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Creating and analysing the effects of a multiple-choice learning mobile application on human memory retention

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I hereby declare that this dissertation is all my own work, except as indicated in the text: Signature: _____
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Abstract

In this dissertation, I will present a mobile learning application which utilises multiple choice questions and the spaced repetition learning technique to aid users with memory retention. This project will examine the effects that the mobile application has on the learning capability of two groups of participants which are both partaking in two different revision methods. These methods correspond to either revision using written study notes, or revision with the mobile application. The results will be then analysed to identify whether there is a clear difference in results, and if so if there is a place within the current market for a revision application like this. The study ends with a conclusion of the results which state that revision over a shorter period (~2 weeks) with either method results in an end difference of under 5% of the total grade. However also showing that the mobile application kept up with the normal forms of studying and that it shows great promise in terms of user feedback. With further work being placed into the application or a longer study better results to support the mobile learning application can be achieved.

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Chapter 1: Introduction to the Study

1.1 Project Overview

Addressing the most efficient way to learn, interpret and retain information is of vital importance to any individuals who are aiming to improve in their area of study. Correctly identifying the most suitable method of revision for a user to process information will not only improve the rate of consumption but also increase the length at which they can keep retention of that information.

Previous research that has been conducted into this area has led us to a deeper understanding of how individuals may best learn. An example of this would be a learning model that has been presented by Neil.D.Fleming which describes multiple different learning styles into which a user can resign themselves to. These learning styles are categorized into what's known as the VARK model" [1]. This model will be explained at greater depth in future chapters of this dissertation.

The project is based around a similar idea and aims to examine to what extent a mobile multiple-choice learning application might affect memory retention in participants by utilising several different aspects of this model. As proved by Neil.D.Flemings research it is important to understand an individual's learning preference in order to tailor the way they absorb information and maximise the amount of information they can learn and retain through their selected period of study.

These principles along with the spaced repetition learning technique have both been proven effective in educational circumstances. An example of this would be a study conducted on junior-high-school students which shows that spaced review produced a higher rate of facilitation in retention of material compared to massed review [2]. Spaced repetition is a process in which users are prompted to continuously revise over a prolonged period of time rather than mass-consuming data. These principles have been applied to the mobile application and tested to determine effectiveness. Being able to determine effectively into what category a user falls into, and the prime way for them to revise would be of a great benefit to everyone. Good results from this study may affect future users' approach to learning.

This project contribution to this area of study will involve creating the application and testing it within a group of 20 participants. Results will be taken at 3 separate stages of the revision process. An initial test will be taken before any revision has taken place in order to determine a base foundation of knowledge for each participant. The participants will then be split into two working groups, Group A and Group B. Each group will be given different methods of revision. Group A will initially begin their revision period through the use of paper notes whilst Group B will be started on the mobile application.

After a period of 7 days the participants will be required to take a further test in order to gather results at the midpoint of the study. Following this test, the groups will be switched with Group A being transferred to the paper notes and Group B being transferred to the mobile application.

A further 7 days of revision will be provided to the participants in which after a final test will be taken by both set of groups and the results analysed.

1.2 Project Aim

The aim of this project will be to create a mobile learning application which utilizes a mixture of learning styles in order to enhance an individual's abilities to comprehend and recall information on the go. The mobile application will make use of multiple-choice questions as well as visual and auditory cues in order to help implant the information for the user. The application will also allow users to create their own questions and place them into categories allowing them to further expand on their revision if necessary. The final product of this application will be tested against other methods of revision and results compared to determine effectiveness.

1.3 Project Objectives

In order to achieve the above aim, the project was initially split into multiple objectives:

- Research alternative revision methods and applications available to the public and analyse strengths and weaknesses pertaining to them.
- Further analyse studies on memory retention and approaches to revision in order to understand the most effective approaches to studying and how they suit individuals.
- Creating the mobile application and ensuring it works to set requirements.
- Completing two set of tests to gather adequate data to analyse
- Evaluate the performance of the application through these tests and compare the results to evaluate whether the application is working as intended.

The project consisted of two major phases. An initial research stage was present where information was gathered pertaining to the study including designs for the application and the different ways in which the testing of the application can be approached. And a subsequent development/testing stage where the application, after ensuring it meets all functional requirements was released to the study groups in order to test effectiveness.

1.4 Motivation

There are numerous different revision applications on both the Android and iPhone market place. These revision applications are usually tailored towards a certain learning style and do the job they are created for well. However, most of the revision applications only allow users to organise their notes, and not necessarily study from them directly. There are not many applications which allow users to test themselves regarding their own notes. Therefore, even though there are many applications which utilise a quiz as their interaction method between the user and their mobile device, many of them are created on predetermined topics with users basing the questions and answers on a relatively open area of the subject and henceforth not being suitable for revision methods. creating an application which combines the previously mentioned

1.5 Outline of the study

This dissertation has multiple chapters, all covering a different part of this study. These are the chapters the dissertation has been split up into for easy referencing.

Related Works and Research: Throughout this chapter, the steps required to fulfill the above task will be discussed. Initially, an overview of the research and related works will be explored outlining important factors in both, such as the strengths and weaknesses of related works and why they are important to this study. Further studies which support the background research will also be presented.

Methodology: The methodology chapter will cover the approach taken towards the development of this application and the reasoning behind it. Further detail will be given about the testing methodology and why it was conducted in that manner, including participant recruitment and the reasoning behind module choices. A talk about ethics and privacy forms will also be mentioned.

Design: The design chapter will include early design concepts, the tools used to create them and the several stages of application development.

Implementation: Subsequently, an implementation chapter will follow. The implementation chapter will be covering the current version of the application including reasoning behind operating system choice and platform choice as well as the non-functional testing of the application.

Evaluation: The evaluation chapter will be discussing all the questions used and the reasoning behind them as well as the Limitations of the study.

Reflection: The reflection chapter will cover time and resource management as well as a challenges section which will summarise and cover problems which were encountered throughout the development of this project.

Results: The results chapter will provide and analyse all the results gathered from this study.

Future considerations, self-reflections and conclusion: This chapter will cover any future considerations for the work if it was to be revisited, a final reflection looking back at the project and a conclusion to bring the dissertation to an end.

Chapter 2: Research and Related Works

Research

The VARK model

Visual learning style

The visual learning style is based around the user's ability and need to “see” information in order to process and learn it. The ability to “see” information can be presented to a user in a multitude of ways including but not limited to spatial awareness, puzzle solving, photographic memory, colour/tone and brightness/contrast. Visual learners usually have increased proficiency for memorisation and recalling of information using images or colours by associating information with them. Due to this, visual learners have been found to excel at tasks which include spatial

components such as solving puzzles, tracing mazes, duplicating designs, visual transformation, mental rotations and more. [3]

Auditory learning style

The auditory learning style is based on the individual's ability to learn through listening. This is usually done by communication with other individuals or being able to recall information better with sounds (such as creating a song to help you remember information). Auditory learners need to be able to speak, listen or interact in order to interpret information efficiently. Lectures have been found to be an effective tool for this learning style [3].

Reading/Writing style

This style utilises information being displayed as words, text-based input and output. This could be any form of text such as manuals, reports, essays or assignments. Initially the Reading/Writing style was not included in the model, however after testing it was deemed to be significantly different from the Visual style and important enough to include.

Kinaesthetic learning style

This style is based around two criteria. The “kinaesthetic (movement)” criteria which allows the individual to carry out physical activities in order to aid them in their learning process. And the “tactile (touch)” criteria which allows user to learn through physical sensations. This could involve using their hands to scan paragraphs when reading or using coloured highlighters to separate important information. Furthermore, these individuals may create drawings or diagrams to further represent information. It has been found that most of the time Kinaesthetic learners have a difficult time staying on target and can become unfocused effortlessly [4] so tailoring revision material to suit their style would improve their overall performance.

The VARK model acknowledges that different individuals process information in different ways and uses the above learning styles to categorise them. By correctly doing so, we can increase the individual's ability to comprehend and use information. and henceforth potentially change their future revision methods. Understanding this has been a major research topic in the past, and the more we learn about this topic the more we can influence people's lives in all positions from students to people in the workplace. By being able to adapt how content/knowledge is displayed to the user, as well as how they can take the learning of it into their own hands. We can ensure that everyone is benefiting the most from their own personal style of learning.

However, many of these learning styles have been criticised when used in an e-learning perspective. One of the main criticisms being that mismatching a user’s learning style can have the opposite effect than intended and cause further issues with their education. For example, a user who is not aware of their learning style, may looks online for guidance. Without knowledge of their direct learning style, and simply following advice off the internet the user may attempt to revise in an incompatible way, and they might find they are harming their own progress and be frustrated when results do not come as easy. Also, whilst there is a broad majority of studies completed on learning styles, there does not seem to be any agreement or approval of any one theory regarding this between researchers. [5]. Further negative feedback on learning styles states that each style deals with a different aspect of learning, however there isn’t one that can successfully incorporate them all. And in fact, there is arguments that because of this the learning

style of the student should instead be matched to their tutors instead of attempting to deduce their own. [6]

However, this is not the only issue with learning styles in an e-learning environment. Peter Honey ran a test to determine the existence or non-existence of e-learning styles. He asked a sample group of 242 respondents about their individual learning style preferences and reacted to a list of likes and dislikes about e-learning. However, there was little to no correlation to the learning preferences presented and that the study revealed that they "did not reveal any significant differences" and that the "likes and dislikes were remarkably similar regardless of the preference". Many researchers agree with this notion too. Ruth C. Clark and Richard E. Mayer stated in their book that "e-learning has the potential to customize learning to the unique needs of each learner." however they were not talking about "learning styles - a myth still popular amongst practitioners despite a lack of evidence to support it" [7]. They stated that they did not believe in learning styles but instead believed that content could be tailored based on the needs of individual learners. Another paper published in 2014, studying the effects of personalisation for technologies such as e-learning also criticised the notion of learning styles existing. The paper performed a study on two learning style systems and found that personalising the content to a "student's preferred learning styles yielded no significant difference" and that in fact "matching the personalization to the opposite of their preferred learning style had no effect" [8].

Spaced Repetition

Spaced repetition is a learning technique which makes use of the "spacing effect". The spacing effect is a phenomenon which implies that learning potential is greater when the studying of the subject is spread out over time rather than covering the same amount of content in a single session. This effect basically suggests that intense last-minute studying will provide the individual with worse results and that it is instead far more effective to work in a longer time frame. However, research has also pointed out that the benefits of spaced presentation aren't always present at short retention intervals.

The spaced repetition effect was originally identified by "Hermann Ebbinghaus" in which he proceeded to publish a study about in 1885 in his book titled "*Memory: A contribution to Experimental Psychology*" [9]. His findings were then continued to be supported by further studies in topics such as *free recall, recognition, cued-recall* and *frequency estimation.* An example of this would be of a study performed in 1989 which states that the memory for repeated items on a list improves as a function of the spacing between repetitions [10].

Years of further research on memory and recall have also produced further proof to support these conclusions and findings on the spacing effect. An example of this would be a study conducted by Cepeda et al. (2006) [11] in which it was found that participants who used spaced practice on memory tasks outperformed those using massed practice in 259 out of 271 cases.

Spacing effect has also found further use in education. A recent study in 2017 by John.H. Byrne [12] has shown that significant learning gains are prevalent in learning, especially when the spacing gaps are on the order of days or weeks. Although widely accepted that spacing is

beneficial when learning a subject (including revisiting and practicing previous topics). Textbooks and other forms of revision are not tailored in a way which supports these findings.

Further study by Rohrer and Taylor also indicates that in other educational subjects for example students solving math problems, either using spaced or massed practice, spaced practice showed a significant improvement when tested a week later [13] as compared to the students who revised using massed practice.

More studies to support the long-term effects of spacing have also been conducted in the context of language learning. Bahrick et al applied the spaced repetition learning style to foreign vocabulary words and examined the level of retention from each participant, the study ran it's over the course of a 9-year period. It was noted that both the total amount of sessions revisiting each subject as well as the number of days between revisiting the subject had been found to have a major impact on retention [14] and that utilising the spacing effect provided the highest benefit to all participants.

Lag Effect

The lag effect can be identified as the time interval between repetitions of learning. It is a subcategory of the spacing effect and is basically an idea which states that the longer the lag between revision periods, the more effective it will be. Specific studies have been done in order to address this statement such as the 2005 study on the effects of lag in free recall. [15]. In the study they stated that they found an overall advantage for the recall of spaced lists when the lag period was larger as well as significantly better recall when the time between repetitions was widely spread compared to moderately spread. Further tests on this topic were carried out in similar subject areas. For example, a study on lag effects was also conducted on inductive learning (learning through observation without direct contact or making notes). The study also suggested inductive learning is far more effective when spaced rather than massed [16].

Related Works

In this part of the chapter an analysation of a majority of revision applications will take place. Listing not only how they function but their strength and weaknesses also.

2.1 Duolingo - Application Review

Duolingo [17] is an application which utilises the multiple-choice quiz-based approach. However, Duolingo is specifically aimed towards learning a language. Duolingo makes use of this learning style exceptionally well and is considered one of the best applications for learning languages. It is a very straightforward application which is simple to set up and use. This is as easy as setting up your profile, choosing your target language and setting up your weekly goals. From there it’s up to the user to ensure they are meeting their set requirements. Whilst Duolingo does not leave you alone to do this, it is still up to the user to be dedicated enough to come back daily in order to accomplish their goals. This application also lets the user progress overtime by adjusting

difficulty levels which upgrade once the user has gained enough points in the area. With harder difficulties only becoming available if the user has successfully passed the lower versions of them.

The reason Duolingo is such a successful language learning application is because it recognises that learning a language is a complex process and it makes the experience easier for the user through, not only how it teaches its lessons, but also how it keeps users coming back to the application. Duolingo uses several tools to help users with motivation. One of these tools is a goal-setting tool which allows users to set how many points they want to earn daily and frequently promotes the individual to complete their daily goals through their notification channels [18]. By setting these goals it's almost like the user is agreeing to a formal arrangement with the application which might make them feel more inclined to come back. Furthermore, Duolingo also congratulates the user when they meet their daily requirement or go above their set target. Which makes them feel accomplished.

Duolingo also makes use of the spaced repetition learning effect which due to the previous studies listed, works great. The theory indicates that over time you can have large intervals of several months without revision on that topic, yet you won't forget what you have learned. Duolingo will get you to cover a task less and less frequently the further you go into the language course. However, individuals realise that even if they haven't covered it in months, they can still remember the definitions. This approach promotes initial frequent revision of these words, which doesn't take long as each Duolingo task can usually be done in a couple minutes or less. And slowly allows the repetition to fade out only coming back once every couple month as a reminder. A daily goal on Duolingo can take anywhere between 5 and 15 minutes and can be done while travelling or waiting, making the application a more appealing choice for revision. The user saves time by doing so, instead of separating an individual time slot dedicated to revision specifically.

The project draws inspiration from Duolingo. Ideally being able to combine features from both Quizup which was designed as a fun application to pass the time and Duolingo which was designed as a language learning application would be ideal. Combining the best of these two applications and making the application relevant to any topic the user would like to create questions towards will be beneficial to anybody looking to learn through this type of style. Furthermore, adding to the market with an application similar to this would be beneficial as one currently does not exist.

Strengths:

- Application is user friendly and contains free, simple to understand and informative lessons
- Allows the user to set daily motivational goals.
- Learners can play against their friends as well as monitor others progress.
- After each section user can view comments where people discuss their answers and provide more insight
- Multi-Platform including computer availability
- Virtual Shop - currency awarded in which the user can buy helpful items
- Varying difficulty levels

- Good time utilization does not require prolonged periods of study every day.

Weaknesses:

- Some activities are platform/operating system dependent. For example, not all activities that can be done on a computer can be accessed on a phone
- Requires internet connectivity - no offline mode
- Not all language courses support verbal practice
- Relies on a small set of methods to teach user about the language (e.g. Teaching you new words by showing you pictures paired with words.) and not all of them are related to retrieving from the memory.

2.2 QuizUp - Application Review

An example of an application which is largely popular but not directly targeted as a learning tool is "Quizup" [19]. Quizup is a mobile trivia application which allows the user to test his knowledge against himself or against others in a multiplayer variant where they compete for points. The application houses hundreds of categories on a multitude of topics however the questions within the topics are very generalised and while the user can test his knowledge against them, they can't specifically be used very well for revision purposes. However, the application has a great user interface design and by allowing users to create their own tests also makes the application more fun to use as you can test your knowledge against your friends in niche topics which may not exist in the application. Quizup also keeps users interested by pitting them against each other in a topic they both agree to and comparing their scores. Furthermore, winning games also grants each user experience points within that topic that "levels" them up and with certain levels the user is also awarded titles which can be displayed next to his name in matches. The user can also compare his level and titles to other competitors. This gives the users a sense of progression which makes them feel more attached to the game and allows them to have more fun.

Strengths:

- User friendly user-interface.
- Broad range of topics and the ability to create own questions and answers.
- Capability to add friends and keep track of their scores and challenge to quizzes.
- Social feed allowing users to share information and posts with each other.
- Activity page which allows the user to track what other individuals are playing or which of them has downloaded the game.

Weaknesses:

- Not tailored towards revision, and generally tailored towards a social setting.
- Internet connectivity required, does not allow the user to quiz themselves if offline.
- Hosts advertisements frequently

2.3 Memrise - Application Review

Another example of a learning tool utilised by students is "Memrise" [20]. Memrise is a learning platform available both online and for mobile devices which makes use of flashcards and mnemonic techniques to aid in teaching foreign languages primarily as well as memorising information from other subjects. The application utilises images to help the user remember vocabulary and to help build connections between phrases or words to a topic. Memrise also

targets the use of “spaced repetition” as its main learning technique. Frequently prompting the user to come back on an incremental basis to test themselves on flashcards which have been created. Each flashcard also has pre-generated hints associated with it to help the user remember ques, but you are also given the option to create your own. The effectiveness of Memrise was explored in a paper in 2017 [21]. The paper separated a classroom into two and assigned one group with traditional(non-mobile) methods of learning and one group who made use of Memrise to revise and recycle the material. The objective was to pass a Latin test where users had to memorise up to 475 words. The research results showed that individuals who revised using non-traditional methods had a larger fail rate as well as overall worse grades. With ⅓ of students failing, over half of the students receiving a satisfactory grade, and only 1 person achieving a good grade. Whereas students who had utilised Memrise only had a 17% fail rate, half of the students received a satisfactory grade and a third of the students received a good grade. The study then concluded that “learning with Memrise as a tool positively influenced the test results achieved by the students” and that “One in three students who did not facilitate their learning process with Memrise failed the test, while among those who revised with Memrise – only one in six. [21]

Strengths:

- Allows the individual to create their own content.
- Many different variations of memorising information.
- Vocabulary is repeated to help users remember.
- Good time utilization does not require prolonged periods of study every day.

Weaknesses:

- Variation in what the phone application allows you to do, and what the website application does.
- To unlock complete content, have to pay an annual membership -a lot of features are locked out.
- Low amount of vocabulary.
- Requires volume for majority of content.
- Some of the lessons are too long.

2.4 IMindMap - Application Review

Further related work includes applications such as IMindMap [22]. IMindMap is a successful mind mapping software with more than 250 million users worldwide. The application states that it boosts “productivity in a range of tasks, from brainstorming, organising ideas and project planning to studying, teaching, presenting” [22]. The application works by moving away from the traditional pen and paper mind mapping, to a more widely available online platform. A mind map is a visual representation of information that all centres around an idea. Creating the iMindMap is a process that “involves a distinct combination of imagery, colour and visual-spatial arrangement”. This technique allows the user to connect thoughts to key words which can be used to trigger associations in the brain to “spark further ideas”. By using a mind map it allows for users to represent information in a different and more colourful way. Studied have been conducted on the effectiveness of Mind Mapping in different teaching backgrounds. An example study conducted in 2017 on college computer programming teaching shows that the use of mind maps can “strengthen the students’ ability of logical thinking and innovative thinking, motivate

the development of students' life-wide learning thinking, and enhance the students' understanding [23]. A similar study was also conducted in 2013 on sixth grade students. It showed that using mind maps had a "significant effect on student's academic achievements" [24].

2.5 Peak - Application Review

Peak - Brain Training [25] is a mobile application which advertises itself as a cognitive training application. It provides the user with everyday activities they can use in order to train their brain to stay "sharp". Their games are designed to work different parts of your brain and are categorised into several categories such as

- Focus
- Memory
- Problem Solving
- Mental Agility
- Language
- Emotion
- Coordination

An initial assessment is completed based on these categories and the user is given feedback on their performance. Each of these games when played provides the user with a score which is saved to their account. Over-time by completing these games the user is given statistical data which represents their overall abilities and which they can use to compare themselves to either friends or other individuals within their age-group. The user is also asked to set goals and areas in which they would specifically like to improve, and an in-app helper is used in order to help the users achieve these goals.

Some of the games developed through peak are backed by academic professionals such as

- **Prof. Barbara Sahakian / Cambridge University** - Developed two games. One which aids memory and another which aids attention span. These games(along with 5 other peak games) were a part of Bruno Bonnechere's study in which they were assessing whether mobile games can be used to assess "cognitive functions of elderly with and without cognitive impairment". Bruno's research was later published in the Journal of Alzheimer's Disease in 2018 in which they stated that there were "Statistically significant differences" and that the application could be as an alternative to other cognitive measurement tools such as the MMSE(The Mini-Mental State Examination) and the ACE-R(Addenbrooke's Cognitive Examination) [26]. The study also stated that one of the developed games named "Wizard" was shown to improve memory in individuals and that another game called "Decoder" was shown to "significantly improve attention span in standardized tests when compared to other control groups.

Strengths:

- Allows the user to compare themselves to other individuals on the application
- Wide variety of learning tools which target different learning styles for users
- Allows the user to specifically target a skill area to focus on and improve.
- Adheres to user disabilities/learning difficulties such as color-blindness or dyslexia and allows users to choose games which won't affect their conditions.
- Competitive aspect where the user can compete with friends on specific games.

- Has an in-built “coach” which is there to help users progress and challenge themselves.

Weaknesses:

- Content is locked behind a paywall. Only allows the user to do one test per day.
- Advertisement-heavy.

Chapter 3: Methodology

Agile Methodology

Throughout the creation of this project an agile development approach focused on Extreme Programming has been utilised. This methodology was thought to be best suited to the project due to the ability of subdividing the project into smaller parts. In this case each part represents a feature which will be included in the mobile application upon its completion. These parts functioned as a to-do list and were followed in an incremental order by initially prioritizing those that need to be completed first as well as categorizing others in related groups and giving them an estimated deadline, which had to be followed to ensure that the project would be finished by its estimated completion date. Each of the project parts functioned as a “sprint” (development cycle) within the agile methodology.

The reason an agile methodology was chosen for this project is due to the ability to continuously test the product after each stage of development. Once the initial sprint cycle had been completed and the current stage of the application was tested to ensure correct functionality; product feedback was gathered regarding both the looks and the feel of the software. The feedback after each cycle allowed the product to be further improved with regards to customer opinions and brought to light ideas which were not thought of before. Furthermore, due to the methodology chosen in which the project was created in multiple segments, individual requirements needing to be addressed could be done so after each cycle, rather than leaving the whole spectrum of the testing and re-design being left to the last stage. The ability to discover further requirements for the software after each cycle allowed the sprint cycles to be changed accordingly and features which were deemed to be more important to be focused on first. This allowed for the application to be better suited to the user needs.

The duration of each sprint was set to be a default value which ensured that regular review of the product would take place as well as the direction in which the project was heading. Due to the nature of this, it ensured that deadlines had to be met in order to stay on track as falling behind and having to catch up would be tough. By choosing the Extreme Programming model (a model that is focused on releasing parts of the project in a maximum of a two-week developmental period) allowed for the project to be more flexible when changing the set requirements throughout the sprint. This was deemed to be of high importance, as whilst everything might have looked good at the initial design, it was not known if new features had to be discovered and prioritised.

One example of where this was found to be useful in the project was that initially time was not allocated to learning the Android Studio [27] integrated development environment (IDE). Previous experience in coding applications using Java was present, however transitioning from desktop programming to mobile programming introduced many new concepts which interfered with the set development plan for the project. Therefore, by incorporating this developmental style it allowed for a change of requirements and the order they had to be executed in. This helped

alleviate any pressure for the time lost learning this new piece of software. A further sprint was added allocating sufficient time to learn both the IDE and the new concepts which greatly aided the development of the mobile application.

One tool which was used to aid the development cycle and keep everything on track is a Gantt chart. By adhering to deadlines which were previously set it ensured that everything was completed in a timely manner as to also allow for any revisions which occurred during the feedback and testing phase of the application.

Overall, the Agile principles outlined in the "Agile Manifesto" [28] were found to be a correct fit for the project and effectively allowed for better time management. The principles mentioned are:

- "Early delivery, creating shippable software in two-week 'sprints'"
- "Responding to changing requirements"
- "Measuring progress with working software as the metric"
- Simplification - not making software overly complex
- Small, self-organising teams that regularly reflect on best practices

This was the approach that had been followed for the developmental cycle. However, once the application was created; further tests had to be run in order to analyse the effectiveness of the software.

Participant recruitment

In order to run further tests, first participants had to be gathered. The participants gathered for these tests consisted of a range of university students both male and female at the age range of 18-24. A large majority of the students participating in the experiment were computer science students, and the rest were students of a varying degree whose classes presided at Jubilee Campus. The recruitment of these students was largely completed through word of mouth. The criteria the students had to fit was that they were university students, that they owned an Android smartphone and that they were available for participation for 3 tests over a 2-week period. The students also had to be willing to spend 5-15 minutes of their day looking at provided notes or revising through the application.

Study topic selection process

The students also took part in the selection process of the topics of study. As they were not receiving any monetary compensation, the topics selected were best chosen to adhere to their module choices. The students were asked which modules they were most interested in learning throughout the revision periods, and the large majority of students voted for Computer Security. This was a compulsory module for all 3rd year computer science students and therefore was chosen as the initial study topic. With the idea of replacing monetary rewards with study notes which could instead help them achieve a higher grade at their end of year exams and therefore provide them with an incentive to revise for the forthcoming tests. The students were asked to vote on a further topic, which was decided to be Fundamentals of Information Visualisation. The revision questions for both of these topics were chosen from a mixture of early lectures which were made available by lecturers as well as questions randomly chosen from end of year exams which the topics were found to be frequently occurring.

Test methodology

These tests were described earlier in this dissertation in the project overview section. However, a rough overview of the tests looks like this.

A total of 20 participants (male and female) aged 18-24 were gathered to take part in this study. Each of these individuals were required to take an initial test in order to determine their foundation level of knowledge within the subject area. Following this, the participants were split into 2 groups of 10 members each. One group was instructed to revise with the application, whilst the other group were provided with written notes to revise from. A week later, the participants were gathered, and another test was conducted in order to gather mid-point results. After conducting the test, the revision methods between the groups were swapped and the participants were told to revise using the new style. They were instructed to come back a week later after which a final test was carried out in order to gather final results. The results from this were then analysed in order to test the effectiveness of the mobile application. These are also further discussed later in this dissertation. These tests were conducted a total of 2 times. The first test was based on the "Computer Security" module, whereas the second test was based on the "Fundamentals of Information Visualisation" module.

Further feedback was also gathered regarding the overall functionality, usability and appearance of the application after the study was officially over. This was conducted through the use of an online questionnaire. The questions used along with their reasoning and the results from the participants are also discussed later in this dissertation in further detail.

Ethical Procedures

Initially to start off this project, permission had to be gained from the university in order to be able to use human participants within the study. In order for this requirement to be fulfilled an ethics checklist had to be submitted. The ethics checklist was found to not be enough, and a furthermore detailed one had to be submitted as well. This ethics checklist was found to be sufficient and allowed for participants to start being gathered for the testing phase of the study.

Users partaking in the study were presented with a consent form as well as an information sheet detailing the purpose of the study and the extent of their engagement. These forms also addressed what would happen to any information they submit and how they could go about withdrawing from the study if necessary. The only private data collected about individuals was their names, this was only done with the purpose of keeping track of their performance throughout the tests. Once the tests were completed the data was anonymised and participant names were deleted. All data collected was stored on a password-encrypted excel file which only the researchers had access to. To see related information please see the Appendix forms.

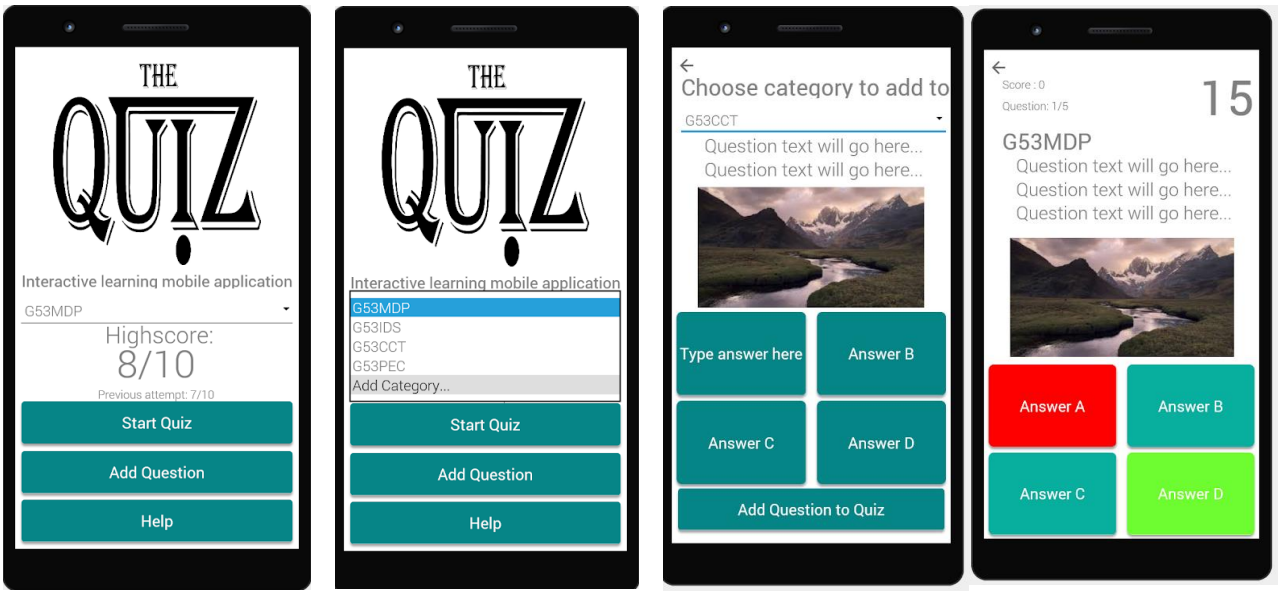
Chapter 4: Design

Design stages

Overall, the design phase for this study was a mixture of several phases. An initial phase of identifying user needs took place where the most fundamental functionality of the application was written down along with how the user is expected to interact with the software. It was

decided that for the simplicity of this study and due to the time allocated to create and test the software that the application should remain simple, as well as have an easy to use design to promote usability on the go.

Following this, sketching out a prototype was conducted where basic functionality for the application was drawn out on paper with comparisons being made to other revision apps in order to ensure no features needed for the completion of the project were left out. These designs were shown to random helpers where they proceeded to voice their opinions. This resulted in features of the application being changed and/or the location of features being moved. Once the designs were found to be of a satisfiable level a prototype was built using" Justinmind" [29] an application prototyping tool. Members of the public within university were then asked to test out the application to check if everything worked as they would expect. Since this was the first version of the design, it was kept simple.



Feedback was taken from each participant and the application changed accordingly. The early concepts design above allowed for a clearer view of how the application would function when complete and allowed for easier planning in regard to programming. The participants in the test were found to have shown a positive attitude towards the feel of the application with comments being made that the appearance should be modified for the final version. After the designs were approved implementation was the next stage of the process. The implementation stage will be talked about next in this dissertation.

Chapter 5: Implementation

Mobile Application and Language Chosen

The mobile application has been developed using the Android Studio IDE with a system API version of 15(also labelled as "Android 4.0.3 Ice-cream Sandwich). The reasoning behind this system version is that as stated on Android Studio "API 15 and later, will run on approximately

100% of devices." Whilst using this API version made it difficult to use features which are otherwise implemented in newer versions. Accessibility of the application to all individuals took priority and had made it easier when looking for test participants later in the recruitment and testing stages of this study. Being able to find more test participants was a priority as the pool of potential participants had already been lowered by targeting only one mobile operating system.

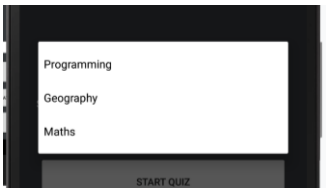
Furthermore, the choice between creating this software as a desktop application instead of a mobile application had also been considered. But it had been decided that users would be more motivated to use the application in their spare time if they were not forced to sit down and do it all in one sitting. But instead were allowed to access the application anytime during the day as long as a mobile device was present.

The reason behind choosing to create the software as an Android application instead of an iPhone application is due to familiarity with the products and coding language used to create these. Having no prior experience with iPhone or the Swift coding language makes that choice less ideal due to the time which would have to be spent learning the language. Furthermore, there were also access issues such as the lack of an Apple device in which to program this application. Whereas previous experience using Java and owning multiple Android devices over the years made that the preferred choice. Furthermore, the android operating system also monopolizes the iPhone in market share, with Android having 84.8% and IOS coming in at 15.1% [30].

Current implementation

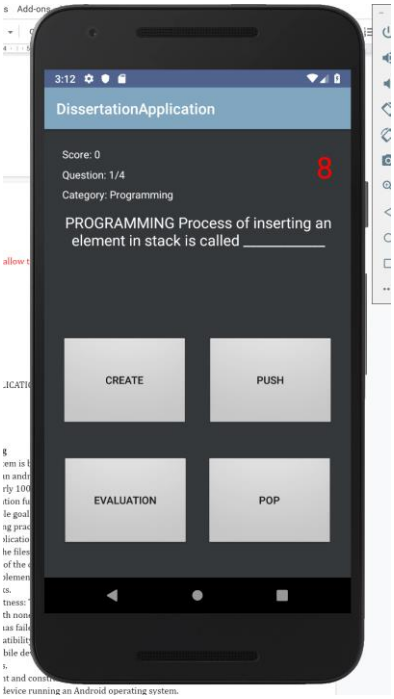
This is the current implementation of the mobile application. This image depicts the main screen where the user can choose a category to revise from. Add further questions or categories, as well as view all questions currently in the application. Once the user has decided on a category, he would like to revise he can simply press on the start quiz button to initiate the quiz. The image below it depicts what the selection screen for the modules looks like. In this version of the application, test questions for Programming, Geography and Math's were tested out.

The image below shows the view questions screen. The view questions screen will display all questions currently in the application as well as when a question is clicked on it will load a new window where the user can edit all answers. If the user chooses to update the answers, he can press the update button which will send a request to the database, where as if he decides to delete the question, he can simply press the delete button.



The two screens which allow the user to add a category or questions both look similar to the view questions screen.

The image to the right depicts the quiz screen, in this menu the user is displayed with a multiple-choice question and up to 4 answers. The screen states the number of questions left in the category as well as an on-screen timer which counts down from 15. If the user answers a question correctly a score will be added to his total and the answer will turn green, where as if the user answers a question wrong it will instead turn red. If the user fails to answer a question within 15 seconds, the correct answer will automatically be highlighted however no points will be given to the user.



Testing

Non-functional Testing

1. Accessibility: The system is based on the Android mobile platform and can be accessed easily by anyone using an android with an operating system version of 4.0.3(Ice Cream Sandwich) which is nearly 100% of all android devices on the market.

2. Usability: The application functions properly and as expected. It is easy to use and understand with a simple goal on each screen.

3. Maintainability: Coding practices have been established and maintained throughout the development of this application. The code is modularized, and the functionality is clearly separated between all the files and relevant functions. Good naming practices has been used with good commenting of the code for easier understanding of future programmers.

4. Extensibility: The implementation of the application allows for it to be easily modified or extended in future works.

5. Reliability and Robustness: The software created is stable and has been tested against crashes and/or bugs with none found. Good commenting of the code allows for detecting which part of the code has failed if an error occurs.

6. Cross Platform Compatibility: The mobile application has been designed specifically for use with an android mobile device. It is not suitable for use on mobile devices using utilising other operating systems.

7. Resource Requirement and constraints: The only resources required for this mobile application is a mobile device running an Android operating system.

8. Documentation: The documentation for the system is comprehensive and complete.

It is all archived on GitHub and Google Drive.

Chapter 6: Evaluation

The evaluation process was a qualitative approach where all twenty of the participants were asked to answer a survey on their experience with the application. The age range for the participants was 18-24 and was comprised of university students. The evaluation process was no longer than 5-10 minutes and was used to simply gather data about the user's thoughts and

feelings towards the mobile application. The questions used for the evaluation were carefully chosen and their explanation and reasoning are below.

Research questions used

One of the first tasks undertaken after the completion of the initial revision studies was to gather feedback from participants, in order to ask them their opinions about the application. The following questions were used and their reasoning behind them:

Did the idea of revising through mobile application appeal to you? why/why not?

This question was used in order to test the concept behind this application. If the participants, after using the application for several weeks returned negative results it is important to understand why and what could have gone better. Overall, the majority of results returned a positive outreach with most participants saying that they found the application "useful" for revising on the move and they preferred it compared to when they were assigned to revision through the use of paper notes. Only a few select individuals stated that they preferred revision with the paper notes and that they had felt it provided a better result for them by being able to sit down and concentrate.

1. ***What did you like the most about the mobile application?***

This question was used to gather what users though positive aspects about the application were. By researching into what users enjoyed, it allows for future work to include the positive aspects of the application.

Many participants stated that the application was straightforward to use and that they enjoyed this approach. Some users also mentioned that they enjoyed the ability to add their own questions to topics they are revising.

2. ***What did you dislike the most about the mobile application?***

This question was used to gather what the users though negative aspects about the application were. Through the use of this question's participants were allowed to voice their concerns about this application, what they didn't enjoy and what could be improved in future works.

Some users stated they did not like the "bland" look of the application and that more could have gone into the design stage. Other users pointed out that whilst the ability to add your own questions to the application was good, that the application did not support the revision of more detailed answers due to the nature of the application (Multiple-choice questions). Further feedback was given that the revision notes provided did not go into enough detail about certain aspects they felt needed more covering.

3. ***Would you use the application in future scenarios? why/why not?***

This question was used in order to figure out if the application has a foundation which the users find valuable.

The responses were varied with some users saying they would not mind using the application in the future (however they did not note if that would include creating their own questions and answers to revise from).Whilst others said that they would only use it specifically if other members of the community had provided them with questions and answers. A majority of the answers also noted that they would like to use the application, but further features would have to be added. Overall a majority of the answers said they enjoyed the application and if it was more polished, they would use more frequently.

4. ***What features would you like for the application to have included?***

This question was asked to provide information for future work and if anything was done to the application what it should be targeted to specifically. Asking the users for their personal feedback and incorporating it into the application allows us to target it to a specific audience.

The majority of users stated that they would have liked online interactivity added to the application with the capabilities of being able to keep track and challenge friends. With further features such as other game modes to aid revision. Further feedback suggested that an overhaul of the design was necessary as the current one was too "simple and bland".

5. ***How would you rate the mobile application?***

This was a simple question asking the user to rate the application between 1 and 5 stars. This question was simply used to gauge the interest and overall opinions of the application.

The average score of the application after taking in the averages equaled to 3.65 stars.

6. ***Which of the following was the biggest issue for you when using the mobile application? (The app was confusing to use, I experienced bugs, the app was visually unappealing, the app was missing features I needed, the app crashed, Other (please specify))***

   This question was asked in order to cover several aspects of the application that were thought to be problematic. There was a mixture of "the app was visually unappealing" and that there was a lack of further game modes.

Limitations of the Study

Due to the nature of the study and the way it was conducted, users were set with a revision task and left to their own devices. Unfortunately, because of this it was not possible to track the frequency of revision for each user or the overall time spent. It is possible that participants from the control group which were set to revise on mobile devices instead of focusing on the spaced repetition approach left all the revision to the last moment and instead turned it into a massed presentation approach. This would provide the study with incorrect data as it is not possible for the researchers to be there at each revision period unless the study was done in a way where they were coaching.

Furthermore, due to there being only one researcher and a total of twenty participants, when the tests were being taken it was not always possible to gather all the test subjects at the same

time. Therefore, certain tests had to be completed at different times allowing those individuals more time to revise compared to everyone else. This would also provide the study with incorrect results. Also due to the lack of monetary reward on the user's behalf, it is not known if they were motivated to stick a revision schedule.

One of the other issues encountered throughout the use of this project was the use of questionnaires to gather feedback on the mobile application. Whilst questionnaires are not necessarily a bad way to gather such data they can be quite limiting based on the depth of the questions and the questions asked. The questionnaires allowed me to provide a structured approach to gathering data to a set of questions. This was good as each user answered the questions and the opinions varied between participants allowing me to gather varying data. However, this does not allow me to gather any further elaboration on these questions or the answers given. A better approach would have been to invite the users to a face-to-face interview and go over the questions in a manner where they can express more freely what their opinion is as well as potentially show changes they would have liked for the application. Although this necessarily wasn't an issue as adequate information was gathered, it could have been completed in a better manner.

Another issue which was encountered through the study of this project was that the spaced repetition approach meant to be utilised for the mobile applications could not be fully partaken in. The spaced repetition approach is shown to work best over long periods of time where the user can overtime frequently revisit any information they have learnt. Unfortunately, due to the way the tests were conducted (spanning over a 2-week period). This was barely enough time to see any progress through the spaced repetition approach. This allowed for participants a maximum of one week on each topic effectively using the mobile application before they were swapped to the revision notes. The ability to produce these tests over the course of 4 or 8 weeks would have been greatly beneficial and provided the study with more concrete results. Another way which the study could have been further backed by data is to have run each group only on one revision method respectively and then later revisiting the tests and taking results again to understand to what an extent memory retention has occurred between both the mobile application group and the written study notes group. This was however unfortunately not possible due to the time constraints of the study and the fact that after one test was finished, we would immediately have to advance to the next test/study period in order to gather more data for analysis.

Chapter 7: Reflection

Time Management

As previously mentioned, Time management has been adhered to throughout this project with the use of a Gantt chart. Whilst in reality not all tasks took the planned time due to the discovery of new requirements or tasks simply taking longer than expected. The main functionality of the application has been created in accordance to the Gantt chart set deadlines. With only online database functionality missing.

Resource Management

Source code

Throughout the development of this project all source codes have been stored through the use of a GitHub repository. Further back-ups have been stored both locally and on Google Drive. Therefore, if any issues were to occur with the code, a previous version can be brought up quickly to resume work form.

Materials

The materials pertaining to this project include:

- Two tests (Computer Security, Fundamentals of Information Visualisation)
- Two pairs of Study Notes (Computer Security, Fundamentals of Information Visualisation)
- Excel file including all test data
- Ethics forms

All of the above materials are stored in digital files in relevant folders on Google Drive with the exception of the physical tests retrieved from the participants.

Challenges

I have already explained most of the issues which occurred when completing this project however this is a summary of all the issues encountered.

One of the issues previously mentioned but not in detail is that due to time constraints the development of an online database system was scrapped. The online database system would have allowed all users with the application to connect to a single source and be able to download or upload questions for other users to utilise. Luckily this was not a core functionality of the application and did not affect end results. However, the ability of the online database system would have made the application more enjoyable to use and provided participants with further options to explore about subject learning. It was also stated in the feedback that users would have enjoyed a feature like that and that they would use the application in the future if updates were added. A further feature that was also strapped to time constraints was a notifications feature, an initial implementation of it was included however there was not enough time to match the functionality to the requirements and it had to be removed.

Chapter 8: Results

Twenty participants in total were enrolled as part of this study with all twenty of these individuals completing both two-week tests. On average, male participants made up 65% of the study. The twenty participants present for the study were randomly placed into teams through the use of the online tool "https://www.randomlists.com/team-generator". And an initial test was taken to gather results on the base knowledge of each individual within the test groups.

Test 1 - Computer Security

Initial test

The first test presented to the participants was based around the "Computer Security" module and consisted of 10 questions total adding up to 20 marks. The questions used were a mixture of multiple-choice questions and open-ended questions. An initial test was taken for all of the participants. Out of both control groups, Group 1 had an average score of 3.2/20(16%), with Group 2 being close behind with 2.9/20(14.5%). After the initial test was taken Group 1 was assigned to revision through the use of the mobile application, whereas Group 2 were assigned to revision through the use of paper notes. The participants were advised to revise using their handed method for the next week and instructed to come back 7 days later for a follow-up exam.

Midpoint test

One week later, the test had been repeated and all of the consequent results from the participants written down. After the midpoint test was completed the participants in both groups had been switched to the opposite revision method. Group A started to revise using the provided paper notes whereas Group B were switched to the mobile application. The results gathered from the midpoint test showed that Group A (which had revised with the mobile application) had seen a 39.5% increase compared to initial scores with their new average increasing from 3.2(16%) to 11.1(55.5%). On the other hand, Group B (which had revised using paper notes) had seen a 38.5% increase compared to their initial score of 2.9(14.5%). Their new average was 10.6(53%). At this midpoint of the test, the improvement although whilst minimal showed that the participants with the mobile application had a vague difference in results. Once the tests were completed the users were instructed to come back a week later for the final test with their new revision methods.

Final Test

At the final test, participants took the exam again. The results showed that Group A (which had previously been swapped to the paper notes) had seen an average change of 21.5% compared to their midterm results. Previous average being 11.1(55.5%) and new average being 15.4(77.7%). On the opposite end Group B (which had now been swapped to the mobile application) had a new average of 14.8(74%). With an average change of 21% from their previous result 10.6(53%). A standard deviation was also taken from the results at this point in order to measure the distribution of scores. The standard deviation of Group A equaled 8.08% compared to Group B's 5.39%. The results show that Group A had a larger distribution away from the mean which can be understood that some participants were better acquitted to this type of learning. However overall the change in scores stayed consistent through both methods of study and overall the final increase for Group A and Group B was within 0.6 marks of each

other with both groups showing improvements at the different revision stages of the study. Overall this test showed no direct correlation in improvement between method of study and result.

Test 2 - Fundamentals of Information Visualisation

Initial test

The second test presented to the participants was based around the "Fundamentals of Information Visualisation" module and also consisted of 10 questions total adding up to 20 marks. The questions used were also similarly a mixture of multiple-choice questions and open-ended questions. An initial test was taken for all of the participants. Out of both control groups, Group 1 had an average score of 1.8/20(9%), with Group 2 being ahead with 1.9/20(9.5%). They were told to once again revise using their method for a week and come back to do a midpoint test.

Midpoint test

One week later, the test had been repeated and all of the consequent results from the participants written down. After the midpoint test was completed the participants in both groups had been switched to the opposite revision method. Group A started to revise using the provided paper notes whereas Group B were switched to the mobile application. The results gathered from the midpoint test showed that Group A (which had revised with the mobile application) had seen a 42.5% increase compared to initial scores with their new average increasing from 1.8(9%) to 10.3(51.5%). On the other hand, Group B (which had revised using paper notes) had seen a 38.0% increase compared to their initial score of 2.9(14.5%). Their new average was 9.5(47.5%). At this midpoint of the test, the improvement although whilst minimal showed that the participants with the mobile application had a vague difference in results. The gain in score was larger than the previous test, with there being a 4.5% difference in result between the mobile method and the paper method. However, that is not conclusive enough to say that the method was successful. Once the tests were completed the users were instructed to come back a week later for the final test with their new revision methods.

Final Test

At the final test, participants took the exam again. The results showed that Group A (which had previously been swapped to the paper notes) had seen an average change of 26.5% compared to their midterm results. Previous average being 10.3(51.5%) and new average being 15.6(78%). On the opposite end Group B (which had now been swapped to the mobile application) had a new average of 15.2(76%). With an average change of 28.5% from their previous result 9.5(47.5%). A standard deviation was also taken from the results at this point in order to measure the distribution of scores. The standard deviation of Group A equaled 5.5% compared to Group B's 8.67%. The results show that Group B had a larger distribution away from the mean which can be understood that some participants were better acquitted to this type of learning (Mobile). However overall the change in scores stayed consistent through both methods of study and overall the final increase for Group A and Group B was within 0.4 marks of each other with both groups showing improvements at the different revision stages of the study. Overall neither test showed direct correlation in improvement between method of study and result.

To view the results please see the Appendix.

Chapter 9: Future Considerations, Self-Reflections and Conclusion

Future Considerations

Whilst the overall study and tests were approached correctly using the right methodology, the results were not directly supporting of the application. If the tests were to be redone, there are many factors which could be modified to produce stronger results to support the software.
An example which comes to mind is to have 2 tests running in parallel. One test would be run similar to how the current tests were conducted; however, an overall longer study time would be provided for each participant. Ideally increasing the length of each study period to a total of 2-4 weeks. Resulting in a potential overall study time of 2 months. This would be done so that the spaced repetition approach can start taking effect. Studies have shown that at shorter revision periods the spacing effect is not clearly visible in results as I think was displayed clearly by the tests run in this study.
Another test would be run at the same time, however there would be no swap over period. The test will take place over a 2-month period and there will once again be an initial and an end test where results will be compared. Extending the length of the study would provide better results as users would not be tempted to revise every night using the study notes and instead revise more naturally over the study period. In both of these cases a further test will be conducted two months after the study ends in order to gather more concrete data about the findings as that is where the spaced repetition learning effect is shown to work.

Self-Reflection

Looking at the project as a whole, it definitely had its moments of highs and lows. However, I cannot consider it a negative experience. The project has allowed me to learn and improve as well as allowed me to gain experience in planning and executing long-term projects. This study has allowed me to understand the amount of work which goes into these projects as well as how to deal with time management issues which may occur and understand that complications can happen at any time. It has further allowed me to develop my programming skills and learn new technologies which will surely help me in future careers.

Conclusion

Whilst most mobile learning applications are designed around language learning or organising your own notes, in this dissertation I have presented a functioning multiple-choice learning tool. Even though the overall the results which the study has produced have been inconclusive, with the difference in results between the multiple-choice learning method and the written study notes method being minimal (less than 5% difference in total). Not seeing a drop-in result between the methods is a positive conclusion in its own, it shows that the revision through the mobile application managed to keep up with the normal studying methods and therefore is a viable option to students who enjoy that learning style. Furthermore, a majority of the gathered feedback indicated that users enjoyed the use of the mobile application and I believe that further testing with prolonged study periods and different testing methods could provide beneficial data to further support this study.

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