) and the focus point". This was investigated by having participants play an FPS game in death-match mode. Participants were allowed four minutes of training without blur and then completed two five-minute sessions with and without blur. A second part involved a performance test of six sessions of five minutes each where blur conditions were swapped amongst participants. The slight performance decrease observed was only seen as significant for more expert players, however any performance impact should still be actively avoided. Parallax effects where users cannot focus on more than one depth can also cause discomfort (Unity, 2020) and should be avoided.

Furthermore, scenes which are highly realistic have been shown to increase the likelihood of virtual reality sickness. As a user becomes more immersed in the scene from the higher graphical fidelity (Slater et al., 2009) they expect vestibular inputs corresponding to this, which cannot be acquired, and so virtual reality sickness increases (Chang et al., 2020). One of the ways Slater et al. assessed this was by having participants answer a questionnaire regarding a rendered room. The same room was rendered with ray casting or real-time recursive ray tracing. Participants reported a higher level of presence in the room with real-time recursive ray tracing.

A higher graphical fidelity could also not be as performant on computers with less powerful hardware. This is of importance as the participant's computer specifications could range from powerful to weak. Less powerful hardware could cause lower framerates in the virtual reality scenario leading to a display latency between the participant's actions and what is displayed to the participant. This can cause increased virtual reality sickness (Stauffert et al., 2018). Stauffer et al. had participants undertake a number of search tasks within virtual reality involving head rotation and translation. Artificial latency jitter was experienced by one group of participants. This group had a significant increase in virtual reality sickness when compared to participants without the added latency jitter. Stauffert et al. concludes the potential for latency jitter “needs to be considered when designing experiences for Virtual Reality”.

In addition to this, both the real-life scenario and virtual reality scenario only require the ball to be caught from one direction, the user does not have to turn. Large amounts of rotational movement within virtual reality can induce sickness as “yaw is the most natural rotation for a human to turn” (Chang et al., 2020); meaning it may be highly susceptible to sensory conflict (Kim and Park, 2020). Kim and Park conducted a study where participants were asked to focus on a red anchor dot-point. This point would appear with a delay of three seconds before particles appeared. Participants were required to anchor their eyes to the point even after it disappeared, for which they reported what their experience was in regard to sickness. Kim and Park suggest “that it is more effective to minimize rotation scene movement than a translation one” when preventing sickness.

To check for any other influences, participants were asked to complete the Virtual Reality Sickness Questionnaire after completing the study (Kim et al., 2018). A VRSQ score can be calculated which can then be used to warrant if a participant’s results should be thrown away due to them being heavily affected by virtual reality sickness.

Avoiding the mentioned virtual reality sickness triggers allows the results to maintain their reliability. Any question of this can also be supported by the VRSQ. This will determine if the participant has still suffered from any sickness and dictate whether their results are reliable or not.

3 Methodology

3.1 Project Management

Project management requires the defining of goals, planning of tasks, gathering skill for the work and the estimation of time to completion (Stellman and Greene, 2005). Project management is important as it ensures that budgets are better maintained, stay on schedule while still meeting the objectives and quality standards (Lucidchart Content Team, undated). Furthermore, it ensures risks are managed and avoided so that they do not become issues, affecting the project (Aston, 2021).

The aim of the project was to "*determine if a ball catching game within virtual reality can be used to accurately perceive a user's depth perception. Providing that it can; then to study if this method could be used as indicator for dyslexia or dyspraxia or if the use of virtual reality could impose extra factors.*". (Project Proposal). Based on the aim several objectives were defined within the project proposal and adapted to further fit within the time constraints of the project.

1. "*To explore literature relating to my project and goals by comparing methods used in this project against those from other studies. To account for unforeseen shortfalls or to add extra functionality, to gather more useful metrics. This will also highlight limitations of methods or theories used prior, providing topics for further research. This will take place throughout the project.*"
2. "*To create a virtual reality ball catching game and perceive depth perception by evaluating how precisely a participant can catch a ball. In virtual reality this would involve seeing how close the ball is to a centre catching point, as the user cannot physically catch a ball in VR. This is to be completed before objective to leave ample time to carry out user testing.*"
3. "*Create an Android app to display test data gathered by participants. Data would be sent and contained within Firebase to avoid in person contact. It would also allow participants to easily view their results. This would be completed before testing is carried out in objective 4.*"
4. "*To objectively ascertain if virtual reality itself could have impacted participants' depth perception, by asking participants to film themselves catching a ball with a member of their household. The catching exercise would be standardized and would try to match the VR catching game as close as possible. The results would be compared to see if there was a significant difference between them; if there is VR may have impacted the results.*"

(Project Proposal).

Objective 5 has been omitted due to time constraints (see appendix 3.1.1). Separating the aim into objectives ensures clarity and focus (Lucidchart Content Team, undated). "The primary cause of failure was a lack of clearly defined objectives and milestones to measure progress" (PMI, 2017).

The above objectives can be analysed and assessed to mitigate against risks. Such information was formed in the project proposal and improved after.

Risk	Severity	Mitigation
"*Not enough participants with dyslexia or dyspraxia found.*"	3	"*Professionals in the fields related to dyslexia, dyspraxia and VR will be consulted to review the validity of objective 5's approach. Furthermore, enough data could still be gathered without dyslexia or dyspraxia participants (objective 4).*"
"*Participant loses Internet connection while completing the tests meaning that data cannot be sent to cloud storage.*"	2	"*Data gathered from a participant will also be stored locally in an easily accessible place.*" **Participants will also be warned that they do not have an Internet connection when attempting to login; the login will fail.**
"*Not enough participants are found who own a VR headset.*"	3	"*A web-based version of the game will be created measuring depth perception with the hand being replaced with a cursor.*"
"*Participants do not own an Android device to use the app.*"	1	"*Participants will be asked to download an Android emulator if they wish to view the results within an app. The results can also be given verbally.*"
"*Participants become sick because of the effects of VR sickness; effecting the reliability of the results.*"	2	"*Participants will express any discomfort they had during the experiment in the debrief session. If anything, significant happened their results may be disregarded as invalid.*" **This will be measured using the VRSQ identified prior.**

(Project Proposal).

Risk analysis allows specific tasks to mitigate against those risks to be prioritized. If they are not addressed, it can lead to the project overrunning, and requirements which are not met or not of high standard (Wallace et al., 2004).

With all the above information considered it can be mapped to create a Gantt chart. By planning an indication of the start and end dates of work packages the time to completion can be visualized. In addition to this, a Gantt charts helps identify which tasks are bottlenecks in development and should be optimized. Milestones set in the Gantt chart can also be used to track progress. (Stellman and Greene, 2005). It is important to recognize that the risk analysis and Gantt chart is not to be treated as the concrete implementation; they should both remain open to change and iteration. Both tools should be used to shape to project's development but not constrain it. This will be discussed further in section 3.2. The Gannt chart, completed as part of the project proposal, can be seen in figure 3.1.1 and figure 3.1.2.

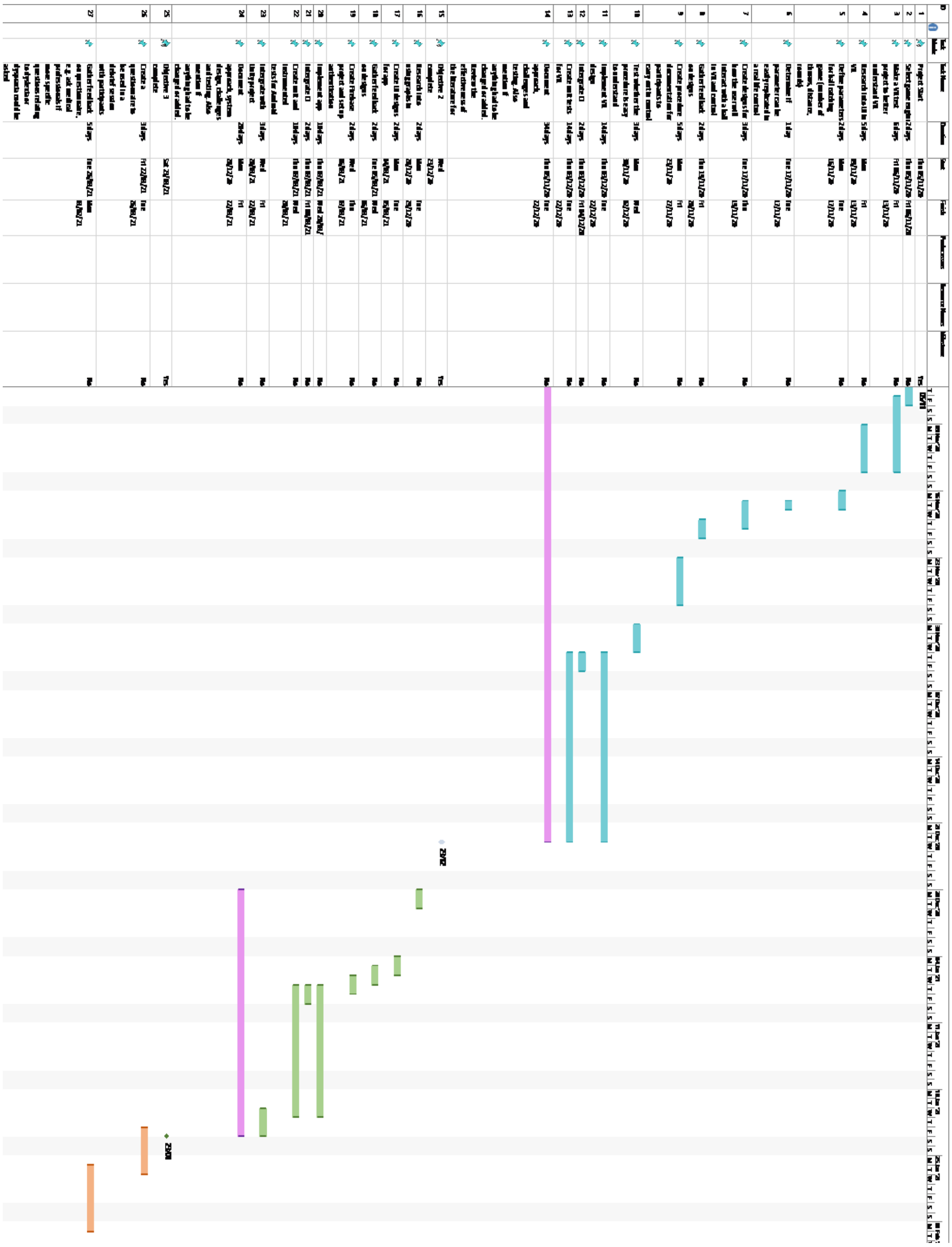


Fig. 3.1.1. Key: Objective 2 | Objective 3 | Objective 4 | Objective 5 | Report

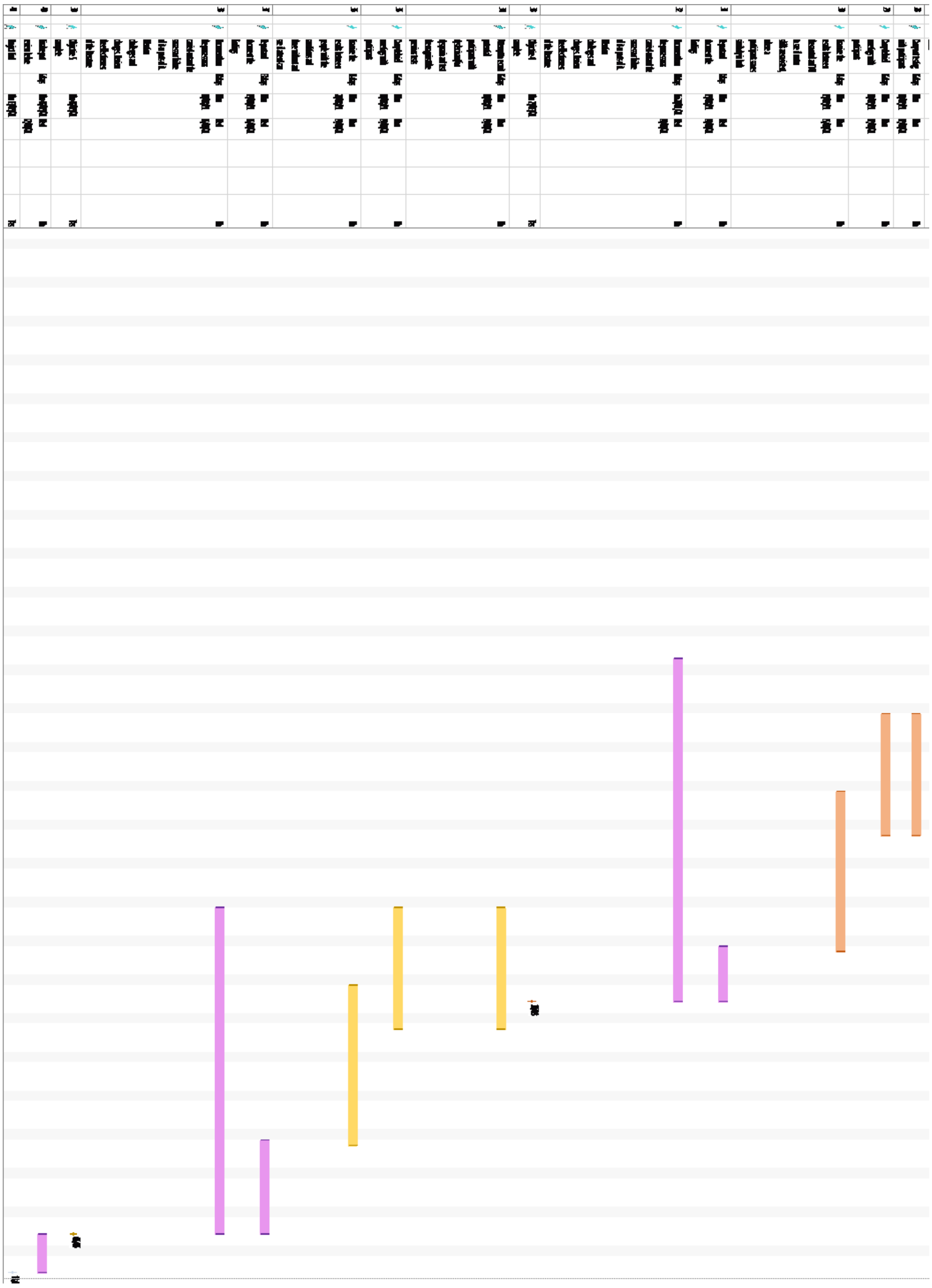


Fig. 3.1.2. Key: Objective 2 | Objective 3 | Objective 4 | Objective 5 | Report

3.2 Software Development

The characteristics of the project are as follows:

- The developer and stakeholder are both the same person (author).
- The timescale of the project is unmovable, and no extensions would be given. For this reason, combined with limited experience in some of the used technologies, the project can be considered high-risk.
- The budget for the project is low, a £100 allowance.

The project requires data to be digested within an editor environment, virtual reality environment and mobile environment, and so to be flexible in case of any incompatibilities or changes between these solutions was crucial (Li et al., 2010).

As mentioned previously it was important to recognize that the Gantt chart and risk analysis were not be taken as the concrete implementation; it was not be treated like a Waterfall methodology. Due to the implementation being used across multiple environments constant testing was crucial. Testing within a Waterfall methodology only occurs once the prior phases have been completed (analysis, design, development), (Balaji and Murugaiyan, 2012). This would not have been sufficient as it was imperative any changes made to the design would still work across all environments. It could be argued that this may have been planned in the Waterfall analysis phase, however if any changes did occur it would require a redesign across all environments voiding work done prior to the testing phase. An agile methodology was better suited to this as a testing phase occurs each iteration, therefore such problems would be quickly rectified in all environments. Furthermore, an agile methodology allows research and capture approaches to be adapted quickly to any changes during the project or from a pilot study.

A Kanban approach was determined best for the project. Roles and responsibilities are not predefined within Kanban, unlike Scrum. Therefore, with only one team member Kanban is more flexible when considering size (Alqudah and Razali, 2018). Other approaches such as FDD (Feature Driven Development) are also not ideal for team sizes of one due to the various roles (Lucidchart Content Team, undated). In addition to this, Kanban "focuses more on improving quality when compared to Scrum" (ibid) and so would create a more seamless integration of the project across multiple environments. The smaller feature set favoured by Kanban (ibid) can also be easily mapped onto a Kanban board from the Gantt chart previously created. This allowed development and design to begin immediately, which was important under the strict time constraints.

The test-driven development (TDD) practice was not appropriate due to the toolset used. Virtual reality is unable to be fully emulated within an editor environment (Oculus, undated), and so any Unit Tests ran would fail due to library incompatibilities. Also, benefits such as "more modularized, flexible, and extensible code" (Wikipedia, 2021) may not have been realized or taken advantage of due to the smaller timeline and project size.

The project relies largely on observed data which the project as described above has been designed to allow this data to be used across multiple environments. The project also includes an additional questionnaire to measure virtual reality sickness (VRSQ) which is taken directly after the study. The questionnaire only contains the set of VRSQ questions and no additional ones, this is to avoid questionnaire fatigue. The results from this questionnaire are imperative to show that virtual reality sickness did not influence the participant's results. If lots of extra questions were added questionnaire fatigue could occur, where respondents may "engage in "straight-line" responding (i.e. choosing answers down the same column on a page)" or an incomplete questionnaire (Lavrakas, 2008).

3.3 Toolsets and Machine Environments

Game Engine

Game Engine	Unity	Unreal
VR Support Installation	Straight forward	Straight forward
Language Support	C#	C++, Blueprints
In Engine Emulation	✓	X
Android Build Support	✓	✓
Online Support	Extremely well supported	Limited outside of official documentation

Unity was chosen to develop the virtual reality ball catching simulation. The main factor for this was the in engine partial virtual reality emulation. This makes it far quicker to test any changes, large or small, without having to load it on the actual headset. Furthermore, there is a far greater number of resources from online communities (YouTube, game development forums) in virtual reality within Unity. This ensures, that if any problems did arise, there would be several possible avenues for them to be resolved.

Project Management

Project Management	Git with GitHub	OneDrive	Local Storage
Industry Standard	✓	X	X
Ease of Use	Requires some extra learning	Straight forward	Straight forward
Upload Size Reduction Support	✓	X	X
Max Upload Size	100MB	Unlimited within capacity	Unlimited
Version control	✓	X	X
Branching and Merging	✓	X	X
Stored Securely	✓	✓	X

Git was chosen to manage the project, with it being hosted within a GitHub repository. Much of the complexity of Git can be from the command-line interface, this can be easily avoided by using a GUI, such as GitHub Desktop. GitHub Desktop allows much of the same functionality through graphical elements instead of the memorization of commands.

Even though the max upload when using Git is 100MB this does not become an issue if using a “gitignore”. This avoids the unnecessary upload of large files and templates for both Unity and Unreal.

Much of the benefits of using Git come from its version control. If any changes which have caused issues are identified they can be easily rolled back. This is strengthened by the ability to make small incremental changes rather than large ones. This is not possible with OneDrive or when using local storage. In addition to this, changes are stored in the cloud, and therefore avoid the chances of deletion or corruption if any problems occur on the development computer. OneDrive is stored securely in the cloud, although when merging changes errors can occur corrupting or damaging important files (e.g. meta files). Without version control these changes cannot be reverted.

Cloud NoSQL Database

Cloud NoSQL Database	Firebase	AWS	Azure
Direct Engine Support	Unity SDK	X	X
NoSQL Database Support	✓	✓	✓
REST Support	✓	✓	✓
Online Documentation and Support	Very good	Good	Good
Free Tier Option	✓	✓	✓
Ease of Setup	Extremely easy	Requires some extra learning	Requires some extra learning

Firebase was chosen to host and store the data which is collected from the virtual reality ball catching simulation. Unlike AWS and Azure, Firebase has far fewer features (only supporting NoSQL databases). Although, these extra features were not needed for this project. Due to this, Firebase can be integrated much more easily through its ease of setup and intuitive user authentication. A NoSQL database would have been used no matter the cloud provider as it allows for data to be read/wrote to quickly and sorted simply.
Furthermore, it supports a Unity engine specific SDK unlike AWS and Azure. Unfortunately, this was not able to be used because Google Play Services are not supported on Oculus (discovered during development). However, this was easily rectified by swapping the SDK out with REST APIs.

Headset

When the project was planned the original intention was to use university provided headsets (Oculus Quest). This was unable to occur due to Covid restrictions, however the Oculus Quest and Oculus Quest 2 headsets were still developed for as they allow six degrees of freedom wirelessly. This allows the virtual reality ball catching simulation to carried out without participants feeling like they are tethered by a wire. This could have impacted how users moved to catch the ball, impacting the results.

Mobile Application

The mobile application was something extra to allow users to view their results after the study; it did not have any impact on the outcome of the project. Due to the small importance of the app the toolsets chosen were based solely on prior experience held. The app was chosen to be constructed natively with Kotlin for Android. If users did not have any Android device the results could still be viewed through an emulator.

Testing

As discussed, prior within section 3.2 most testing strategies were not appropriate for the project. This only left a single option for testing, ADB Driver. This is a "bridge" which allows a developer to interface with an Android device (Oculus Quest). A PC can interface with the virtual reality headset through a command-line interface. This enables outputs to be read, such as log messages.

A pilot test was also conducted with one participant before the main experiment occurred. The pilot test raised a number of concerns within the virtual reality scenario.

1. The participant did not know where the ball was aiming for, this was addressed by adding a red target mirroring where the ball would need to be caught.
2. The participant's first login attempt failed as the headset was not connected to the Internet. A number of possible fail cases including this have been handled by outputting a helpful message to the participant.
3. The participant was unsure when the test ended. A thank you message has been added once the virtual reality scenario simulation has finished.

The pilot test allows some issues to be observed and rectified before the final experiment is conducted. For example, if an issue such as the above was found during the main experiment and was fixed it could affect future participant's results as it would involve changing the scenario. It ensures that serious issues do not occur in the main experiment and that all participants experience the same scenarios.

3.4 Research Methods

One of the aims for this project was to improve on existing research. As mentioned, in the paper "Size and Distance Estimation in Virtual Reality" (Lammi et al, 2019) participants were asked to estimate the distance and height of objects within virtual reality. This interview style of data collection can introduce bias, one source being the participant (Höher et al., 1997), the subjectivity of the participants opinion can affect the validity of the results. This project will take a deductive approach to validate if virtual reality can be used to accurately perceive depth perception by analyzing primary observed data. One of the challenges of observed data is the collection of that data itself. The procedure (described in section 4) aims to alleviate this. In summary, data from the real-life scenario will be recorded (with a camera) and sent to the observer and data from the virtual reality scenario will be automatically uploaded to a cloud database without the need for intervention. These methods of collection aim to make it as easy of possible for the participants, to ensure a high response rate. These scenarios will provide quantitative data, reducing bias, due to the numerical nature of the data helping avoid confirmation bias (Sarniak, 2015). The numerical data removes the chance to "judge and weight" the evidence (ibid).

On each throw the mean of distances from the centre of the hand (dependent variable) in real-life and virtual reality (independent variable) will be compared. This will be in the form of ratio data (as the categories are a known factor, but there is a "true zero"). The data will be determined if its distribution is normal or non-normal using a Shapiro-Wilk test as there are less than 50 samples. Based on this distribution a parametric or non-parametric paired-samples t-test (or version of) will be used to analyze the data as the same participants are used for each scenario and the means are being compared. This will be done using SPSS Statistics (build 1.0.0. 1447 64-bit edition)

A questionnaire will accompany these results. This will be used validate that virtual reality sickness did not impact the results. The questionnaire will remain small and will be taken directly after the virtual reality scenario to ensure all participants respond with their experience still 'fresh'.

4 Design, Development and Evaluation

4.1 Participant Recruitment

Participants were recruited primarily through direct contact. As participants were required to have access to an Oculus Quest headset, tennis ball and another household member recruiting indirectly was harder due to the needed equipment. Participants who were contacted directly were loaned the equipment if needed; the equipment was sanitized after use and participants were made aware of its prior use. A participant information sheet (see appendix 4.1.1) was given to prospective participants to make them aware of the projects goals and what was required from them. No participants with dyspraxia or dyslexia with appropriate equipment could be found.

Participants were targeted to remove any effect on motor skills due to age (Hillman et al., 2002). Participants were in the age range of 18-30 of any gender (mean age of 21.3). No other demographics, geographics, psychographics or behaviours were controlled. Targeted participants were screened to ensure they did not suffer from any kind of motion sickness to avoid it being induced within virtual reality (virtual reality sickness). As the experiment took no more than 40 minutes no additional measures were taken to retain participants or incentivize participation (except from completing a participant’s study in return).

4.2 Ethical Procedures

As mentioned above, participants are given an information sheet (see appendix 4.1.1) to brief them of the project goals and requirements. Participants are also screened to avoid the potential for large amounts of virtual reality sickness. Before taking part, participants are also required to sign a consent form, ensuring that they have understood the participant information sheet and any potential outlined risks (see appendix 4.2.1). The consent form also gives permission to securely store data obtained from the study. All responses from the consent form and VRSQ are stored securely on a password protected Google account using two-factor authentication. Other data gathered from the study is stored within a password protected OneDrive account using two-factor authentication. Videos of participants gathered from the study are blurred around the face, so they are not identifiable.

4.3 Study Design

The null hypothesis for the study is: The mean distance from the centre of the ball to the centre of the hand will not be significantly different.
The alternate hypothesis for the study is: The mean distance from the centre of the ball to the centre of the hand will be significantly different.
A Shapiro-Wilk test will be carried out on the data to test for normality. If the data is normal a paired-samples t-test will be conducted as the same participants are used for

both the real-life and virtual reality scenarios. If the data is not normal a paired-samples t-test will still be conducted as it is robust to violations of normality (Rasch and Guiard, 2004).

4.4 Procedure

Firstly, the real-life scenario is carried out. The participant is considered the catcher and the other household member is considered the thrower. The thrower must walk 6.5 steps forwards from the catcher to create a distance of around 5 metres. Catchers are instructed that a ball can only be caught with one hand at a time (either hand can be used to catch the ball) and they can only move one step forward when attempting to catch the ball. Throwers are recommended to hold a video recording device in the centre of their chest to film the catcher and throw with the other hand. When throwing, throws are encouraged to be thrown hard enough to reach the target but soft enough to still be catchable. Throwers are given a set of five target positions replicating targets used in the virtual reality simulation, see figure 4.4.1.

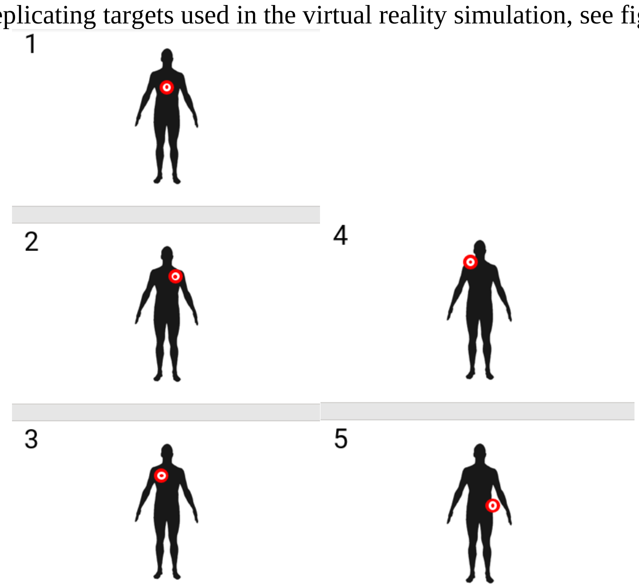


Fig. 4.4.1. Real-life scenario targets.

After completing the real-life scenario, the catcher immediately begins the virtual reality scenario. Once the catcher has signed in (see figure 4.4.2) they are instructed to turn around. When the catcher turns around (with a successful sign in) a trigger begins the simulation.

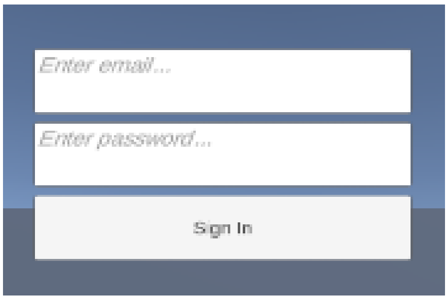


Fig. 4.4.2. Sign-in interface.

Within the virtual reality scenario, the ball is thrown 5 metres away from the catcher. A red cylinder marks where the ball is being aimed towards (see figure 4.4.3.) with a countdown, this is to replicate the thrower aiming in the real-life scenario.

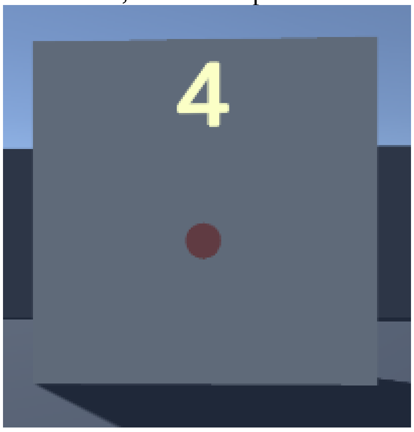


Fig. 4.4.3. The ball is being aimed towards to the centre of the catcher in 4 seconds.

See figure 4.4.4 to see an example of throw 3.

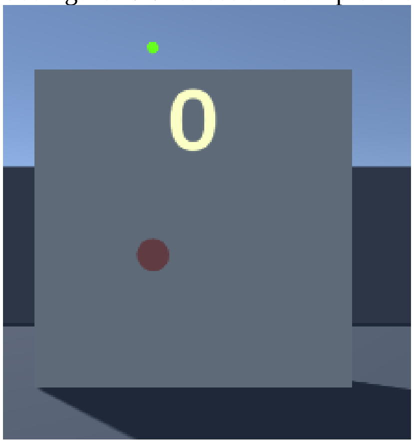


Fig. 4.4.4. A recreation of throw 3 in virtual reality.

Once all five throws have taken place the catcher is presented with a message thanking them for their participation (see figure 4.4.5). The catcher's results are uploaded automatically to the cloud database with no intervention needed from the participant.

Fig. 4.4.5. The simulation has finished.

After completing both scenarios participants are instructed to immediately complete the virtual reality sickness questionnaire. This is the last step of participation.

Distances within virtual reality are measured from the centre of the ball to the centre of the hand, or the closest distance it has been, in that throw (if not caught). A box collider is used to represent the area to check for a catch, see figure 4.4.6.

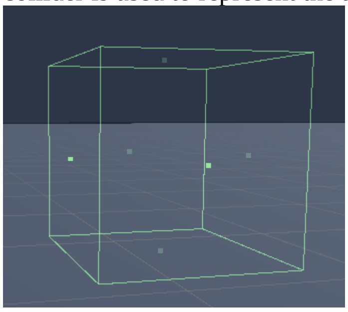


Fig. 4.4.6. Catch.

The cube length, width and height are 8.382cm, which is the average hand diameter (healthline, undated). Within the real-life scenario the distance is also measured from the centre of the ball to the centre of the hand. It is measured at the point that the ball is estimated to enter this same area (used in virtual reality), before making absolute contact with the hand. In the acquired videos this was 1-2 frames before contact.

4.5 Implementation

The implementation involves the usage of data in multiple environments: Unity, Firebase, and an Android application.

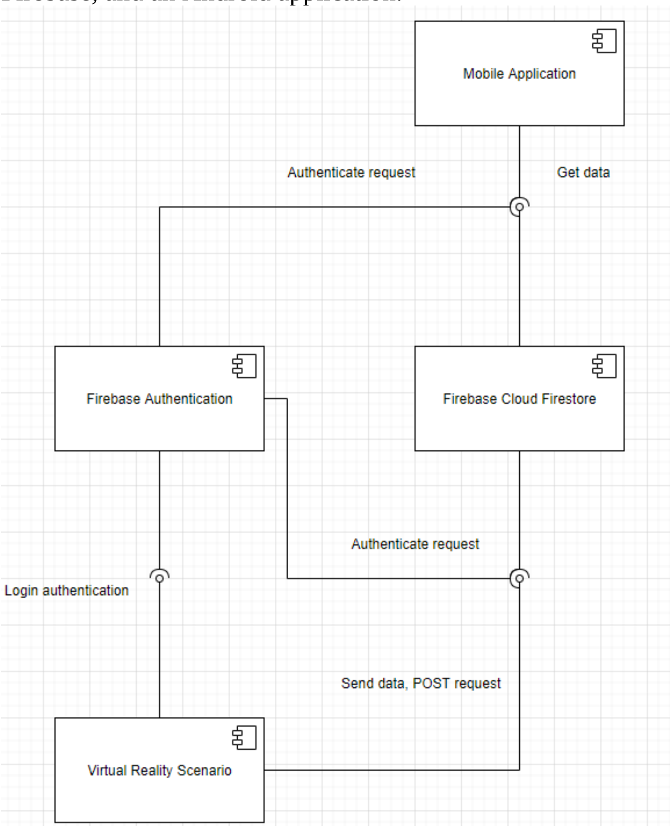


Fig. 4.5.1. Transfer of data across multiple environments.

Before a participant can complete the virtual reality scenario, they must login. Accounts are created and authorized through firebase. The method “SignInUser” within the “SignInController” class takes an email string and password string parameter. This is used to create a local string variable (“userData”) which is sent to Firebase to authenticate the user.

```
string userData = "{\"email\":\"" + email + "\",\"password\":\"" +
password + "\",\"returnSecureToken\":true}";
```

It is important that a secure token is returned, as this token is used to make future POST requests.

Using RestClient a POST request is sent with “userData”. If the login is successful a “SignInResponse” is returned. This response stores the user’s local id and id token which is passed to a property named “LoginDetails” for future access. If the login is unsuccessful the bad request is caught and handled based on the following error codes.

```
Catch(error =>
{

  _errorText.transform.parent.gameObject.SetActive(true);
  Debug.Log(error.Message);

  var e = (RequestException)error;

  if (e.IsNetworkError)
  {
     _errorText.text = "Please check your Internet connection";
  }
  else if (e.StatusCode == 400)
  {
     _errorText.text = "The username or password is incorrect";
  }
  else
  {
     _errorText.text = "Something went wrong";
  }
 });
```

The error message is displayed to user on screen as well as to the console within the editor.

Once a user has successfully logged in, they are instructed to turn around. A ray is cast in direction the user is pointing, and on its collision with the ball backboard the simulation commences. A ball is thrown from the blackboard based on predefined target values.

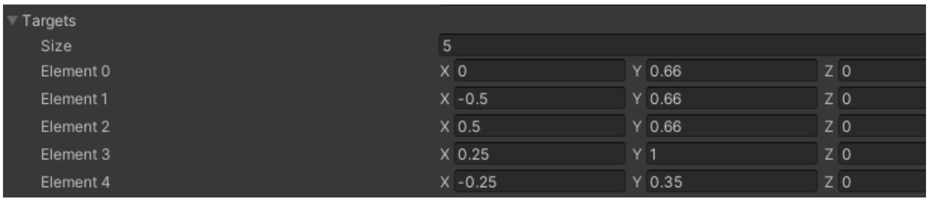


Fig. 4.5.2. Ball targets.

These target values themselves dictate where the red target on the backboard will be moved to. A constant offset (0, 5, 0) is added to each target value to ensure the ball will reach the participant and be in line with the target when thrown.

```
var direction = _currentTarget + _targetOffset -
transform.position;

_rigidBody.AddForce(direction * _throwForce);
```

The ball is thrown using Unity's built-in 3D physics system (PhysX). The participant then attempts to catch the ball as explained within the procedure. The player's hand collider is tracked by parenting it to the hands within the OVRPlayerController game object. The OVRPlayerController game object is provided by Oculus and handles all the virtual reality tracking (movement, rotation) within the scenario.

Once all throw distances have been collected, they are sent to the Firebase Cloud Firestore database through a POST request. By using a POST request, the user can only complete the simulation once, as if data for that participant is already stored a conflict will occur if another POST request is sent. Furthermore, Firebase Cloud Firestore REST does not support PUT requests, only PATCH. However, PATCH requests are not supported by Unity Web Services or RestClient.

```
var requestHelper = new RequestHelper
{
   Uri = $"{RESTCon
   stants.BASE_URL}users?documentId={fields.uid.stringValue}",
   Method = "POST",
   Timeout = 10,
   Headers = new Dictionary<string, string>
   {
           { "Authorization", $"Bearer
           {_signInController.LoginDetails.idToken}" }
   },
   Body = document
};

RestClient.Post<Document>(requestHelper).Then(response     =>     {
callback(); }).Catch(Debug.LogError);
```

This time the request is sent using the “RequestHelper” class. This is important as the id token needs to be added to the authorization header. “document” contains the throw data.

If the request is successful a callback method is called which outputs to the console that the data has been sent, otherwise an error message is outputted.

The mobile application is designed as follows:

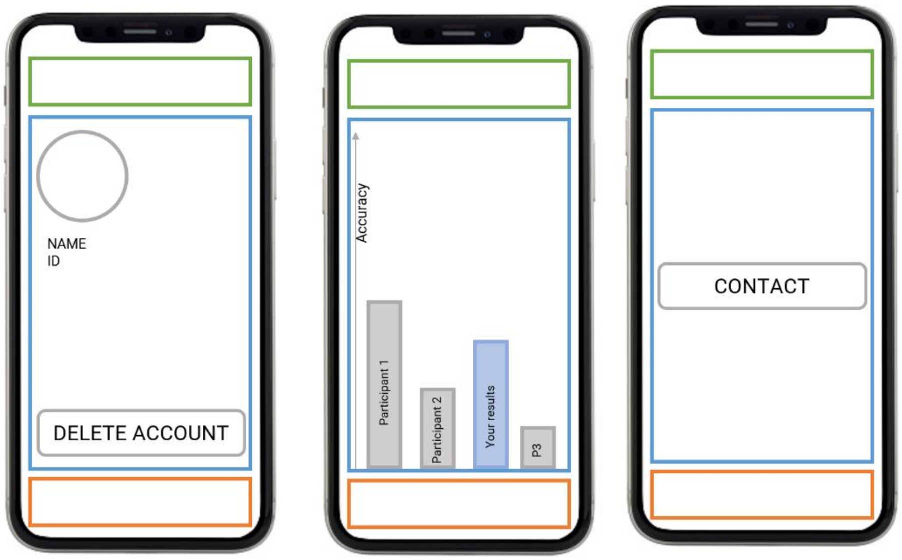


Fig. 4.5.3. Mobile application design.

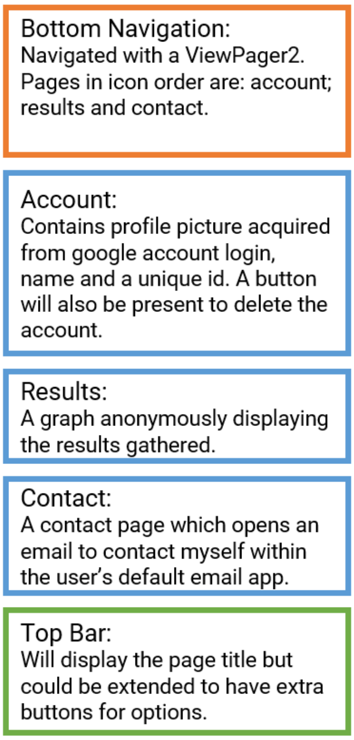


Fig. 4.5.4. Mobile application key.

Based on the designs a mobile application was created within Android Studio using Kotlin.

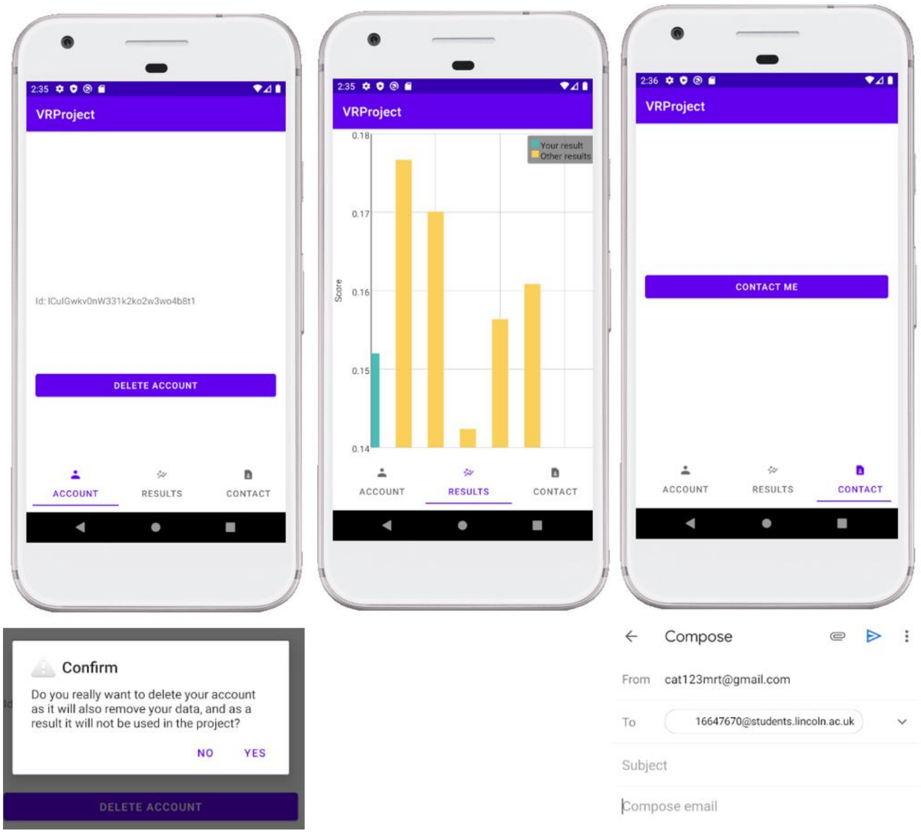


Fig. 4.5.5. Mobile application with button events.

Before viewing their results, the user must log into the application using the same credentials they used for the virtual reality scenario. This is authenticated by Firebase using the 'com.firebaseui:firebase-ui-auth:6.3.0' package. This package handles the login views as well as the authentication requests.

Data to populate the graph is retrieved using the 'com.firebaseui:firebase-ui-firestore:6.3.0' package. A set of helper methods to use the package when communicating with the database were created.

Firstly, a reference to the collection is made.

```
private val COLLECTION_NAME = "users"

fun getUsersCollection(): CollectionReference {
   return
   FirebaseFirestore.getInstance().collection(COLLECTION_NAME)
}
```

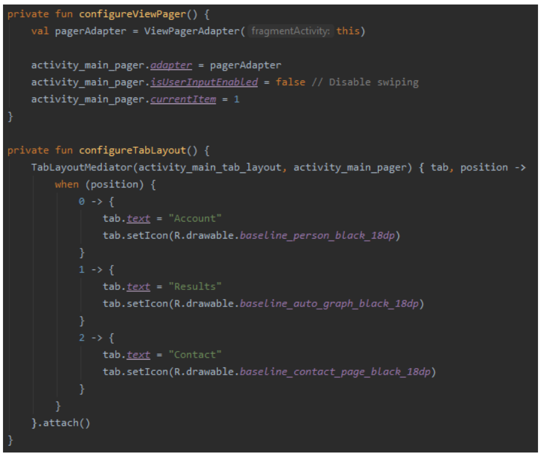
To retrieve the user data this collection is simply returned.

```
fun getUsers(): Query {
   return getUsersCollection()
}
```

To delete a user the collection is retrieved, then the correct user is found and deleted.

```
fun deleteUser(uid: String): Task<Void> {
   return getUsersCollection()
       .document(uid).delete()
}
```

A ViewPager2 contains all three fragments (account, results, and contact). This is navigated by attaching a TabLayout to the pager, populating each tab with an icon and title.



```
private fun configureViewPager() {
    val pagerAdapter = ViewPagerAdapter( fragmentActivity: this)

    activity_main_pager.adapter = pagerAdapter
    activity_main_pager.isUserInputEnabled = false // Disable swiping
    activity_main_pager.currentItem = 1
}

private fun configureTabLayout() {
    TabLayoutMediator(activity_main_tab_layout, activity_main_pager) { tab, position ->
        when (position) {
            0 -> {
                tab.text = "Account"
                tab.setIcon(R.drawable.baseline_person_black_18dp)
            }
            1 -> {
                tab.text = "Results"
                tab.setIcon(R.drawable.baseline_auto_graph_black_18dp)
            }
            2 -> {
                tab.text = "Contact"
                tab.setIcon(R.drawable.baseline_contact_page_black_18dp)
            }
        }
    }.attach()
}
```

Fig. 4.5.6. Pager and tab layout setup.

Results are displayed using the 'com.jjoe64:graphview:4.2.2' package. Retrieved users' scores are iterated through to add new data points to the graph.

```
for (user in users.indices) {
   if (users[user].scores.isNullOrEmpty()) continue

   dataPoints.add(DataPoint(dbi, users[user].scores.sum() /
   users[user].scores.size))

   if (users[user].uid ==
   FirebaseAuth.getInstance().currentUser?.uid) {
      currentUserPosition = user
   }

   dbi++
}
```

If a user has been added but their scores have not been collected, then their potential data point is ignored. "dbi" stores the x value of the next data point. The user indices are not used in case a user has no scores. Using the indices where some users have no scores would create gaps within the graph (as their mean score is 0). The "currentUserPosition" is used to colour the current user's data point differently.

4.6 Results

Throw	1	2	3	4	5
Participant 1 distance (cm)	11.1	7.65	10.6	7.6	5.8
Participant 2 distance (cm)	16.1	7.7	10.6	15.15	12.65
Participant 3 distance (cm)	6.7	16.4	5.9	16.1	9.35
Participant 4 distance (cm)	8.65	10.9	8.85	8.7	9.85
Participant 5 distance (cm)	11.5	N/A	14.3	14.25	10.5
Participant 6 distance (cm)	17.4	N/A	11.1	10.7	7.8

Fig. 4.6.1. Real-life scenario results.

Throw	1	2	3	4	5
Participant 1 distance (cm)	0.99	27.38	12.87	13.32	21.43
Participant 2 distance (cm)	11.71	24.14	17	12.8	22.69
Participant 3 distance (cm)	16.26	17.19	29.04	11.78	10.76
Participant 4 distance (cm)	10.86	16.41	14.34	14.12	15.45
Participant 5 distance (cm)	18.22	17.5	20.65	10.03	11.77
Participant 6 distance (cm)	22.29	20.36	11.4	5.8	20.58

Fig. 4.6.2. Virtual reality scenario results.

Results labelled N/A means that the distance was not readable, this was due to the hand being outside of the camera view when caught. Where a catch cannot be seen within the real-life scenario the corresponding catch within the virtual reality scenario is removed so that the number of samples remains equal. In the case of this, data points VR5.2 and VR6.2 are ignored in figure 4.6.2. (where 5.2 is participant 5 throw 2 in virtual reality).

Data point VR1.1 was marked as erroneous and its corresponding data point ignored, as the closest the ball could reach within the virtual reality scenario is half the cube length (4.191cm).

Throw	1	2	3	4	5
Participant 1 distance (cm)	-	19.73	2.27	5.72	15.63
Participant 2 distance (cm)	-4.39	16.44	6.40	-2.35	10.04
Participant 3 distance (cm)	9.56	0.79	-	-4.32	1.41
Participant 4 distance (cm)	2.21	5.51	5.49	5.42	5.60
Participant 5 distance (cm)	6.72	-	6.35	-4.22	1.27
Participant 6 distance (cm)	4.89	-	0.30	-4.90	12.78

Fig. 4.6.3. Difference between virtual reality and real-life scenario results.

The difference between data point VR3.3 and RL3.3 was found to be an outlier, so it has been removed from the statistical analysis, see figure 4.6.4.

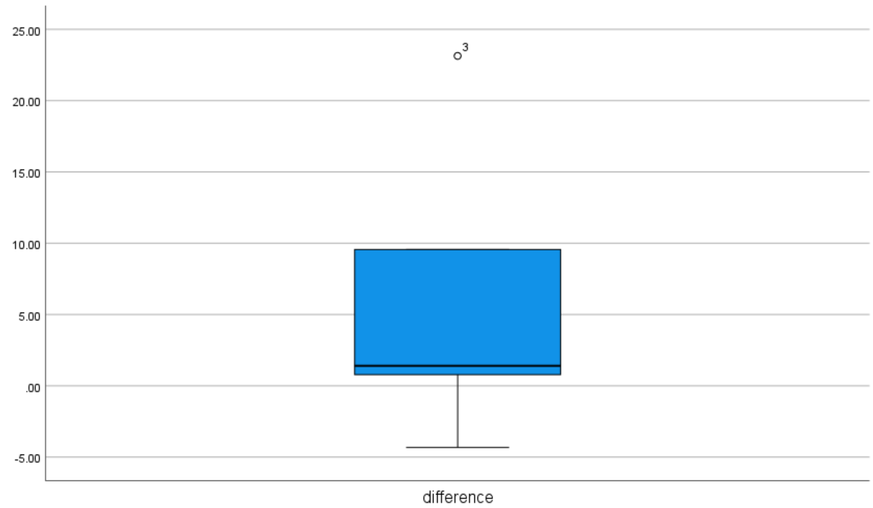


Fig. 4.6.4. Difference between VR3.3 and RL3.3 is an outlier.

4.7 Analysis

A paired-samples t-test was carried out on each throw between the two scenarios. Firstly, the normality for each throw's set differences were checked using Shapiro-Wilk test.

- The differences between the real-life and virtual reality scenarios for throw 1 were normally distributed, as assessed by Shapiro-Wilk test ($p = .767$).
- The differences between the real-life and virtual reality scenarios for throw 2 were normally distributed, as assessed by Shapiro-Wilk test ($p = .528$).
- The differences between the real-life and virtual reality scenarios for throw 3 were not normally distributed, as assessed by Shapiro-Wilk test ($p = .179$).
- The differences between the real-life and virtual reality scenarios for throw 4 were not normally distributed, as assessed by Shapiro-Wilk test ($p = .025$).
- The differences between the real-life and virtual reality scenarios for throw 5 were not normally distributed, as assessed by Shapiro-Wilk test ($p = .473$).

Even though throws 3, 4 and 5 did not show a normal distribution a paired-samples t-test was still performed as it is robust to violations of normality as explained in section 4.3.

For the experiment to be considered successful the mean distance across all throws would be expected to not be statistically significant (accept the null hypothesis). Data are mean ± standard deviation, unless otherwise stated.

- The virtual reality scenario (15.868 ± 4.725 cm) for throw 1 did not elicit a statistically significant increase in distance compared to the real-life scenario (12.070 ± 4.624 cm) of 3.798 (95% CI, -2.787 to 10.383) cm, $t(4) = 1.601$, $p < .0005$. Therefore, we accept the null hypothesis and reject the alternative hypothesis as p (.185) > .05.
- The virtual reality scenario (21.280 ± 5.349 cm) for throw 2 did not elicit a statistically significant increase in distance compared to the real-life scenario (10.662 ± 4.116 cm) of 10.618 (95% CI, -3.603 to 24.838) cm, $t(3) = 2.376$, $p < .0005$. Therefore, we accept the null hypothesis and reject the alternative hypothesis as p (.098) > .05.
- The virtual reality scenario (15.252 ± 3.658 cm) for throw 3 did elicit a statistically significant increase in distance compared to the real-life scenario (11.090 ± 1.988 cm) of 4.162 (95% CI, .758 to 7.567) cm, $t(4) = 3.395$, $p < .0005$. Therefore, we reject the null hypothesis and accept the alternative hypothesis as p (.027) < .05.
- The virtual reality scenario (11.308 ± 3.046 cm) for throw 4 did not elicit a statistically significant increase in distance compared to the real-life scenario (12.083 ± 3.569 cm) of -.776 (95% CI, -6.012 to 4.462) cm, $t(5) = -.380$, $p < .0005$. Therefore, we accept the null hypothesis and reject the alternative hypothesis as p (.719) > .05.
- The virtual reality scenario (17.113 ± 5.166 cm) for throw 5 did elicit a statistically significant increase in distance compared to the real-life scenario

(9.325 ± 2.344 cm) of 7.788 (95% CI, 1.502 to 14.075) cm, $t(5) = 3.185$, $p < .0005$. Therefore, we reject the null hypothesis and accept the alternative hypothesis as $p\ (.024) < .05$.

A majority of the throws (3/5) show no statistical difference between the distance observed between the hand and ball in the two scenarios. However, this is only a slight majority and it should not be concluded that because of this depth perception can be perceived accurately in virtual reality. Further research should be conducted taking account of the points outlined below.

All throws show a wide confidence interval, this dispersion makes the significance of the results less certain (Prel et al., 2009). In future research this should be addressed by having a much larger sample size to lead to “more confidence” (ibid). GPower (version 3.1) shows this to be around 15 people when taking all throws into account. The confidence interval is also affected by the standard deviation (ibid), which is high. This is not necessarily detrimental as this just shows that there was a range of catching skills between the participants, it is not a reflection on if that person was better or worse at catching within virtual reality (Deborah Rumsey, undated).

As explained by Cesqui et al., 2012 interception when catching a ball can be predicted and guided by visual information. Therefore, being able to see where the ball is being aimed before it is thrown is important. Even though the virtual reality scenario did include the target as to where the ball was thrown from, it did not recreate the aiming motion (of retracting the arm, moving the arm forward, and releasing the ball). This could partially account for the increased standard deviation between throwers in the virtual reality scenario. Less skilled catchers may have relied more on this extra visual information, placing them at a disadvantage when compared to more skilled catchers.

The difference in results between scenarios may have been impacted by the user’s initial distance and size perception within the virtual reality scenario. This may also have been influenced by the participant’s prior experience with virtual reality. It is appropriate to conclude that a person who has never used virtual reality compared to a person who has may not expect how it feels to be inside a virtual world and interact with it. Siegel and Kelly, 2017 explain a procedure of participant’s carrying out a walking task to improve distance and size perception. As explained in the literature review this was unable to be carried out, although if it had it may have allowed participant’s without prior virtual reality experience to have better size and distance perception (as well as participant’s with experience). This is crucial as Park et al., 2005 explains that the size of an object influences the perception of speed. Cesqui et al., 2016 explains that catching “involves bringing the hand to the aimed interception point at the right time”. Participants who perceived size wrongly may have judged the interception point prematurely or late due to their perception of the ball’s speed, impacting their catching ability. These differences in experience could also be improved by adding steps prior to the procedure where participants perform numerous virtual reality tasks.

Lammi et al., 2019 concluded that participants underestimated distances between themselves and unfamiliar objects. This underestimation as visual information may be another reason for the differences observed between the two scenarios as such perception influences how a person catches a ball (Cesqui et al., 2012). Lammi et al. goes on to explain that this perception can be improved by having a known object next to unfamiliar ones. The ball within the virtual reality scenario could have been seen as unfamiliar as it was not very realistic in terms of its texture (no fuzz). Furthermore, known objects present in the real-life scenario (furniture) were not present in the virtual reality scenario. This lack of other objects may have impacted how participants perceived the visual information, affecting their catching ability. If such improvements were undertaken it would be important to remember the link between increased graphical fidelity and immersion (Slater et al., 2009) on the expectation of vestibular inputs, which cannot be acquired, and so virtual reality sickness increases (Chang et al., 2020). The VRSQ carried out would be able to assess if these improvements impacted the participant in the study, questioning the validity of their results.

5 Conclusions

The results from this project are inconclusive as to whether depth perception can be perceived accurately in virtual reality. Even though a majority of the results showed no significant difference between the results observed within the real-life scenario and virtual reality scenario, confidence intervals were wide, and the standard deviation was large. The standard deviation size is not necessarily detrimental as it just shows that some catchers were better than others on the same scenario. Although, limitations may have influenced its size as well as the confidence intervals.

As well as increasing the sample size in future research a number of limitations should be addressed.

5.1 Limitations and Future Work

1. The distance from the centre of the ball to the centre of the hand did not always assess catching skill within the real-life scenario. For example, a participant who caught the ball with the top of their hand when compared to a participant who touched the ball with the centre of their hand but failed in catching the ball would score lower. The second participant may have perceived the speed of the ball incorrectly.
2. The throwing of each ball within the real-life scenario was impossible to be recreated exactly the same among each participant. Depending on how the thrower threw the ball there would be inconsistencies in speed and direction.
3. Participants were more reluctant to move when catching the ball in virtual reality when compared to the real-life scenario. One of the main reasons was the fear of breaking an expensive piece of equipment. Participants would make more effort to adapt themselves to the movement of the ball within the real-life scenario. The controllers may have also impacted how participants tried to catch a ball.
4. The reading of the results within the real-life scenario included estimations which could introduce bias questioning the validity of the results.
5. Participants undertook the experiment inside different rooms/environments which may impacted how the participants tried to catch a ball. For example, a person within a smaller room may adapt less to the movement of the ball. Furthermore, the thrower may also throw the ball slower in fear of hitting furniture.

Future work could use a controlled room where all participants undertake the experiment. The real-life scenario would also no longer rely on a human thrower and would instead use a machine to throw the ball; this would allow all throws to be reproducible. The room itself could also be recreated within virtual reality so that both environments are as close as possible to each other. Participants would undergo a series of virtual reality experiences across a number of days so that they become more comfortable with the headset and less scared of breaking it. It is important that the headset is not chained to something like a ceiling so that participants feel they can freely move. In addition to this instead of having the ball caught in virtual reality participants could catch a real ball with the headset still on. A ball within virtual reality could exactly mirror a real-life thrown ball, participants would then reach out to catch the virtual ball, actually catching the real ball. This would remove the impact controllers could have on the experiment. Lastly, the method to which depth perception is measured should include a number of factors. These could be:

- If the ball was caught.
- Distance from the centre of the hand to the ball.
- Body movement.
- Comfort level when catching.
- Wrist movement.

By addressing the above limitations more reliable results could be collected, helping to determine whether depth perception can be accurately perceived within virtual reality.

6 Reflective Analysis

In terms of time management and planning the project went very well. The Gantt chart created as part of the proposal provided a good visualization of milestones and tasks; allowing sections to be prioritized if progress slowed due to other work needing to be completed. It was most important when reflecting on if all objectives could be completed. Objective 5 was omitted due to time constraints (see appendix 3.1.1), however the Gantt chart made it clear which tasks would also need to be omitted if the objective was not to be completed. Furthermore, it also showed that no future tasks would be impacted by its omission.

Additional time should have been allowed to conduct a more thorough Pilot study. This section was not planned in the Gantt chart and if it had other limiting factors may have been identified. The Pilot study did highlight required improvements on the design of the virtual reality scenario; however, the Pilot study should have included more than one participant. One limitation identified in the main study was the contrast between participants with and without virtual reality experience. Some participant’s needed extra time to become comfortable with the equipment and virtual environment. This contrast could have been observed if the Pilot study had included more participants. In addition to this, the Pilot study should have been conducted prior to objective 3 being started. Objective 3 involved creating a mobile app for participant’s to anonymously few their results. Unfortunately, this app was not utilized by any of the participants and the time in completing objective 3 could have been used elsewhere within the study. By conducting the Pilot study at the time when the minimum requirements (objective 1 and 2) to undertake the main study had been completed, information regarding improvements and further work could have been more efficiently collected, rather than predicting what participant’s would want (objective 3).

During the project I was able to quickly adapt to unforeseen problems. One of these was the lack of support for Google Play Services on Oculus devices. This meant the cloud database could not be communicated through the SDK and had to use REST services instead. This problem would have only been found through testing on the device itself. However, the reliance of third-party services by Firebase makes it a less desirable product and next time this would be a strong contributing factor in choosing a service for storing data in the cloud. AWS has support for .NET packages which do not require such constraints so this may be a better solution in the future.

As mentioned in section 3.2 TDD methods were unable to be employed due to the Oculus emulator incompatibilities within the Unity editor environment. If this research is to be continued in the future, employing the suggested improvements, a more robust testing strategy would be important. The improvements would increase the scope of the project warranting the need for testing to allow for the efficient integration of new features without causing new issues. For this reason, instead of using much of the provided elements within the Oculus SDK, the VRTK package could be used instead. The VRTK package includes a simulator which can be used instead of the Oculus headset emulator. Furthermore, it allows for development across multiple headset brands instead of just Oculus. This would be useful in case the research warranted using a different virtual reality headset manufacturer.

7 References

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8 Word Count

This document contains 10705 words.

9 Appendix

3.1.1 Omitted objective 5.

"*To see if the approach has any merits for indicting dyslexia or dyspraxia, by asking people with these conditions to take part, comparing their results against those without the conditions. If this is not possible due to Covid-19, medical professionals in this field could be consulted to evaluate the validity of the approach.*"

4.1.1 Participant information sheet.

Participant Information Sheet

Title of Study: Can Virtual Reality be Used to Accurately Perceive Depth Perception?

Department: School of Computer Science

Name and Contact Details of the Researcher:

- **Callum Thompson**
- **16647670@students.lincoln.ac.uk**

1. **Invitation Paragraph**

   You are being invited to take part in a research project. During this study you will use your own HMD, or one provided to catch a virtual ball. You will also replicate this in the real world with a member of your household.

2. **What is the project's purpose?**

   The purpose of the project is to test depth perception within VR.

3. **Why have I been chosen?**

   You have been chosen because you have your own device, or one provided and are capable of participating.

4. **Do I have to take part?**

   Participation is completely voluntary, and you may withdraw at any time.

5. **What will happen to me if I take part?**

   For the VR portion you will be asked to sideload an APK onto your headset. Instructions for both the VR and real-life portion are provided separately.

6. **Will I be recorded and how will the recorded media be used?**

   You will be recorded when catching the ball in real life and data will collected within the VR app. No other information is collected.

7. **What are the possible disadvantages and risks of taking part?**

   Some people get simulator sickness in VR. There is no movement in this experiment so the risk is minimal. Still if you have any adverse symptoms or feel discomfort, please exit the application and report them to the experimenter.

10. **Will my taking part in this project be kept confidential?**

    All the data collected will only be accessible by myself. It will be stored securely, and your face will be blurred from the recording.

12. Use of Deception

There is no deception used in this study.

13. What will happen to the results of the research project?

The results of this study will be used in my project report.

17. Links to Consent Form

If you agree to take part, please sign the digital consent.

- Consent Form
  - https://forms.gle/6V7DWviDz8x6sEMC8
- VRSQ
  - https://forms.gle/T6cP4rtwjNQZQw7h9

Instructions can be found for installing the APK here, if required:
https://uploadvr.com/sideloading-quest-how-to/

Thank you for reading this information sheet and for considering taking part in this research study

Adapted from: (Friston, 2021).

4.2.1 Consent form.

Consent Form

* Required

Name *

Your answer

Email *

Your answer

I confirm that I have read and understood the Information Sheet. I have had an opportunity to consider the information and what will be expected of me. I have also had the opportunity to ask questions which have been answered to my satisfaction. *

- [ ] Yes

I understand my data is stored securely, and can be withdrawn and deleted at any point. *

- [ ] Yes

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason. *

- [ ] Yes

I understand the potential risks of participating as described in the Information Sheet. *

- [ ] Yes

I understand that I will not benefit financially from this study or from any possible outcome it may result in in the future. *

- [ ] Yes