# To What Extent Does Speech Recognition Increase User Engagement With A Dream Diary Application?

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***Abstract*—There has been considerable interest in research regarding lucid dreaming, with some research communities showing evidence that lucid dreaming can be used in ways that provide a positive mental health impact for the dreamer. Dream diaries are an easily accessible method that can be used to contribute towards inducing lucid dreams. At the point of writing this study, dream diary applications do not commonly feature speech recognition as an input method, however there is not a clear reason why this is the case. This study researches if the implementation of speech recognition into a dream diary application improves the users engagement with the application. A ten day study had users interact with a dream diary using keyboard input for half the study and speech recognition input for the other half. There was a significant drop in user engagement with the application when using the speech recognition input method. The main reasons for this was inaccuracy of the speech recognition software and being too loud/disruptive as a morning activity. Therefore it is currently not recommended to spend time implementing speech recognition for dream diary applications as users will likely avoid using it.**

## I. Introduction

LUCID dreaming is a form of dream in which the dreamer has a conscious awareness of the fact they are currently dreaming. This awareness allows the dreamer to take control of the dream and in essence do anything they want within the dream [1]. For most people lucid dreaming is a very rare occurrence however when achieved it is felt to be a pleasurable experience [2][3]. Lucid dreams can be utilized for creativity, to solve problems and work through psychological issues [4][5]. While some people can be sceptical about the differences between lucid dreaming when compared to non-lucid dreaming, electroencephalography(EEG) imaging techniques have shown differences between brain activity for lucid dreamers and non-lucid dreamers [6].

Due to the rarity of lucid dreams and the positive impact they are thought to be able to have on the dreamers well-being [7] a plethora of research has been conducted into ways to induce lucid dreams [8][9][10][11]. Many of these induction methods are out of reach for the general population such as drug trials [11] and specifically created portable devices [12]. None-the-less there are largely accessible methods that can be used by individuals wishing to induce lucid dreaming such as; dream diaries and reality checking techniques. Mobile applications have been developed to facilitate the use of these methods, see fig 1 for examples.

Speech recognition application programming interfaces (API) have become available for free over the past decade, opening up more options for developers and researchers. Research into methods of human computer interaction (HCI) has changed computing throughout the years for users, researchers and developers [13]. We can expect to see speech recognition play a role in changing how we interact with computers in certain situations, especially as it continues to improve.

The focus of this study will be to evaluate ways in which mobile applications can be improved in a way that might help users to reach their goal of inducing lucid dreams. It will be structured the following way;

- Clarification and the reasoning behind the research question.
- A literature review focusing on the current state of products available on the market and lucid dreaming itself, this will help discover possible avenues for improvement.
- The hypotheses of the study will be discussed in detail.
- The design of a research artefact will be outlined in accordance with the previously discovered information, showing what was created for the study in order to gather data and answer the hypotheses.
- The methodology of the study will be outlined and justified.
- Results of the study will be presented along with statistical analysis.
- Discussion about points taken from the results.

This study culminates in knowledge that can be disseminated through academic literature with the hopeful outcome of guiding the improvement of future lucid dreaming application design. Since these applications are so readily available to the general population [14] managing to improve the functionality of them can have a large overall impact even if the improvements are small. Although this study originates from the goal of improving lucid dreaming applications, by it focusing on dream diaries it has broadened the implications of it results into also effecting dream diary applications that are not designed for lucid dreaming induction.

## II. Research Question

Engagement as a term is used with multiple meanings and generally depends on ones own perspective [15]. Therefore it is important to clarify its meaning when used in regards to this paper. For this we will take a definition outlined from the Oxford Learner's Dictionary for the word engage; "to succeed in attracting and keeping somebody's attention and interest" [16]. Then with engagement itself meaning; "the

act of engaging : the state of being engaged" [17]. With this definition of engagement we are able to measure user engagement with the diary application in multiple ways which will be discussed later in the hypotheses section. Generating good engagement is crucial to the success of most applications.

The question the this study aims to answer is: 'To what extent does speech recognition increase engagement with a dream diary application?'. Dream diaries have shown a significant increase in improving the induction of lucid dreams [18]. They are also readily available to anyone with a smart phone at minimal to no cost, see fig 1. If it is possible to increase user engagement with these types of application it could have beneficial impacts on future research by helping supply additional users to research. Additionally if lucid dreaming is proven to have a significant positive mental health benefit then all ways to help people achieve this type of dream will be of importance to the health and well being sector. Finally current applications charge for speech recognition input as a feature, see fig 1. Hopefully this study can help provide users with data to support or disprove value for money.

## III. Literature review

### A. History of Lucid Dreaming Research

During the 1800's dream research began its resurgence, at this time Saint-Denys wrote a book which refers heavily to *'rêve lucide'* [19] or lucid dream in English. Later Frederik van Eeden used the term lucid dream in his paper *'A study of dreams'* [20]. At the start of the 1900's Sigmund Freud wrote multiple articles regarding his thoughts on dreams [21][22]. His thoughts were that dreams show a disguised fulfillment of a repressed wish, which allowed the mind to achieve fulfillment without having to do so in the waking world. Researchers J.Hobson and R.McCarley did a study in 1977 [23] where they tracked brainwave activity of dreamers using an EEG. These findings suggested that dreaming is a subconscious bodily process and not a mental one. They went on to theorise that dreams are formed of the mind trying to make sense of random electrical signals and grounding them in unconscious reasoning [24]. This explanation of dreams appears not to support the feasibility of an individual to take control of their dreams, as they do in lucid dreaming. A recent study from J.Hobson *et al*. [6] shows that dreamers who achieve a lucid state have a shift in EEG patterns indicating that dreams and lucid dreams are different even if they are of similar origins.

### B. Health and Well-being

Recently there has been a shift in focus in the HCI community towards designing products concentrating on mental health and well-being [25]. Dreams have been shown to be important for memory consolidation, emotional regulation and general information processing [26]. Some researchers have claimed that there is no evidence lucid dreams are distinct from rapid-eye movement (REM) sleep, or as it is more commonly known the "dream state" [27]. However as previously mentioned, EEG machines have been used to suggest that there is a difference in how these dreaming states are created in the brain [23].

If we are to believe that dream state and lucid dreaming state are indeed different processes then we need to question what effects can come from the ability to have conscious awareness and control of your dreams. States of altered consciousness, such as the use of psychedelics and religious ceremonies, have been known to provide powerful and often life-altering experiences [9]. Lucid dreaming is a form of this but one that gives the dreamer much more control over the experience. The dreamer can use this lucidity as an introspective tool which shows suggested results of an increase in mental well-being [7]. People who manage to achieve lucid dreaming have reported their ability to use it for introspection [4], it has also been suggested that lucid dreams could have application in treating depression, reducing nightmares, and rehabilitation [28].

A study conducted by Dresler *et al*. has helped to support the argument that lucid dreaming is the same as actually experiencing the scenarios in waking life [29]. If this is the case then there is a possibility for lucid dreams to be used as a time to practice physical tasks as well. To support this another study has focused on experiences of dreamers while in lucid dreams [4]. Results showed that 21 percent of participants sometimes chose to practice skills during their lucid dreams. This suggests that people choose to bring tasks from everyday life into their dreams in the hope of improving them, which supports the theory that both experiences are similar. The other applications of lucid dreams recorded were; having fun, changing nightmares, problem solving and creativity.

Although all of the above creates a strong argument for the positive effects lucid dreaming can have on the human mind, it is still stated that not enough empirical studies exist to back these claims [9]. Therefore it is expected to see ongoing research into this topic in the coming years. Given this, improving the ways we can achieve lucid dreaming will allow for easier access to possible test subjects making later research into this area easier to be carried out.

### C. Induction Methods

Lucid dreaming induction methods are techniques that can be used to increase the frequency of achieving lucid dreams. A large number of different types of induction methods exist for lucid dreaming, each with varying success. Stumbrys *et al*. have classified the different methods into three empirically based groups [30];

- Cognitive Techniques - Cognitive methods to induce lucid dreaming
- External Stimulation - Stimuli applied during REM sleep to trigger lucid dreaming
- Miscellaneous Techniques - Other techniques that do not fall into the above categories

Mobile applications currently on the market often employ cognitive techniques, see fig 1, therefore we will focus on some of the key techniques available in this category.

*1) Dream Diary:* Keeping a dream diary is a long standing technique known to increase dream recall frequency [31]. Aspy [18] showed a significant increase in lucid dream induction for participants using a dream diary compared to

their estimated baseline. Alternatively Zunker *et al*. [32] found no significant increase in a similar study. The Apsy study was advertised in specific regards to lucid dreaming whereas the Zunker one was not. This possibly played a part in the difference as participants for the Apsy study are more likely to be interested in lucid dreaming. We might take away from this that dream diaries without the conscious thought of lucid dreaming do not have the same effect as those used when trying to achieve lucid dreaming. Another possible reason could be that the participants of Apsy's study were employing other methods to achieve lucid dreaming as well.

*2) Reflection/Reality Testing:* Reflection/reality testing is done throughout the day, you ask yourself regularly if you are dreaming or not, using the environment and physical attributes about yourself to help you clarify reality and dream. This method has been shown to help raise the frequency of lucid dreams [33][34] and is one that we see appear often in the mobile applications in fig 1. The additional ease of use that a mobile application brings to reality testing is clearly evident when you try it with and without the application. The applications allow you to set yourself reminders throughout the day to make sure you remember to do your checks. Some even add a sound to the reminder that can be set to play during your REM sleep stage in an attempt to trigger your dreaming self to check. It is possible that this is one of the current greatest synergies between cognitive methods and mobile applications.

*3) MILD:* Mnemonic Induced Lucid Dreams (MILD) consists of rehearsing a dream in your head before sleeping, visualising becoming lucid in the dream. There is not a feature to help with this in any of the applications seen in fig 1 but some had guidance for it in their information sections. MILD shows signs of giving a slight increase when used before going to sleep [35] compared to not using the MILD technique. An adaption to the technique has been to wake up an hour or two early then apply the MILD method, doing it this way lucid dreaming has been shown to become much more likely [36].

### D. Speech Recognition

Speech recognition has the potential to be a useful form of interacting with a computer and has seen progress in its development over the years [37].

A paper by A.Jadhav and A.Patil [38] looks to discover if speech recognition can provide a competitive alternative to keyboard text entry. The paper claims that speech recognition does actually provide a very competitive alternative, however on further inspection the paper makes this claim on no evidence. Jadhav and Patil have merely outlined their study plan without delivering any data and analysis.

Access to speech recognition API's for Android operating systems has become easy for software developers thanks to Google allowing use of their "SpeechRecognizer" features [39]. Books and guidance on how to implement these features exist to help extend the reach of speech recognition into applications [40]. With this in mind we are likely to see a growing amount of applications looking to use speech recognition were it to be proven to have benefits over keyboard entry methods. It also allows for research to be conducted by more people without needed access to paid for speech recognition libraries.

A possible drawback to this style API is that they communicate with a cloud server to calculate the text which requires an internet connection [41]. For those with a good connection this helps provide a relatively accurate and quick conversion from speech to text. On the flip side for those without reliable access to internet it can mean that this method is not one that will necessarily work well for them [42].

### E. Review of current products

For this proposal a comparison table of currently available mobile applications to assist with lucid dreaming has been created, see fig 1. These products are restricted to those accessible through the Google Play Store on Android operating systems, therefore it is not entirely comprehensive but gives a decent understanding of the current products and the features that they provide.

| Application ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Price | Free | Free/ £1.99 | Free | Free/ £3.99 | Free | Free/ £3.89 | Free/ £1.04 |
| Rating | 4.4 | 4.5 | 4.7 | 4.3 | 4.2 | 4 | 3.6 |
| Downloads | 50k+ | 500k+ | 1k+ | 100k+ | 1k+ | 5k+ | 10k+ |
| Adverts | No | Yes | No | Yes | Yes | Yes | Yes |
| Dream Diary | No | Yes | No | Yes | No | Yes | No |
| Diary tags | No | Yes | No | Yes | No | Yes | No |
| Voice Recording | No | No | No | Yes | No | No | No |
| Reality Checks | No | Yes | Yes | Yes | No | Yes | Yes |
| Alarm/Notification | No | Yes | Yes | Yes | No | Yes | Yes |
| Sound Selection | No | Yes | No | No | No | Yes | No |
| Sound Test | No | No | No | No | No | Yes | No |
| Information | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Dream Clues | No | Yes | No | Yes | No | Yes | No |
| Dark Theme | No | Yes | No | Yes | No | Yes | Yes |
| Speech to Text | No | Yes | No | No | No | No | No |
| Dream Patterns | No | Yes | No | Yes | No | No | No |
| Statistics | No | No | No | Yes | No | Yes | No |
| "Achievements" | No | Yes | No | No | No | No | No |
| | | | | | | | |
| Key | | | | | | | |
| Behind paywall | | | | | | | |
| Free | | | | | | | |
| Not in app | | | | | | | |
| Premium remove adverts | | | | | | | |

Fig. 1. Current lucid dreaming Android application features table.

All of the applications are available for free with some having a purchasable version to either remove adverts or in some other cases unlock additional features. There is a level of disparity between the different features that the applications provide. High download numbers suggests that particular applications are fairly popular. Informational guidance on lucid dreaming and how to achieve it is seen in every single application that was found on the market. This is likely due to its importance in helping guide users to achieve lucid dreaming and using the application correctly, but also as it is low effort to

implement. The next two features seen most are reality checks and alarms/notifications. These are seen to come hand in hand as the reality checks are often notified to the user through a notification system throughout the day. Tying reality checks into a mobile application is of great benefit to improving users ability to remember to do their checks, as it is likely that users often have their mobile phones on them. With reality checks synergising so well with mobile applications and being a notable cognitive induction method [30] it is of no surprise to see this feature so highly used.

Dream diaries are available in three of the seven applications on the market. It is worth noting that two of the applications providing a dream diary feature only use standard layouts available in Android Studio [43]. The other application to use a dream diary is the one that has drawn the most attention for this proposal; Application ID 2 which is called Awoken.

Awoken is the most popular of the applications on the market and looks well designed, with its layout having a clear structure and theme throughout, see Appendix A for example images. This most likely has some impact on its popularity given the importance of slick user interfaces [44]. The most relevant feature for this proposal is that it is the only application to provide speech to text capability which comes at an additional cost. Considering that only one application uses this feature it brings up the question of why this is, is it perhaps the true reason for this application's success? It could be that using speech to text just is not a sought after feature for users or that speech to text will be more effort to implement into an application than many of the other features available. Finally its possible speech to text just does not work well enough for a dream diary application. The study proposed will be able to find evidence to support or deny some of these possible reasons and give solid grounding into whether or not speech to text should be standardised in dream diary applications.

### F. Review Summary

Research into lucid dreaming has claimed there to be beneficial impacts on the health and well being of those that can achieve it, however these claims are argued to not have enough evidence to back them up. Therefore it can be expected to see future research into the health and well being changes made by lucid dreaming. If it is possible that using speech to text software improves users willingness to interact with a dream diary it could increase the amount of available test subjects for future research. Alongside giving a better reach to this type of application for if health benefits are ever empirically certain.

Using speech recognition software in this study targets a potential gap in the market that is not yet being utilised. Additionally minimal research regarding the use of this feature has been found during the literature review, making it a novel endeavour to research. The study will follow on well from how dream diaries are known to be a possible method of lucid dream induction, looking at new and interesting ways diaries can be improved.

## IV. Hypotheses

The hypotheses for this research are looking to provide insight into what extent speech recognition improves engagement with dream diary applications. All of the hypotheses are designed for one tailed t-tests, although this restricts the results to only one directional examination it keeps the sample size required down. The choice of this test was based on the nature of a longitudinal study requiring an investment of time from each participant and the strict time the researcher has to complete the study. Given that the focus here is on improving engagement this decision was considered to not hamper the study by the researcher.

| | Hypothesis | Null Hypothesis | Data Source |
|---|---|---|---|
| 1 | Speech recognition input increases the length of diary inputs compared to typing. | Speech recognition input does not increase the length of diary inputs compared to typing. | Mobile application |
| 2 | Speech recognition input increases the amount of dreams recorded when dreaming was achieved compared to typing. | Speech recognition input does not increase the amount of dreams recorded when dreaming was achieved compared to typing. | Mobile application |
| 3 | Dream diary recordings input using speech recognition are less accurate than those input using a keyboard | Dream diary recordings input using speech recognition are as accurate as those input using a keyboard | Mobile application |

### A. Hypothesis 1.

Aim to determine the depth of detail users are willing to input into the recording, along with testing an improved amount of recollection of their dreams. A limitation to this is that to avoid users being put off by their dreams being recorded the study will not be taking complete recordings from them, instead it will only take the length of the recording entered. Therefore the ability to say how much detail is used will be less accurate than it could otherwise be. However a comparison between length of recording and detail can be assumed so long as this limitation to its data is clarified. In the same vein breaking apart the length between detail and increased recollection would be troublesome with only the length of recording data. To combat this a completion survey asking the participants if they felt an increase in detail or recollection, will help clarify the data gathered during analysis.

### B. Hypothesis 2.

To target participant engagement with the application in regards to the different input methods. Focusing on if the participant is more likely to use the diary application and if they have dreamed, when given the speech recognition input method. This stems from the idea that participants may be more willing to use one input method over another. A limitation here is that the study will be ongoing over the course of ten days, there is a chance that participants grow bored of the study and no longer want to use the application during it. To counteract this as much as possible the input methods each participant starts with has been randomised to even out the possibility of burnout. This will be split 50/50

across participants randomly selected for each participant to give an even sample. Using random allocation like this is key to avoiding bias in the data collected [45].

### C. Hypothesis 3.

This looks to clarify if the accuracy of speech recognition in this type of application could play a factor in a decline of user engagement. There is a known issue with speech recognition and its accuracy at times which can be derived from the ongoing development in speech recognition accuracy [46][47][48]. With participants being in a drowsy state when using this software there is a thought that the recognition software will have a decreased accuracy rating due to mumbled speech and possible quietness. Knowing if speech recognition has a lower accuracy to typing in this setting could completely rule out the viability of using this software in its current state.

## V. Research Artefact

The software artefact for this study has been designed to be in keeping with the more popular mobile applications from fig 1. Taking inspiration from the dream diary sections of these applications. Screenshots of how the software artefact looks can be seen in fig. 2 and fig. 3. The artefact along with any relevant work for it is stored on a Falmouth University Bitbucket server[1] that has been provided for the researcher. The end product was also uploaded to the Google Play Store for distribution to participants and can be viewed there[2]. The software was written in Java using the Android studio IDE. Android Open Source Project Style Guide [49] was used for guidance when creating the software, making sure to always stick to the key point of always being consistent.

### A. Life Cycle

For the development of the software artefact a V model life cycle has been used as a guideline throughout development [50]. This model focuses on the connections between each of the development stages and their respective tests, by doing this, quality measurements and testing are constantly used during the life cycle [51]. This has been an important aspect needed for the development of this artefact, as a high level of quality across the entire artefact has helped guarantee equal and accurate results from the data gathered. Additionally having tests and opportunities to move back and refactor sections when each new feature was added has allowed for a flexible process, working well with building a growing and evolving artefact. This was needed because the product was being designed with the goals of being accepted by the end user and also being capable of collecting useful data.

Planning and tracking used an online Kanban board HackNPlan [52] for the developer to keep track of current progress and testing information. The choice of a Kanban board was made because using Kanban principles in software development has shown significant improvements in developer processes [53].

[1]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse
[2]https://play.google.com/store/apps/details?id=my.dreamdiary.study

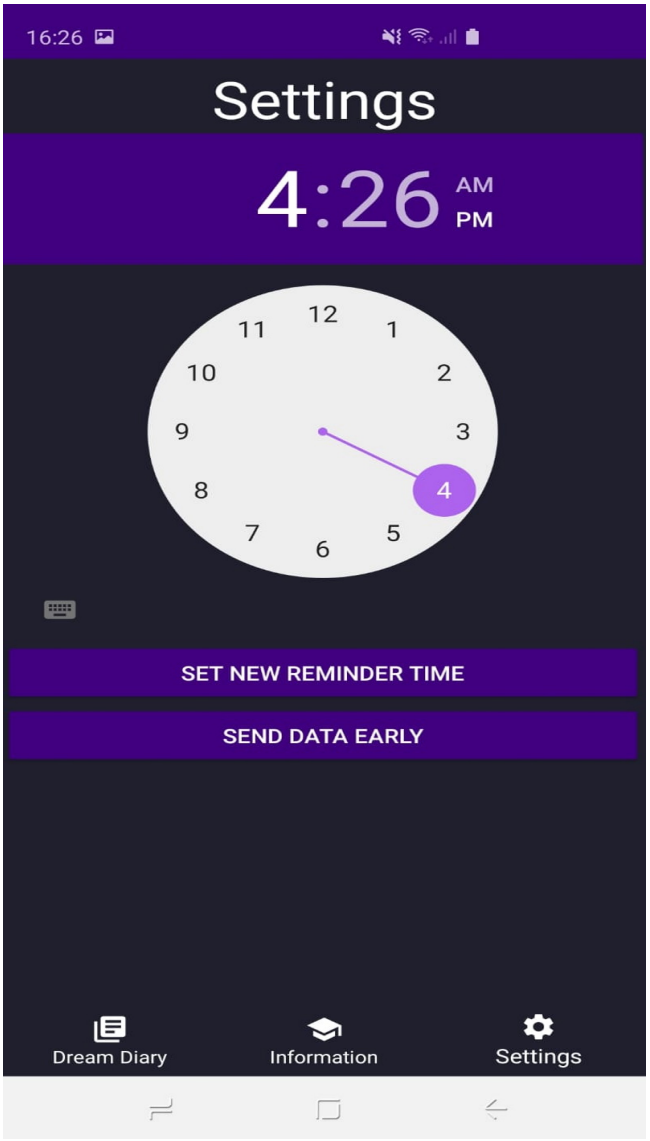


Fig. 2. Screenshot of settings page.

### B. Design

Research into applications of this nature was done during the gathering of data in fig 1. An initial wire-frame had been laid out in the form of UML diagrams, see Appendix B. Throughout the course of development the software design evolved as better working practices were discovered and the required specifications changed.

The key requirements for the artefact by the end of development were;

- Consent form - Selection must be remembered
- Multiple questionnaires
- Diary date selection
- Keyboard and speech input methods
- Database for diary entries
- Notification reminders
- E-mail data to researcher

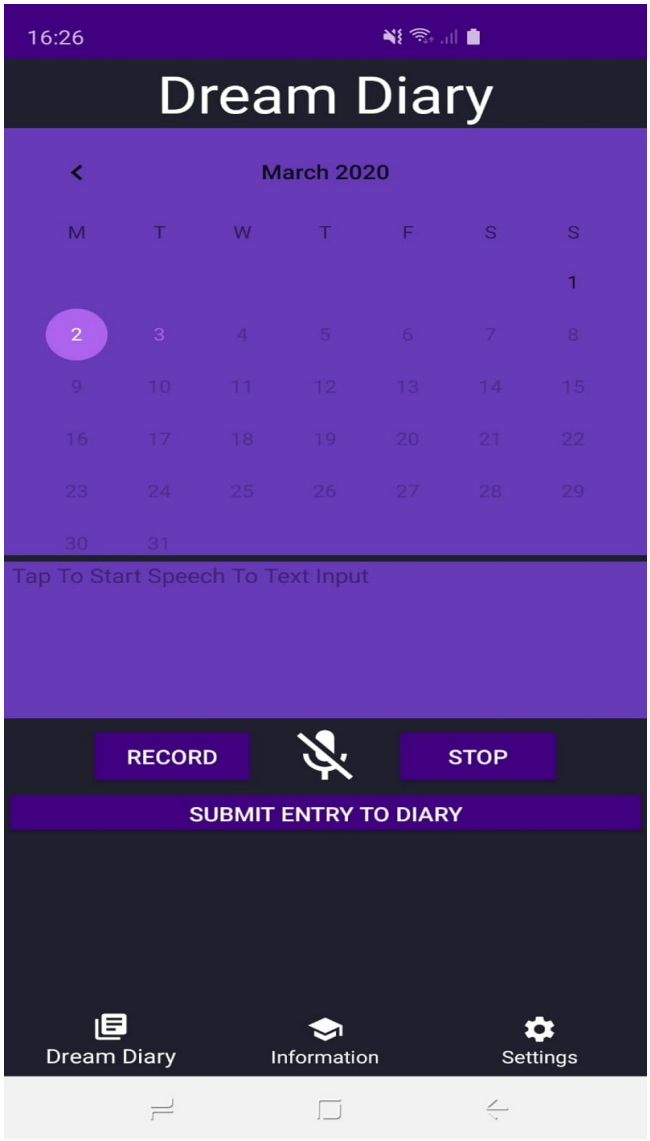


Fig. 3. Screenshot of speech input diary page.

*1) Consent:* When opened the application launches the main activity, each time this activity launches it checks the devices local shared preferences to determine if consent to use the application has been given. Shared preferences on Android devices are used to keep application preferences in the form of key-value pairs, they are stored in a pre-existing XML file and persist even when the application is closed. It was selected to use shared preferences for the persistence it provides while also not requiring any additional file creation on the device from the software artefact before consent has been given. If consent has already been given the user is allowed to continue freely with the software. If consent has not been given the application instead displays the consent form and hides the navigation menu to stop the user from moving away from the consent form. The form itself is a simple scroll-able window showing a string value with an accept button at the bottom. When the user accepts their consent is recorded in the shared preferences of the device so they will not be required to see this page again. The user is then shown the starting questionnaire.

*2) Fragments and Navigation:* Android applications can be broken down into Activities and Fragments all of which are their own classes. These can be used in different ways depending on the requirements of the software. For this artefact one main activity is being used which acts as a container for the different fragments. This allows for easy communication between fragments by using the activity as a middle man and also means the activity can manage the database and other classes, so they need only be created at start up. The fragments themselves hold all user interface (UI) elements and logic needed for that page. The main activity has a navigator that is then used to swap between fragments, this is nice as it automatically handles the stack of past fragments so that the user can use the back button to return back through them. The decision to use one activity was made from a combination of the factors above and a Google Developers session regarding UI which recommends using fragments whenever possible [54]. Fragments are formed of two parts; they have a class which includes all the logic for how they work and they have an XML file that describes the layout and what components exist in the fragment.

The main activity has some general management logic in it that determines a few factors of the application. Once the user has consented the main activity uses the current time to select the initial input method given to the user; even gets one method and odd the other. This was considered an acceptable way of splitting the starting input method between the participants while not requiring multiple applications or communication between the applications. The start time is then stored in the shared preferences. This time is used to calculate how long the user has been part of the study and is checked each time the application is opened. After five days worth of time the users input method is swapped to that of the method they have not yet used. After ten days the study has come to an end and the user will be prompted with the end survey.

*3) Database:* A single database is used to store the users diary entries alongside the data being gathered for the research. It is an SQLite database that is created using the Android built in SQLite database library. A class implementing BaseColumns is used to store the column names as static strings so that when the columns changed during development they would only need to be changed in a single place. A database manager class exists to create and provide access to the database. It was considered to have this manager handle all interactions with the database however due to the specific nature of each interaction that exists it was instead decided to have each fragment deal with its respective interactions to keep them in concise locations. After the application has received consent the database is either created or accessed as a read/write database through the main activity.

*4) Diary and Input Methods:* The diary fragment has many overlapping components but uses SetVisibilty to display only

the required sections to the user at the right time, this keeps the space required down and mitigates confusion by removing any unnecessary components from view.

The built in CalendarView component is used to provide the user a way to select a date from the calendar. Using the built in one allows for consistency across multiple Android API's improving the likelihood that each user will be able to use this calendar. Each time the diary fragment is loaded all future dates are locked to help reduce accidental incorrectly dated entries. When a date on the calendar is selected the database is checked for any entries corresponding to that date, if an entry exists then that information is pulled and displayed to the user for them to read. If an entry for that date does not yet exist then the user is presented with the option to select if they dreamt or not.

If the user did not dream then this is recorded in the database and a Toast notification is used to thank them for their input. Toasts are small pop up notifications that last a short amount of time and can be used to easily inform the user. If however the user did dream they are taken to the entry section. At this point which input method is use is checked and the user is shown the relevant section. Keyboard input entails a basic TextEditor window that is found built into Android. Speech input is more complicated. To do it a nested class has been created in the diary fragment which extends a class called RecognitionListener. This class was nested to increase encapsulation. It is possible to use this as a base class but it does not come with the functionality to continuously record voice input. By creating this class it has been possible to creating looping sections where the SpeechRecogniser starts itself again after each input until manually stopped by the user. The user has complete control over the starting and stopping of voice recognition to make sure they do not feel spied upon.

After an entry has been added the user is requested to rate the accuracy of the entry compared to what they intended. The entry and accuracy are then added to the database using the date as the identifier for the row. At this point these entries are added as an update to the identifier, this cuts down on duplicated rows. When this is done the entry is parsed and its length is also recorded in the database along with the input method used.

*5) Questionnaire:* The two questionnaires in the software artefact follow the same design structure. They consist of grouped RadioButtons that provide the user multiple choice answers where only one answer can be selected. There are also some open ended questions for the user to complete. There is a submit button at the bottom of each questionnaire which activates the logic to write the supplied information to the database and move the user to the next fragment. Unlike with the diary entries no checks are needed to confirm if a row already exists as these questionnaires are always added to a fresh row. Writing to the database does work in the same manner as with the diary entries though, just that it writes to a multitude of different columns.

*6) Notification Reminders:* For the users to set a reminder the TimePicker component is used for them to select a time, When the user presses the button to set reminders for this time the main activity creates an explicit Intent to be called when the reminder time is reached. This Intent is set to repeat using an AlarmManager class. When the set Intent is called it posts a notification to the phone which the user can tap to open the device. An Intent lets you start an activity in another application. Explicit intents specify what application/class is to be called, where as implicit ones let the user decide from valid choices. The AlarmManager provides access to the system alarm services, this way preset Intents can be called even when the application is closed.

*7) E-mail Results:* Once the ten days of study are up the diary fragment flags this and sends the user to the final questionnaire. After completing the questionnaire and that information being stored on the database, the user e-mails the results to the researcher. When the user has gone to e-mail the results edge computing techniques were used, copying the database and preparing it to be sent. A copy of the database was created in the phones External Cache Directory, this is due to file access restrictions put in place between applications. Before the copy was sent the entries column was wiped from the copy. To e-mail the copy an implicit Intent was sent with the copied database attached and the researchers address filled in.

### C. Roll-out

To help maximise the amount of users accessible, the software was hosted on the Google Play Store as a beta application. This provided a hands off installation process for the researcher, while also allowing the amount of users to be tracked, giving an understanding of how many participants had taken up the study. Beta applications do not show up publicly on the Play Store and had to be accessed via a link provided from the researcher to the participants. The process was straightforward and took approximately four days for the application to be approved once submitted. To meet with Play Store regulations an additional privacy policy document was required to be submitted which can be seen within the repository[3].

## VI. Validation and Verification

At the start of development a test plan was drawn out to set up tests based off the original UML diagrams, this plan was created in a spreadsheet covering the expected tests required. Due to the ever changing design for this application the test plan also had to change and adapt to fit the needs of the artefact throughout development. The log of tests can be found located in the repository[4] along with the source code for all unit tests within the software folder[5].

[3]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse/Privacy%20Policy%20for%20Play%20Store.pdf

[4]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse/Testing/TestsSheet.xlsx

[5]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse/Artefact/app/src/androidTest/java/my/dreamdiary/study

Testing was done by the developer using Android studio, virtual Android devices and a physical Android device depending on which was most fitting for the required test. Unit testing [55] was used on most newly created public methods to make sure they worked as intended. Unit tests were created using JUnit4 [56] for method analysis and Espresso [57] for testing user interface elements. As the methods were added to the main body of the application integration testing [55] took place to clarify no new errors had arrived from the integration. This consisted of running through previous unit tests and manual checks of the application being used. When the entire application was all together, system testing [55] was carried out running the full course of the ten day study to guarantee the application worked as intended before the roll-out to participants. Following the V Model life cycle at any point after these tests the developer returned to the design and development phases when it was deemed necessary for the quality and functionality of the application. A more detailed break down of the tests and how they were used can been seen in Appendix E.

Bug tracking was maintained as part of the Kanban board usage, keeping a section updated when bugs were discovered and dealt with[6].

## VII. Methodology

The purpose of this study is to prove or disprove the previously outlined hypotheses. To achieve this a combination of mixed qualitative and quantitative surveys have been used at the start and end of the study for each participant. Surveys of this nature are frequently used to discover user engagement with software applications [58] and so it is possible to take guidance from existing surveys. Data about how the user interacts with the software has been collected throughout use of the software and sent to the researcher at the end of the study, methods like this can be seen being used in software designed to measure and predict user engagement [59].

### A. Data Collection

At the beginning of the study participants were asked a couple of questions to help gauge their existing interest in applications of this nature and the possibility of using speech recognition in conjunction with a dream diary. This base understanding will hopefully give an insight into whether or not engagement is more likely in people without or with, previous dream diary experience. This initial survey is formed entirely of multiple choice questions. At the end of the study a more extensive survey is given to the participants following recommendations from papers looking at measuring user engagement [60][61]. The ending survey is a combination of multiple choice, rating scale and open-ended questions. The open-ended questions need to be combed through looking for any reoccurring or interesting points supplied by the participants. The completion survey forms the main basis for the users personal perception of the software and their engagement as well as giving insight into their opinions and personal choices having used both input methods.

Throughout the study each day the participants have told the application if they dreamed or not, were they to dream they were then given the option to enter this dream with the input method they had currently been allocated. If a user input an entry they were then asked to rate the accuracy of the entry on a rating scale of 1-5. The application tracked entry date, entry length, if the user dreamed, if they chose to add an entry and accuracy of entry. All of this data was recorded by the application and stored locally in a database ready to be sent to the researcher at the end of the study. Although the surveys should give a better background and reasoning for the users choices, this interaction data gathered throughout forms the key data points for answering the hypotheses presented. Collecting these key data points from interaction between the user and application was decided upon because it is possible for users to provide inaccurate data on surveys [62] and the researcher appreciates the solid grounding that can be achieved from usage data.

Using G*Power [63] to determine required sample size it was recommended to have a minimum sample size of 25 participants for this study. All of the hypotheses are able to be tested with one tailed t-tests of means difference between matched pairs. For this study it has been selected to look for a large effect size (0.8) using Cohen's $d$ effect size recommendations [64]. This is due to two factors; The first being that it is believed that the results will show a large difference between the comparative means. The second being that it helps to keep the required sample size to a manageable number of participants given the length of the test this is a highly required factor, but also a restrictive one. Starting with an alpha of 0.05 and using Bonferroni's correction [65] to account for the three hypotheses brings the alpha to 0.016 giving an acceptable level of type one errors. Sticking to a beta of 0.05 allows the power to be 0.95 giving the results a 95 percent certainty of avoiding type two errors.

### B. Data analysis methods

Before the data analysis some cleaning and organisation of data will be done by the researcher. This will tidy and confirm that all data has been gathered correctly from the application. Data points for each user will be split between their two five day periods giving them clear sections to test against each other.

The mean length of diary entry for each participant and each input method will be calculated. All days when the user marked as did not dream will be omitted from this, whereas any entry the user marked as did dream but chose not to add an entry will be scored at zero length. This means will then be entered into a one tailed t-test. To display this information to the reader a box plot will be used, this graphical display has been selected as it provides a simple but powerful way to visually interpret the distribution of our tabular data set [66]. This same method will be used again for the analysis of accuracy. Instead of the mean length the mean accuracy will be taken in the same way and used in the same manner. For

[6]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse/HackNPlan

this any blank entries will be omitted as they will not have an accuracy score.

To test hypothesis two the same method of testing and displaying the data will be used. A percentage based system will give each participant an overall percentage for dreams recorded when dreaming was achieved with each input method. For example if a user dreamt everyday while using the keyboard input but only added entries on four of the days they would be given an eighty percent score for keyboard input. For an example of the R code that will be used see Appendix C, the example includes the t-tests and how the box plots will be laid out.

Correlation tests were used on a multitude of results to looks for patterns within the data found. Shapiro-wilks tests were used on data sets that show correlation to check that the data is of an expected normal distribution. Questionnaire results are presented as a percentage of users allowing for easy comparison between questions, using percentages also allows for figures to be quickly understood and interpreted.

### C. Ethical Considerations

Consideration of ethics when doing scientific research is very important for multiple reasons, such as; making researchers accountable for their actions, ensuring the public can trust research and supporting social and moral values [67]. A clear and succinct example of this can be seen in the Nuremberg code [68] which was created after multiple counts of inhumane and unethical experiments carried out during world war two.

All participants are required to read and sign a consent approval form before they are able to take part in the study in accordance with the Falmouth University ethics policy [69]. This form is tied into the mobile application allowing for a completely hands off set up by the researcher. The form informs the possible participant of the purpose of this study, exactly what data will be collected, how the application and input methods work, who is conducting the study, contact information for the researcher and how the participant is able to opt out of the study at anytime. The information on the form is accessible at any point through the mobile application to allow the participants to re-look at it if they so desire.

Having such a comprehensive form allows the participant to be completely knowledgeable about the study and their role in it, where this is not the case the option to contact the researcher prior to accepting covers any lack of clarity. This mitigates any problems with participants being unlikely to continue the study as it has been forward and upfront. This also means that there is a minimal chance that the participants will be confused or deceived unintentionally.

Dreams can be considered to be very personal information, although not specifically personal data given the definition in the GDPR regulations[70], unless the dream happens to include information that could make the user identifiable. Due to the fact it would be unclear if the diary entries would hold personal data, alongside it being off putting to some users to share this information, the researcher does not collect the diary entries and instead gathers meta data about the recordings and how they were done. The participants are made very aware of this to make them more comfortable with the study, this will hopefully mitigate some participants avoiding taking part in the study from feeling uncomfortable sharing their dreams.

All data is kept anonymous meaning that data can be stored on a GDPR [70] compliant cloud server. Data is sent from the participants mobiles to the researcher to store on the server. Personal data stored in the diary application has not been collected and is the responsibility of the participant to keep safe, they have been made very aware of this in the information form.

### D. Participants

Participants have been randomly selected from those readily available to the researcher meaning a convenience sampling method has been applied. Participants were required to have an Android operating system (OS) mobile device. This was due to a lack of accessibility for the researcher to develop for Apple OS, as an Apple computer is required and the cost of using the App Store is much more expensive. This limited the pool of possible participants however given the availability of individuals with Android devices and available methods of advertising if needed, achieving the target sample size was not too difficult. Were this study to have future follow ups, including more OS would be beneficial as it would not cause selection bias on users. No children were allowed to take part in this study, all participants had to be eighteen or over to be allowed to take part in the study. This choice was made due to the additional rules put in place for testing with child participants [69], having children participate would add safeguarding concerns for the researcher and University without adding much value to the study results as children are not the target audience for this type of application.

## VIII. Results and Analysis

### A. Accuracy

The paired t-test for mean accuracy of diary inputs made, keyboard against speech, gave a p-value of 2.618e-09 with a Cohen's *d* effect size of 2.430227.

A Pearson's product-moment correlation test between accuracy and percentage of entries added when dreamed for keyboard showed a correlation of -0.09109967 and p-value of 0.665. The same comparison for speech gave a correlation of 0.5249059 and p-value of 0.007058. Shapiro-wilk normality tests on speech accuracy and percentage means gave p-values of 0.05034 and 3.38e-06 respectively. Spearman and Kendall correlation tests were then done but showed no outstanding correlation.

40 percent of users mentioned the inaccuracy of the speech input method to be a reason they would not choose or recommend it.

### B. Percentage

The paired t-test for mean percentages of diary inputs made, keyboard against speech, gave a p-value of 0.008669 with a Cohen's *d* effect size of 0.755795.

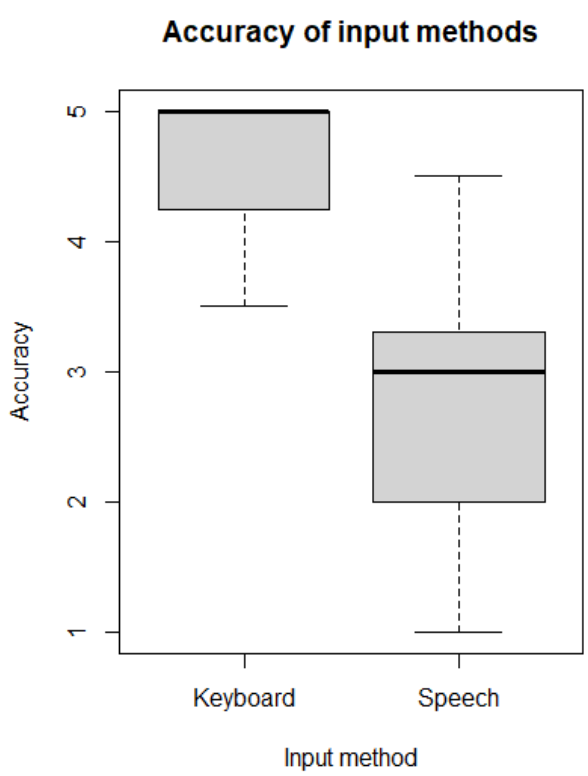


Fig. 4. Box plot showing mean values for accuracy of diary entries.

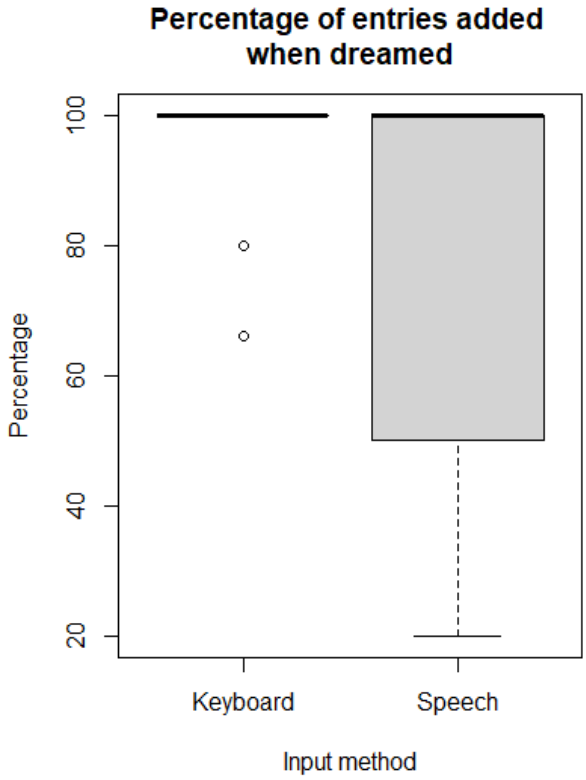


Fig. 5. Box plot showing mean values for diary entries added when a participant dreamed as a percentage.

88 percent of users recorded their dreams every time dreaming was achieved while using the keyboard method, whereas only 64 percent did the same when given speech input. 52 percent of users noted that they were unable to use the speech method when they dreamed as it was too loud.

### C. Length

The paired t-test for mean lengths of diary entries, keyboard against speech, gave a p-value of 0.1542 with a Cohen's *d* effect size of 0.294698.

### D. Questionnaire

At the end of the study 100 percent of users stated they preferred the keyboard input and would choose it over speech recognition as an everyday option. 64 percent did not consider the speech entries to be good enough to revisit them. When asked if the user would recommend a diary application using only keyboard input the mean response was 4.28 on a scale of 1-5 (1 being unlikely, 5 very likely), as for speech input the mean response was 2.24.

## IX. Discussion and Conclusion

### A. Accuracy

Given the small p-value that came from the accuracy t-tests we are able to assume with great significance that these results would be seen again. The results themselves showed that speech recognition does not provide an accuracy level near that of keyboard input. With the effect size of the t-test being so large we could even say that it does not provide anything close to keyboard accuracy. This can be seen in fig 4 where the keyboard accuracy median is at the maximum score, whereas for speech the scoring is much more middling and wide spread. At this point it is worth considering that this study used a basic free access API for the speech recognition and that other systems are available to use that could possibly provide better accuracy. The correlation seen with low speech accuracy appearing to put users off from using the application to record their dreams at first appeared to have significant correlation. However with the p-value of the Shapiro-wilks test being so far below the significance level of 0.05 it is heavily implied that the distribution of that data is significantly different from normal distribution. As such, normality can not be assumed. The idea that users are not willing to use the app with a low speech accuracy is backed up by the 40 percent of users that specified that it was due to the inaccuracy of the speech that they would not choose to use it again. From this we can see that the poor accuracy of the speech recognition method hugely decreased user engagement with the application.

### B. Percentage

The t-test for the percentage of dreams recorded when dreaming was achieved showed a p-value below 0.05 therefore it is significantly likely that these results could be seen again. As can be seen in fig 5, the median result for both methods

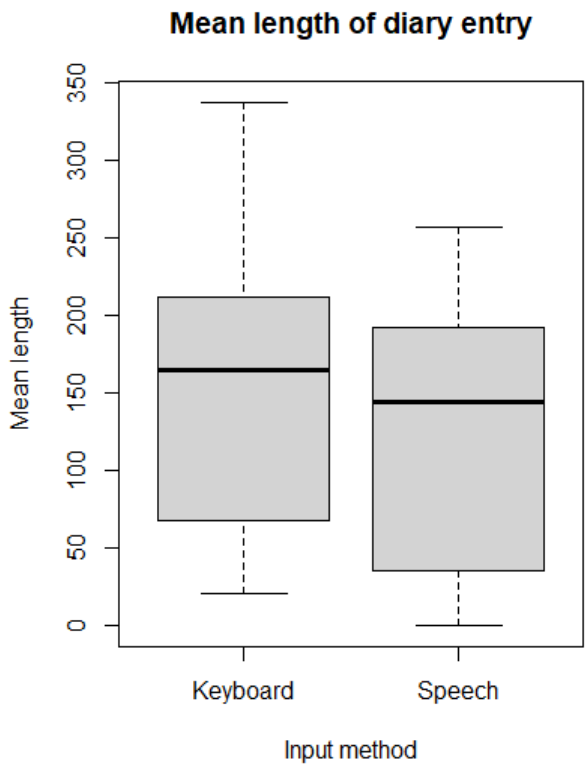


Fig. 6. Box plot showing mean values for diary entry lengths.

was 100 percent diary usage when dreaming was achieved. For the keyboard method 82 percent used the diary every time showing a large willingness to use the keyboard input method. As for the speech input method only 64 percent used the diary every time they dreamt which is a significant drop in user engagement with the application. Some reasoning behind this can be taken from the survey answers where just over half of users mentioned that they were not able to easily interact with the speech method as they worried it would make too much noise and possibly wake their partners or house mates. With so many of the participants having this similar problem it is likely that a speech input method would suffer from this flaw for others in similar situations. Given that 64 percent of users did not consider the speech recordings good enough to revisit this might have been another off putting factor for the user.

### C. Length

The length of entries t-test only gave a 15 percent chance of seeing these results again with a p-value of 0.1542 so we can not say much about these results assuming any statistical significance. Fig 6 shows fairly similar plots for both keyboard and speech input in regards to the length of entry added, which would imply that there is not much of a difference in how much the users entered into the diary. This likely means that speech did not affect engagement in this way at all, but to confirm this with any significance the test would need to be replicated using a larger sample size, increasing the likelihood of a p-value below 0.05.

### D. Questionnaire

At the end of the study when users were asked which input method they preferred, every user said keyboard. This is a huge sign that the speech input method did not provide a better experience for users than the keyboard method. Different reasons that users have found a preference for keyboard over speech input have been seen throughout the study; poor speech input accuracy, entries not being good enough to revisit, having to speak out loud in the mornings. Users mean rating of 2.24 when asked if they would recommend a speech only diary lands close to unlikely to recommend, unlike when asked the same for keyboard input scoring a mean of 4.28 close to likely. With this we can see users unwillingness to want to engage with the speech input method again and their perceptions that it is not a better method for this type of application than keyboard input.

### E. Hypothesis Outcomes

- Hypothesis 1 - Unclear - Results point towards confirming the null hypothesis but tests would need to be replicated with more participants to confirm
- Hypothesis 2 - Null Hypothesis Confirmed - Results show with statistical significance that speech recognition does not increase the amount of dreams recorded when dreaming is achieved.
- Hypothesis 3 - Null Hypothesis Rejected - Results show with statistical significance that input using speech recognition are not as accurate as keyboard input.

### F. Conclusion

In the case of this study, results show that overall using speech recognition as an input method for digital dream diaries has a negative affect on the users engagement with the software. Therefore no improvement in user engagement was seen from the addition of speech recognition. The key factors that drive the decrease in engagement are; poor accuracy provided by speech recognition and having to be loud/vocal in the mornings where this could effect others in the household. While accuracy in this type of software is likely to improve over time the other issue does not show any simple solutions, other than using a silent input method such as the keyboard. As it stands this paper concludes with a recommendation to avoid adding speech recognition to dream diary applications and for users to avoid paying to unlock it as a feature. In a way stopping the degradation and feature bloat of dream diary applications could be taken as a form of improvement and so the researcher still hopes for this study to manage to improve applications of this nature.

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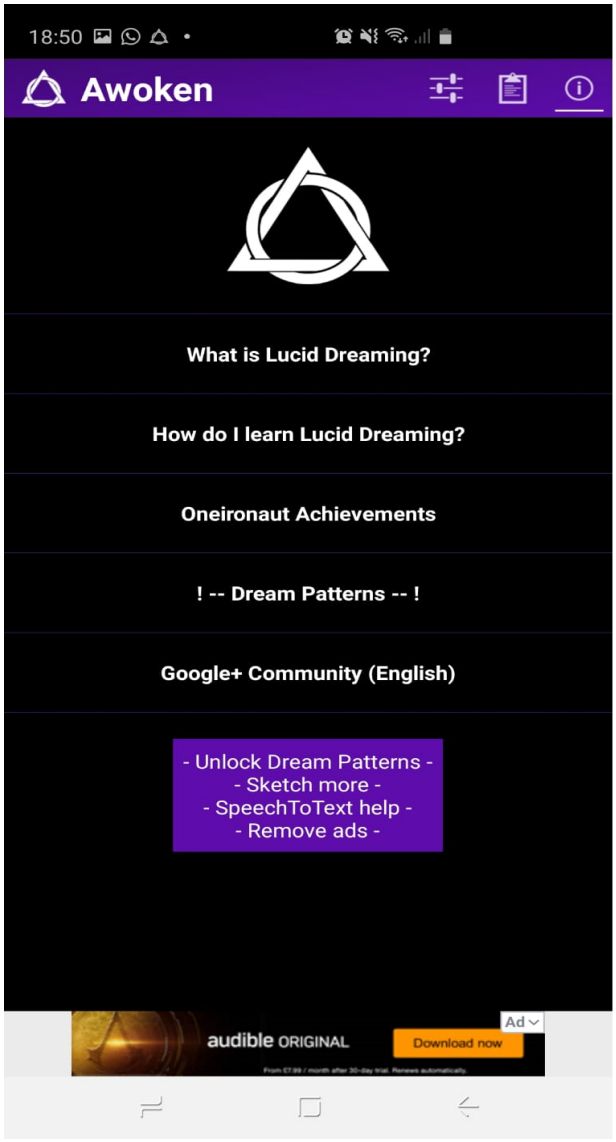
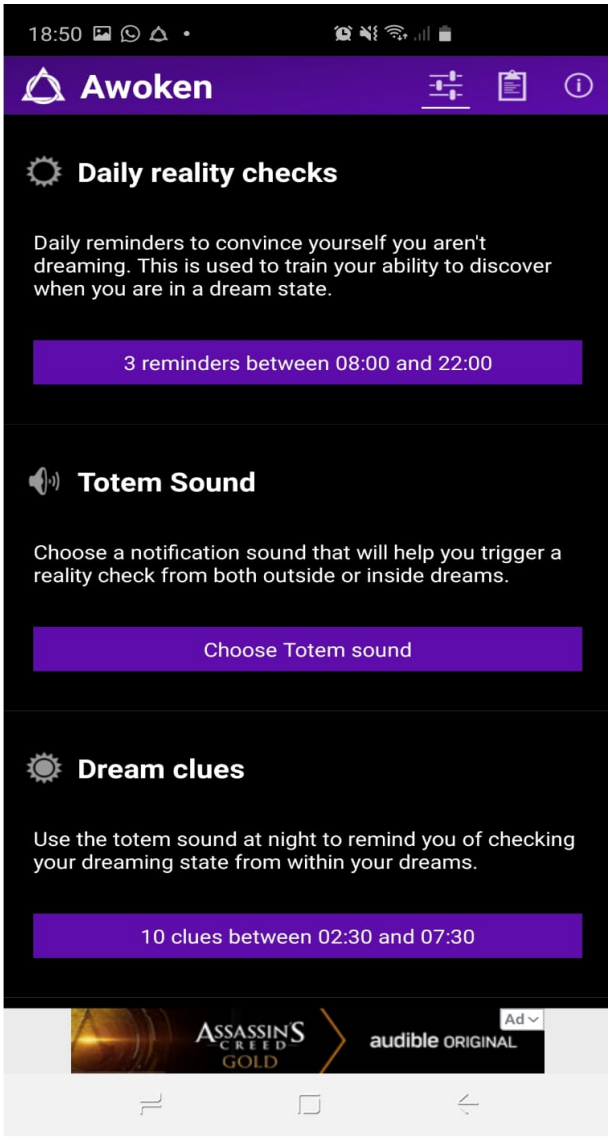
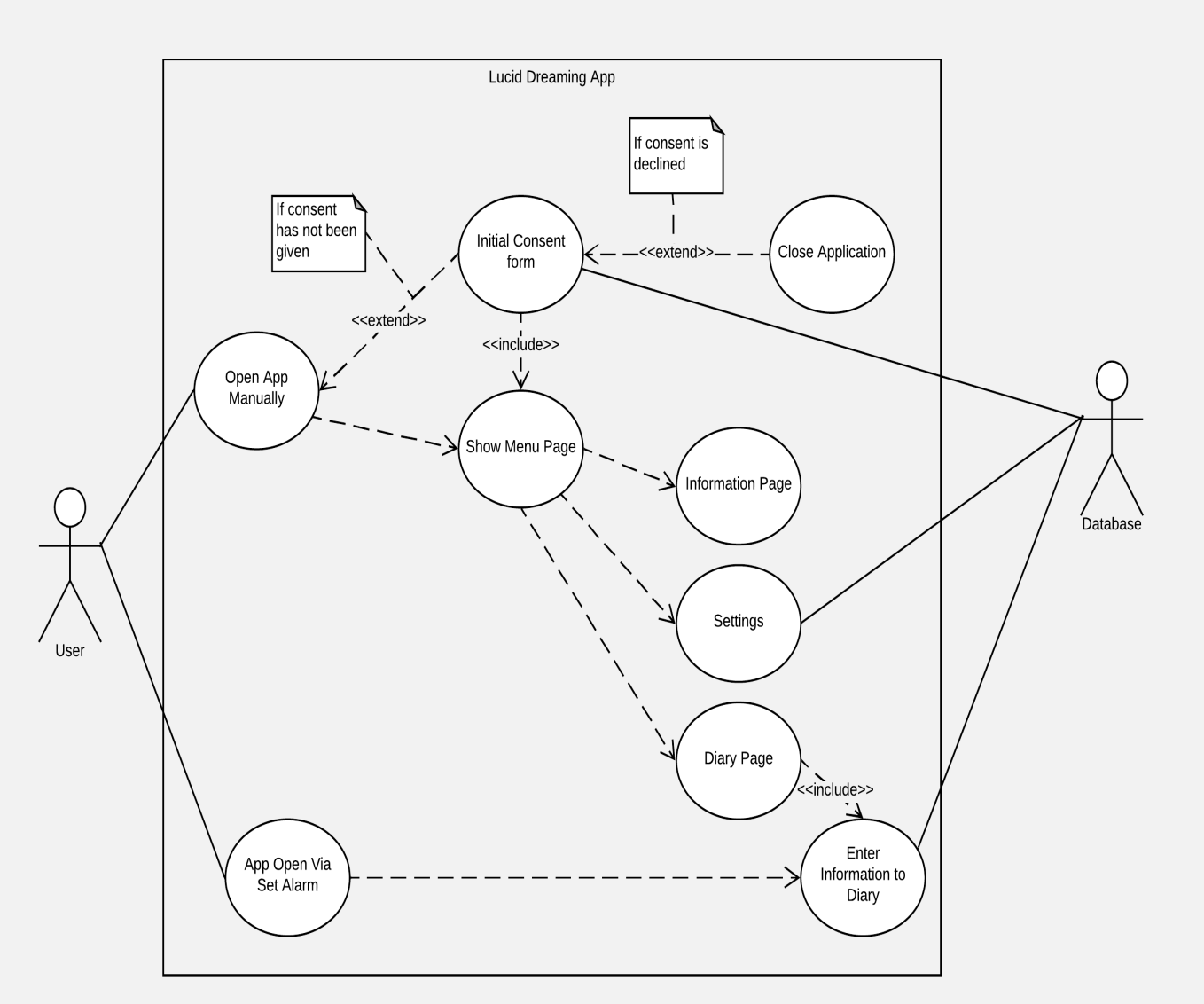
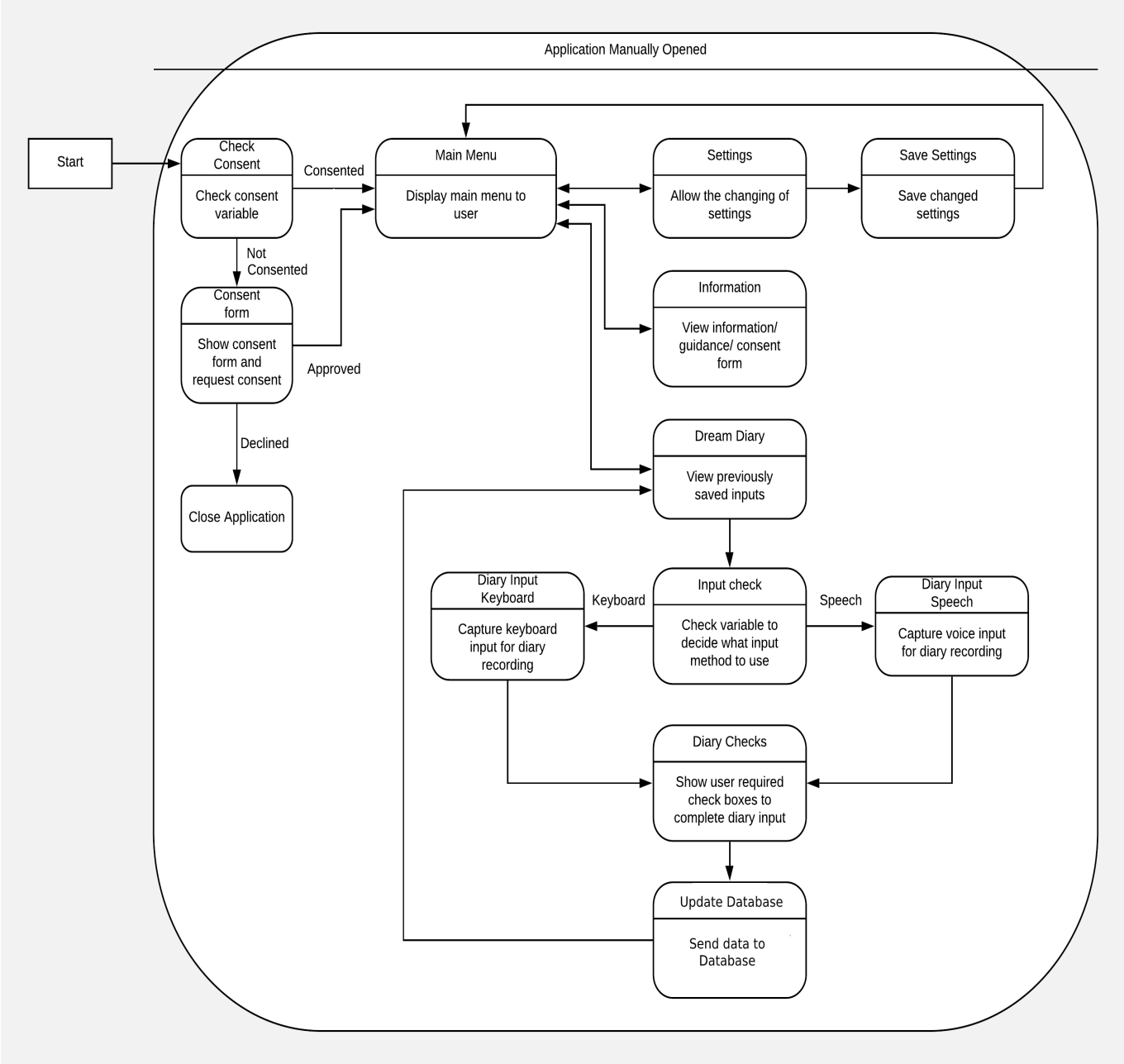
# Appendix A
## Screenshots of Awoken

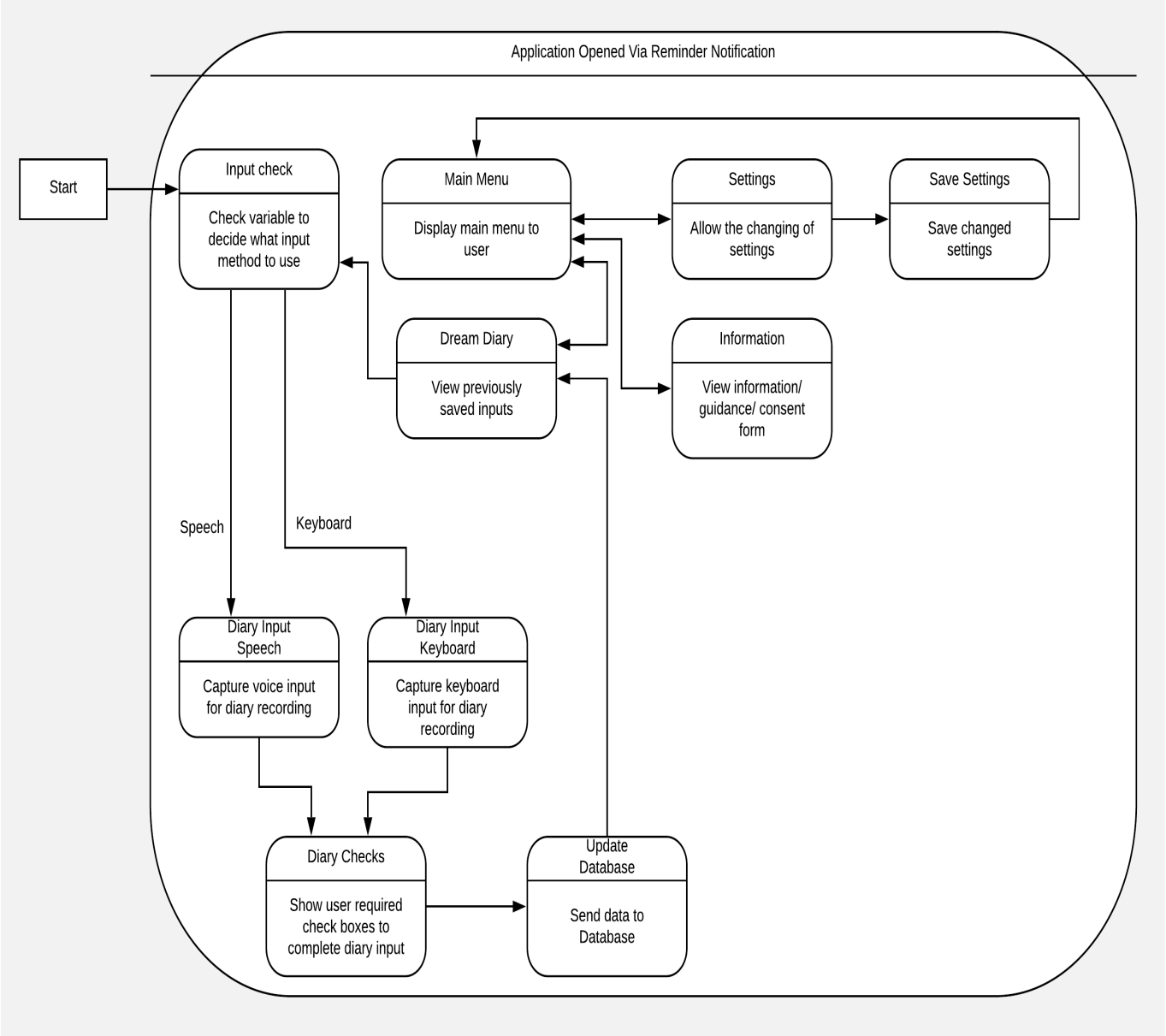


# APPENDIX B
## UML DIAGRAMS OF SOFTWARE ARTEFACT




Application Manually Opened
Start
Check Consent
Check consent variable
Consented
Main Menu
Display main menu to user
Settings
Allow the changing of settings
Save Settings
Save changed settings
Not Consented
Consent form
Show consent form and request consent
Approved
Information
View information/ guidance/ consent form
Declined
Close Application
Dream Diary
View previously saved inputs
Diary Input Keyboard
Capture keyboard input for diary recording
Keyboard
Input check
Check variable to decide what input method to use
Speech
Diary Input Speech
Capture voice input for diary recording
Diary Checks
Show user required check boxes to complete diary input
Update Database
Send data to Database


Application Opened Via Reminder Notification
Start
Input check
Check variable to decide what input method to use
Main Menu
Display main menu to user
Settings
Allow the changing of settings
Save Settings
Save changed settings
Dream Diary
View previously saved inputs
Information
View information/ guidance/ consent form
Speech
Keyboard
Diary Input Speech
Capture voice input for diary recording
Diary Input Keyboard
Capture keyboard input for diary recording
Diary Checks
Show user required check boxes to complete diary input
Update Database
Send data to Database

# APPENDIX C
## EXAMPLE R CODE FOR MEAN LENGTH DATA ANALYSIS

```
#Import data set
library(readr)
dat <- read_csv(file_name)

#Run t-test for length
library(psych)
t.test(dat$keyboard_length, dat$speech_length, paired=TRUE, conf.level = 0.95)

#Run t-test for dreams recorded
t.test(dat$keyboard_percent, dat$speech_percent, paired=TRUE, conf.level = 0.95)

#Run t-test for accuracy
t.test(dat$keyboard_accuracy, dat$speech_accuracy, paired=TRUE, conf.level = 0.95)

#Run correlation test between keyboard accuracy and percentage entered
cor.test(dat$keyboard_accuracy, dat$keyboard_percent)

#Run correlation test between speech accuracy and percentage entered
cor.test(dat$speech_accuracy, dat$speech_percent)

#Perform Shapiro-wilk tests to confirm normality
shapiro.test(dat$keyboard_accuracy)
shapiro.test(dat$keyboard_percent)
shapiro.test(dat$speech_accuracy)
shapiro.test(dat$speech_percent)

#Boxplot of mean diary entry lengths
boxplot(dat$keyboardLength, dat$speechLength, data = dat,
        col = "lightgray", varwidth = TRUE,
        main = "Mean length of diary entry",
        ylab = "Mean length",xlab = "Input method")
axis(1, labels=c("Keyboard","Speech"),at=1:2,las=1)

#Boxplot for percentage of dreams recorded
boxplot(dat$keyboardPercent, dat$speechPercent, data = dat,
        col = "lightgray", varwidth = TRUE,
        main = "Percentage of entries added \nwhen dreamed",
        ylab = "Percentage",xlab = "Input method")
axis(1, labels=c("Keyboard","Speech"),at=1:2,las=1)

#Boxplot for accuracy of input methods
boxplot(dat$keyboardAccuracy, dat$speechAccuracy, data = dat,
        col = "lightgray", varwidth = TRUE,
        main = "Accuracy of input methods",
        ylab = "Accuracy",xlab = "Input method")
axis(1, labels=c("Keyboard","Speech"),at=1:2,las=1)
```

# APPENDIX D
# CRITICAL ADDENDUM

Doing such a long running and in depth paper has been quiet the learning experience. Below are some key points that I consider worth taking a look at and planning ways to improve in the future.

## A. New Skills

At the start of the dissertation I decided to aim to take up as many new skills as possible throughout the study. I decided on this as I have taken this course to learn new skills at every opportunity. This did work in widening my skill range but definitely increased the time it took for me to accomplish tasks throughout the paper. I also feel like it lowered the quality of my work compared to if I had picked a field I was already familiar with. Now, research should always be looking to push knowledge to a new level so it is never expected to have a complete understanding of a subject before researching it, but I have come out of this with the mind set that there should be a balance if you want to output high quality papers. This balance could come from an already in place knowledge or by allocating enough time to research a subject beforehand.

*1) Action:* When choosing topics for future papers I will make sure to have a solid understanding of some of the aspects covered. Any new skills required should be given a month of learning and practice before the detailed research begins on the topic. An amount of time each week will be allocated to this depending on the difficulty and breadth of the new skill. Successful completion of study each week will be recorded so progress can be tracked.

## B. Testing

This project was the first time unit testing had been introduced to me. Although I have been doing manual testing since I first began coding, unit testing has been a new way for me to have consistent and easily repeatable tests. I feel like I do not have a correct grasp on the best way to implement them yet and the correct procedure for doing so. This slowed down the production on the application but also meant that the unit tests I did originally were probably poorly executed. Having learnt about the purpose of unit tests I can see their importance throughout the development process. Having a solid understanding of unit tests and other types of tests used frequently across the software development industry, appears to be a standard requirement if looking to take up a career in said industry. It is therefore imperative that I expand my knowledge of these skills.

*1) Action:* For the first month after university I will spend 3 hours a week researching unit testing methods and best practice. This time will be allocated in my calendar and checked off once completed. At the end of the month I will return to the dream diary application and rework my unit tests to see what I have learnt. If needed this action will be repeated until my skills improve significantly.

## C. House Fire

Early into this project I had a house fire in which I lost close to everything I own and my residence. This meant a lot of additional time was required in my personal life and there was a significant emotional toll. I surprised myself with how well I dealt with this. I had the support of family, friends and the University to thank. With version controlled storage being cloud based all of my work was saved from being lost, but had my data not been backed up in this way then the situation would have been even harder to deal with. Times like this speak wonders for having data back ups for anything you would be unhappy to lose. While sorting out a new place to live, insurance claims and rebuilding a life I had limited work time and choose to focus on the group project as getting that put back would have had a negative effect on others work. I do believe this was the correct call but in hindsight it had knock on effects that I had no considered. Once I had my life sorted out I was in a difficult place of needing to create the software for this project and gather data in time for me to analyse it and finish the paper before hand in. Due to this planning of the software was haphazard at times, but the real downside was missing potential data points that would have really benefited the project. Because of this some comparisons that could have given a deeper understanding to the reasoning behind some results are not possible to be made, and the end clarity of the paper has suffered for it. It is unlikely to have incidents that cause such problems in most work cases but I will now always consider ways to handle them when planning future work goals.

I believe a few actions can be put in place to help and continue to mitigate future similar problems.

*1) Action One:* I will always use a form of version control for any work projects, making sure to commit and push frequently so that work is safe and protected. I will also look to create back ups of any personal data I would like to keep and store them either on a cloud system or in an alternative location.

*2) Action Two:* Were unexpected issues to arise unrelated to work in the future I will again decide what I consider to be best way to prioritise my work load. With an additional focus being put on all side effects a project may suffer from by lowering its priority. How much is spent on this will be dictated by the amount and complexity of planned projects.

## D. Working From Home

I generally consider myself to have a good work ethic however towards the end of this project my motivation to continue it flagged. I'm very aware I could have supplied better work had I been able to keep my motivation up throughout the entire project. One of the biggest factors in this was the forced quarantine due to COVID-19, meaning I had to stay home to work. I have always been aware of how difficult I find it to work from home and normally combat this by having work spaces outside of my home. Keeping different environments for work and relaxation has worked great for me in the past. Now being forced to work in a space I had dedicated to relaxation has made the process even more difficult than before

I had set up separate spaces. As we do not currently know how long this lock down will continue, I consider it imperative to find a way to managed a joint working and relaxing space. After researching ways to help with productivity from home and sadly a lot of them not being applicable, I have drawn together a plan to try out.

*1) Action:* By the end of this week I will create myself a work user account on my laptop using the family management system to lock it out of certain applications and websites to help drive productivity. Whenever in my allocated work times I will use this work account.

## APPENDIX E
## TESTING ADDENDUM

Throughout the project testing to validate that parts of the software worked as intended helped to drive the development forward. It gave me clarity that I was OK to move onto the next section. Having built reusable tests helped make going back and checking that nothing had broken at the integration phase simple and pain free. The results and actions from tests were recorded in the spreadsheet which is located within the repository which I request you look at for an understanding of the detail of testing[7]. Additionally the unit tests can be seen in the source code within the repository as well[8].

### A. UI Testing

To help with testing UI elements in Android Studio I used a feature called Espresso [57]. This built in feature allowed me to quickly create unit tests that would check the states of different UI objects as the application was used in certain ways. It essentially recorded the inputs I gave to the application and allowed me to interrogate the different elements to check they were functioning correctly. Once the elements to check and results were determined this process was laid out as a unit test to be run again at later dates. These UI tests were incredibly useful in helping to confirm that users would be able to navigate the application as intended.

### B. Unit Tests

Other than the UI unit tests all unit tests were written using JUnit4 [56] within Android Studio. These tests, unlike the Espresso ones which had an interesting wizard, were all written by hand. I had a few problems to start with when coming to terms with how to implement these tests. So much of the software had Android framework dependencies that it turned out I needed to run the tests in a manner that worked alongside an emulator or physical device. These are called Instrumented tests and give access to the API but take a longer time to run. Originally I had been trying to design the tests as stand alone segments that could all be run individually.

### C. Database Interactions

For database interacting methods I used a combination of unit tests along with checking how the database was constructed and filled using DB Browser (SQLite) [71]. It worked well for me too have this combination as towards the end of development the time I had allocated for myself for the software to be completed in was running thin, so manual testing of methods that were of a similar nature to those already unit tested saved time. I considered this time save to be acceptable as I am aware that this software will not be passed to others to work on. Therefore the need to be able to sanity check additions and changes made by others with my pre-built tests is not as necessary as getting the software working by the deadline. However were this to be a long running software solution I would deem it worthwhile to invest the extra time into easily reuse-able tests.

### D. Alarm Testing

Testing set alarms would be a tedious process of either waiting or clock manipulation were it not for available software to help with these tasks. Within Android SDK platform tools, I have used Android Debugging Bridge [72] to look for set alarms allowing me to check future alarms are set.

```
adb shell dumpsys alarm > AlarmsOutput.txt
```

The above line was used to dump the log of set alarms into a text file so I could easily search it for the package name needed ”com.example.dreamdiary” at the time. The log files are included in the repository for detailed inspection[9] . Having access to view these logs showed that originally multiple alarms were being set by the application, but some research revealed a more efficient way of achieving the same outcome.

After refactoring the code to use the built in setRepeating method the output gave ”repeatInterval=86400000” with a single set alarm, before the refactoring process the output gave no repeating interval. Although the alarms themselves work in the same way, when you look through the output log before refactoring took place, multiple alarms had been set in the phones system. Refactoring to use the AlarmReciever’s setRepeating function has cleaned up the phones alarm manager, and instead relies on the Android integrated functionality to repeat alarms giving very solid robustness.

[7]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse/Testing/TestsSheet.xlsx

[8]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse/Artefact/app/src/androidTest/java/my/dreamdiary/study

[9]https://gamesgit.falmouth.ac.uk/users/rc205730/repos/dissertation/browse/Testing/Testing%20Alarms