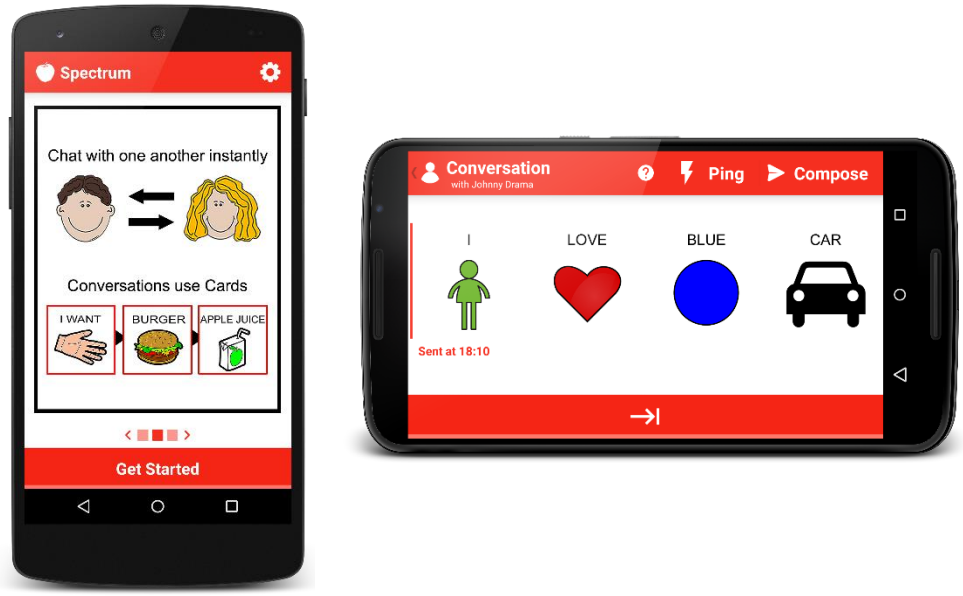
UNIVERSITY OF SUSSEX

FINAL YEAR PROJECT

SPECTRUM: A PECS-BASED MESSAGING MOBILE APPLICATION

FOR PEOPLE WITH AUTISTIC SPECTRUM CONDITIONS (ASC)



11,500 WORDS

WEDNESDAY, 06 MAY 2015

JACK GRAVES

STUDENT 94859

ABSTRACT

This report and application aim to develop a mobile messaging application designed specifically for children with Autistic Spectrum Conditions (ASC) in the age range 6-12 who find it difficult to learn to speak and learn language skills.

As a person living with an ASC, I know it can be hard to learn to begin talking and understand sentences, but also that it is easier to be engaged with something when technology plays a part.

A method of communication that is designed for people with ASC conditions is the Picture Exchange Communication System (PECS), which uses cards that each contain a picture which can be put together in strings to create a sentence structure. At the moment, PECS is mainly used with physical cards, and there isn't an application for the Android and iOS Operating Systems which lets people with ASC converse using virtual picture cards inspired by PECS.

A very important aspect of the application will be the interface design, which has to be designed with its target user in mind and this affects all aspects of the application development. I hope to use concepts that I have learnt through the Human Computer Interaction (HCI) course and through using Participatory Design (Iversen, et al., 2012), develop an application that is tailored to users with ASC, however, due to time constraints this was substituted for a single hands-on test session at a specialist school with potential target users.

PREFACE

This report is submitted as part of the requirement for the degree of Bachelor of Science (BSc) in Computer Science and Artificial Intelligence at the University of Sussex. The work in this report is a product of my own labour, except where clearly indicated in the text.

Jack Graves

06 May 2015

ACKNOWLEDGEMENTS

I would like to thank my project supervisor, **Chris Kiefer** for the guidance and the many discussion sessions which gave me the enthusiasm to compose the report as well as design and build this application.

Thanks to **Ian Wakeman**, **John Carroll** and **Chris Kiefer** for facilitating the loaning of several devices for use with my study.

Thanks to everyone who participated in the testing of the application, particularly the students and staff of **Patcham House School** and especially **Chris Fisher** who helped make the research sessions possible at the school.

Additionally, I would like to thank my partner, **Eleanor**, whose feedback and opinions helped throughout the development and design of this project.

SUMMARY

This report, along with the associated client application and server-side scripts developed has combined several Computer Aided Learning (CAL) techniques to create a unique new application for Android aimed at children with ASC to help develop speech.

This report details the project from conception to end-result, including the requirements analysis, design considerations that were made to support the target user, the development of the client application, issues faced during development, testing performed and the evaluation of the application with the end-users themselves, in the school environment for which Spectrum was developed.

The extensive testing of the application components, as well as manually testing the application on different devices ensured that they performed to the specification.

The suggestions and feedback garnered from the evaluation session at the school were originally planned to feed back into the design of the system through Participatory Design, but due to time constraints this was substituted for an evaluation session where the application was reviewed for unbiased feedback.

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1. INTRODUCTION

The use of applications on mobile devices that allow people to send and receive messages between one another instantly using the internet has grown substantially in recent years, with Mobile Instant Messaging (MIM) use nearly tripling (57 to 160 billion) between 2012-2013 and with the volume of messages in 2014 predicted to be almost double that of 2013, these figures are taken from the diagram below.

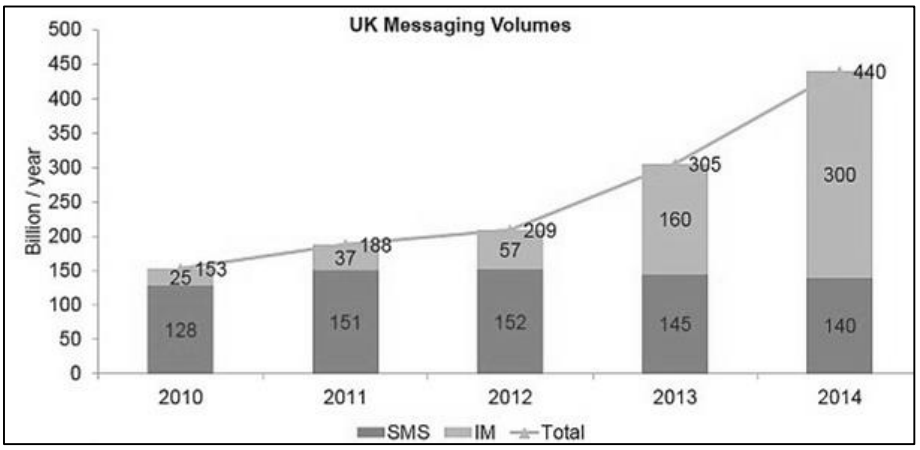


Figure 1 - Chart showing the predicted volume of messages sent in the UK via SMS and MIM based on previous years. (Deloitte, 2014)

Despite this massive growth in the industry, with names such as WhatsApp, BBM and Google Hangouts becoming big names in the recent years, there has yet to be a MIM application designed with children with ASC in mind.

This lack of innovation coupled with the findings that "a number of the studies have found that Information Communication Technology (ICT) and Computer Aided Learning (CAL) based technologies can help to instigate and develop communication skills" in children with ASC (Herring, 2009) means it is possible that a system that includes both of these ideas could further help support the learning of language in children with ASC[1].

Out of the appropriate CAL methods that could be coupled with MIM, including the Voice Output Communication Aid[2], (VOCA), the Picture Exchange Communication System (PECS) has been proven

[1] It has been shown that using CAL methods can increase learning ability, in one study, "communication behaviours either increased when using the iPad or remained the same as when using picture cards." (Flores, et al., 2012)

[2] VOCA has been shown to increate interaction, in one study, "As the (naturalistic teaching and VOCA) procedures were implemented, all children showed increases in communicative interactions using VOCAs" (Schepis, et al., 1998)

by many reports as well as empirical demonstrations to be effective "in increasing spontaneous communication skills for a young child with autism" (Kravits, et al., 2002) therefore it is the system that will be used to converse over the MIM application.

My motivations for choosing this project are to combine MIM and PECS in order to:

- Allow children and carers to communicate using Instant Messaging software which makes conversing a fun and interesting experience, and to make finding the 'card' that corresponds to what the child wants to use easier through the use of machine learning for prediction.[3]
- To introduce children to technology and networking at an early age and show them how easy it is to communicate with other people, hopefully allowing them to improve their language skills in the process.
- To use mobile technology to provide a new medium to use PECS over, in a way that it can be built upon using other Computer Assisted Learning methods that can be provided by a mobile phone/tablet.[4]

The requirements for the system and its interface will be gathered through user research and they are going to impact every stage of this project, from the design of the interface to evaluating how well it caters to its end-user[5].

The system will have to provide several features to make the application more comfortable to use for the target audience, this will include allowing large text on the screen, allowing a background colour that makes it easier to read, making the application simple to use and easy to navigate, and include a feature to speak out loud the cards sent/received through the phone speaker to implement the VOCA CAL technique.

[3] Technology can help hold the attention of children with ASC - "a number of studies have shown that children with ASD do orient automatically or involuntarily to dynamic eye-gaze cues presented on a computer screen" (Chawarska, et al., 2003)

[4] "There is good evidence that computer-aided learning is well accepted by students with autism and is of great potential benefit to them. Despite the potential, however, the field remains relatively unexplored." (Moore, et al., 2000)

[5] Many of the design considerations in this application have been inspired by the premise that "…if apps are user friendly and better in terms of usability, persons with autism would find easier to communicate." (Khan, et al., 2013)

Help through the use of first-time tutorials and a help-button on interface screens where this is necessary is also essential to ensure the user does not get confused. (Khan, et al., 2013, p. 111)

1.1 – OBJECTIVES

This section details the objectives that were initially detailed in the Preliminary Report in Appendix 4.

Primary Objectives

ID	Objective	Risk
1	Users will be able to sign-in to the application using an existing account they have elsewhere through OpenAuth, which will allow users access to their data while protecting their account credentials.	MEDIUM
2	The interface will have a contact list as the main page, which contains other users they have added.	LOW
3	Each person that has had correspondence with the user will have its own 'conversation' in the conversation list and this will allow the user to see what has been sent in the past. This conversation window will scroll the images left-to-right as this is more logical for younger users and makes the conversations flow like normal sentences using the images/symbols.	HIGH
4	Users will have a way to add people to their contact lists, using a username for example.	MEDIUM
5	There will be a picture/symbol database that contains many of the PECS standard 'cards' such as the context cards like 'I want', 'thank you' or 'I see' and objects such as 'Apple' or 'Trampoline' and allow users to string these cards together to create sentences in the conversation view.	HIGH
6	If a user receives a message via the application, their phone will make a sound and a notification will be created and displayed to alert the user in the Notification Center of Android.	LOW
7	A personalised Picture Prediction program will be included in the application, which makes suggestions for the next picture being added based on previous messages. This will most likely use a Hidden Markov Model.	HIGH

Extension Objectives:

ID	Objective	Risk
8	If each user could have a profile along with a status, this would make the application more immersive as it would provide a single place for users to see the status of their friends without moving to external services which may be unsafe for users with severe autism to be accessing such as Facebook and Twitter.	MEDIUM
9	Based on the coloured/tinted rulers that many people with dyslexia use I aim to have an option to tint the background of the application a certain colour such as magenta and cyan which should help children with dyslexia to see what is on the screen.	MEDIUM
10	I would also like to make it possible for the phone to read out loud any messages received, by having alternate text for the built-in cards which can be read via Text To Speech (TTS) on the device.	MEDIUM
11	Location support would be useful to add and would provide users with a way of knowing how close the other person is to them.	HIGH
12	The ability to send a picture from the front or rear facing camera on the phone, or attach an image that is stored on the device memory should be built into the application so that users can include their own images if one is not available in the symbol database.	HIGH

1.2 – RELEVANCE OF DOMAINS

The work done on this project is dependent on a large amount of disciplines that have been learnt throughout the Computer Science and Artificial Intelligence degree course as well as through personal development, this section describes some of the main disciplines that are heavily utilised in this project.

1.2.1 – Artificial Intelligence

This project involves AI in order to make it easier for the users to choose their next symbol in the sentence when they compose a message. This will use AI concepts in order to predict what the next symbol in the sentence they are writing is most likely to be, given the previous symbols that they have input in the past, using a method such as Markov Chains (Shani, et al., 2002) or Naïve Bayes (Lewis, 1998).

1.2.2 – Human Computer Interaction (HCI)

HCI is very relevant to the project, as the computer skills of the target users varies and the fact that touchscreens can be difficult to use means that the interface is of paramount importance and it will have to be designed with its users in mind and be easy to use, drawing on the concepts learnt during my HCI course[6]. The application should be easy to use, obvious what functionality is available on each screen and the navigation structure of the application will be designed so that the user always knows where they are in the application.

1.2.3 – Software Engineering/Development

The coding of the application using the Java language and Android APIs will require a large amount of programming and all aspects of the development will have to use the programming concepts that have been learnt throughout the undergraduate course in order to create an application that is stable. The server-side will be programmed using a server-side programming language such as Java Servlets or PHP contained by a virtual server running a service such as nginx or Apache[7], along with some required

[6] Concepts that are underpinned by the texts "Interaction Design" (Rogers, et al., 2011) and "Designing for Interaction" (Saffer, 2010) and the HCI Course tutored by Kate Howland and Marianna Obrist.

[7] These are just two examples of servers that could be used.
Nginx "a free, open-source, high-performance HTTP server" (Nginx, 2015)
Apache "a secure, efficient and extensible server that provides HTTP services" (Apache, 2015)

libraries and the client-side will be coded in Java Standard Edition as well as some required Android APIs.

1.2.4 – Databases

This project includes databases, as the server and client (device) will have to store data both locally and remotely in databases using open-source SQL derivatives such as MySQL[8] and SQLite[9] in order to enable the messaging application to have persistence, this means that this database will need to be designed to be secure and efficient, especially in the data-tier hosted on the server.

1.2.5 – Networking

Networking is, for a messaging application, essential and so knowledge of this field is essential, I hope to use the knowledge learnt both at university and on my placement at BlackBerry[10] to build an effective way of sending/receiving messages using the Client-Server model, where a web server acts as a middle-man between the source and destination device, which allows devices to poll the server for any new messages that are in the queue and also submit new messages to other users message queues.

The polling of the server should be used secondary to the Push Messaging System that will be implemented to make the system efficient over mobile/cellular networks and minimise battery usage.

[8] An open-source Relational Database (RDBMS), which runs on a server and is widely used for data-tier on servers. (Oracle Corp., 2015)

[9] A widely used in-process RDBMS which is server-less and lightweight, default on iOS and Android devices. (SQLite, 2015)

[10] "I learnt a lot of new skills in my year in the company, both core learning that had to be taken in order to perform the tasks required by the job, but also additional training that was offered to me in any free time I had between tasks (including networking)" (Graves, 2014)

2. PROFESSIONAL CONSIDERATIONS

The considerations that are outlined in this section are followed strictly throughout this report. Due to the nature of this report, there are many ethical considerations that must be adhered to as well as professional ones due to the group of people this application is aimed at.

There is also a Code of Conduct for all BCS members, which governs the conduct of the individual which will be followed during the course of this project. (BCS, 2014)

2.1 – PUBLIC INTEREST

Throughout this project, a strong regard for the health, privacy, security and wellbeing of everyone involved in the research for this report will been paramount.

As the application will facilitate the sending and receiving of messages over the internet by users, any data that is sent or stored using the application must be handled in conformance with the Data Protection Act 1998 (Legislation, 1998), which has specific requirements on the way data is handled by this application such as the location of any web servers that are storing users' data (which must be within the European Economic Area). The act also includes requirements on how long data is stored for, who can access this data and that it is properly secured and well-protected.

At any points when this project uses third party software or libraries, the party will be referenced and credit given. Parts 1c and 1d of the BCS Code of Conduct will be followed and there shall be no discrimination between people and equal access to IT will be promoted whenever possible.

2.2 – PROFESSIONAL COMPETENCE AND INTEGRITY

As this project is a part of my undergraduate studies, the main goal is to "develop professional knowledge, skills and competence on a continuing basis, maintaining awareness of technological developments, procedures, and standards that are relevant to the field." (BCS, 2014).

No part of the application developed will mislead the user into thinking that it performs any other function than the one set out in this report, along with this, all appropriate legislation will be complied with and any evaluations of the application/project, including criticism will be seeked out and respected.

In addition to this, Parts 2f and 2g will also be adhered to and every effort will be made to "avoid

injuring others, their property, reputation, or employment by false or malicious or negligent action or inaction." and I will "reject and will not make any offer of bribery or unethical inducement."

2.3 – DUTY TO RELEVANT AUTHORITY

All work carried out in this project and the application that is developed will in no way break any UK or EU laws and will adhere to the University of Sussex requirements. With respect to this, any requests for information from these relevant authorities[11] will be complied with in full accordance of the law and any requests to disclose information from any party other than these will be denied.

Every effort will be made to carry out my professional responsibilities with due care and diligence and as the author of this project, Jack Graves, I accept professional responsibility for all work performed in this report.

[11] "Relevant Authority" in this document is used to identify the person(s) or organisation(s) which has/have authority over the activity of individuals in their professional capacity. For practising BCS members this is normally an employer or client. For student members, this is normally an academic institution. (BCS, 2014, p. 4)

2.4 – ETHICAL CONSIDERATIONS

There are various ethical considerations due to the high risk nature of this project which are underlined below. All research involving participants has been approved by the Research Ethics Committee (C-REC)[12]. The full details of the Ethics Application and changes made can be found in the "Appendix 5 – Ethical Application" section, followed by the DBS Certificate in "Appendix 6 – DBS Approval".

Any external person that is participating in this report through a survey, questionnaire or through participatory design/evaluation sessions will have to give informed consent, where they will be told exactly how their data will be used and that any data will be anonymised when discussing the opinions of participants. An important aspect of consent is that participants are aware of and understand the nature, purpose and aims of the research being undertaken (Tisdall, et al., 2009) and when this involves children, this involves making sure the appropriate adults (parents and teachers) are also aware of this and consent, as people under 18 are not legally competent to provide consent.

The way in which any children are involved in this project will be carefully considered, with the mechanisms and protocol for child protection being clearly discussed with the appropriate authority as well as a designated person being present throughout the sessions to ensure the safety of the participant. The child will be given as much control over the situation as possible, making the session much more flexible. An introduction and debriefing sheet - as well as the consent form - will be created to inform any participants.

An Enhanced Disclosure and Barring Service (DBS) certificate, previously known as a CRB, will be obtained before any work is done with children, as this "checks for spent and unspent convictions, cautions, reprimands and final warnings, plus any additional information held by local police that's reasonably considered relevant to the workforce being applied for" (Gov.UK, 2014).

The school at which the session was performed was given the completed DBS Certificate and my Driving License as proof of identity (photocopied) and the session format was discussed at length with

[12] The Committee for Ethics and Research Governance (CREC) ensures that ethical review procedures "reflect best practice with regard ethical considerations in research", "meet legislative, regulatory and funder requirements" and "safeguard the reputation of the University" (University of Sussex, 2015)

Chris Fisher, from Patcham House School to ensure that everything was done with all regard to safeguards for child protection.

The materials gathered, the participants, and the pictures of the application in use were all relayed through Chris Fisher to the headteacher, Gayle Adam, who approved their use in this report.[13]

The process of ethical review took 4/5 months to complete and three applications, due to issues with wording on the application and consent/information forms.

The DBS application process could not be started until the Ethical Review was completed. The process took some time[14] and was done in collaboration with SafetyNet for form-checking (SafetyNet, 2015).

Due to the time-consuming nature of these processes, the planned Participatory Design session had to be cancelled and instead a one-off visit to the school was planned to fully test/evaluate the application with several students, this is detailed in the "5.5 – Evaluation Session" section of this report.

[13] The pictures gathered from the school session were taken by a Teaching Assistant, after permission was granted by Gayle Adams, headteacher and do not show any identifiable information about the students that took part in the study – Only the devices are visible.

[14] Further details on timing can be found in the Log section.

3. REQUIREMENTS ANALYSIS

This section describes the requirements analysis that took place before development.

3.1 – EXISTING SOLUTIONS

Some applications that aim to solve the same problem as Spectrum are detailed here.

3.1.1 – SoundingBoard for iPhone/iPad

SoundingBoard (AbleNet, 2014) is an application to make 'boards' of symbols (see Figure 2) and when each of the cards is pressed on, it will speak the corresponding phrase out from the speaker on the device, the basis for the communication (symbols) is the same as the one being used in this report, however SoundingBoard is only for offline use and you cannot use this application to converse with people on different devices and locations. It also doesn't let the users organise the cards into a logical structure which isn't as helpful as the Grace application reviewed next, as people with ASC are mainly visual learners and being able to see sentences of symbols is beneficial to them.

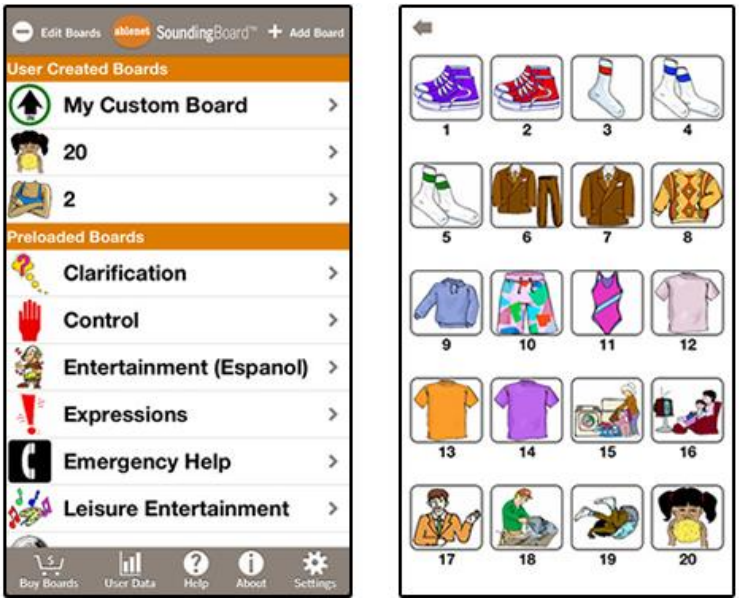


Figure 2 - Screenshots of the SoundingBoard application (AbleNet, 2014)

The interface is generally good, however the board management interface is not very intuitive for users and creating boards is not as good as Grace is, unfortunately a lot of the functionality is hidden behind micro-transactions to buy additional 'boards' and the pictures being used as the symbols cannot be made bigger and symbols cannot be made bigger (they are very small on the screen of the phone).

The negative customer reviews back up the claims made in this section, "I cannot see any of my students using this as a communication tool." and "It crashes everytime I go into the app" (AppAnnie, 2015).

3.1.2 – Grace, Picture Exchange for Non-Verbal People

The Grace application (Troughton-Smith, 2014) is similar to the SoundingBoard application, but doesn't support reading out of symbols, instead providing a way to organise the cards into structured sentences, and is meant to be used to encourage the user to speak what the cards mean, as it doesn't let them use built-in automatic speech. This helps encourage independent communication in the users.

The interface of Grace is a great example of good UI design (see Figure 3), as it is simplistic and all the

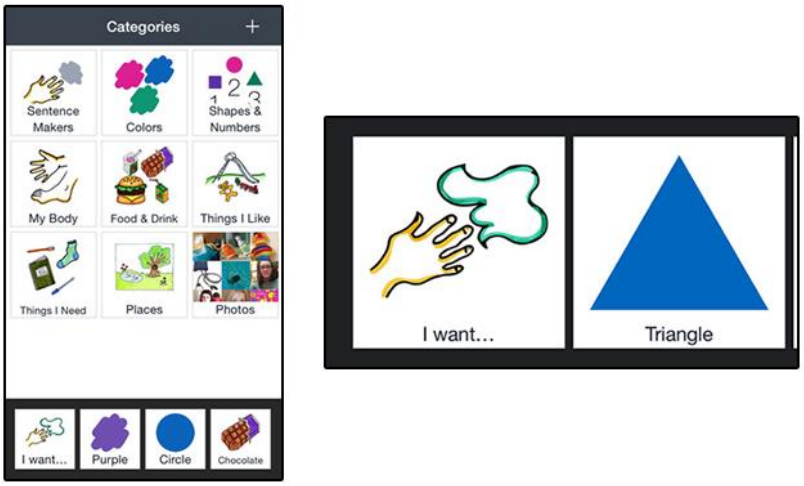


Figure 3 - Screenshots of the Grace application (Troughton-Smith, 2014)

colours (text/background) have been chosen specifically to make it easily readable, especially in the second screenshot shown, as when the sentence of symbols is being displayed it uses the whole screen and this view prevents the user from getting distracted easily (which is common among autistic children).

The images of the symbols themselves are really well designed, using bright colours in order to make them easier to recognise and using a dark grey for the background colour and white for the foreground colour works, as well as a clear black font to help the user navigate around the application quickly and understand the functionality.

The customer reviews are generally positive, praising its interface and the camera feature "Using VB principles we like to encourage communication with vocalisations if possible so we don't use Tap to speak. Using the camera, our daughter can add her own photos to make independent requests and we can add in the text later", however when the PECS system is usable between devices, this feature introduces some protection issues and so this was not a transferrable feature.

3.1.3 – PexPix Autism for Android

The PexPix application (Baumann, 2014), shown in Figure 4, differs to the other applications reviewed in that its interface is much less suited to its users and uses a bad and inconsistent interface throughout the application, which is supported by the reviews that its users have given, for example one reads "If it's too difficult for me I know my child would have problems." and this enforces how important the interaction and interface is going to be in this project, as the layout has to be incredibly clear so that autistic children/people using the application know how to use it without a learning curve. The application offers much simpler functionality than the other two PECS based applications, in that it provides symbols for the user to use and allows them (or presumably their carer) record phrases to be replayed when the card is selected, but the recording function has been criticised for being unstable.

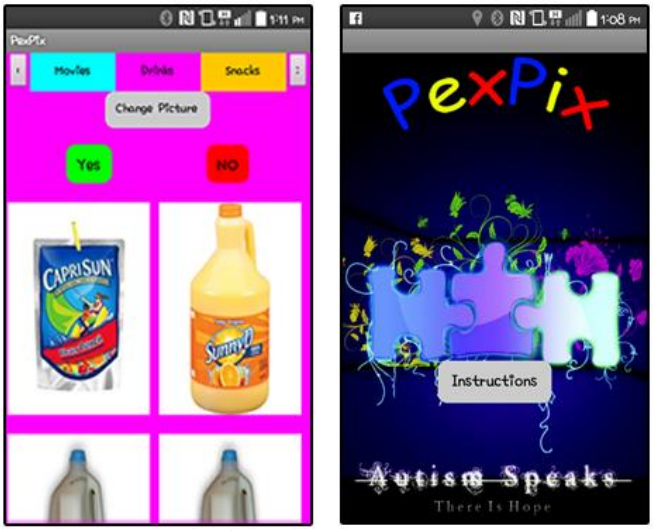


Figure 4 - Screenshots of the PexPics application (Baumann, 2014)

The interface of this application doesn't support its target user-base, having buttons and tabs that don't follow any particular pattern which makes it harder for the user to navigate around the application, it is not clear when navigating the menus where you are and when you can scroll down the page to see other options.

3.1.4 – Evaluation of Existing Applications with respect to Project Goals

None of the existing applications that were evaluated provide the instant messaging functions that this project is aiming to provide, as all are standalone applications that can be used on only one mobile device.

Grace provides the best interface out of all the existing solutions as it is simple and easy to navigate and also easier to visually analyse as it has big pictures on a white background with black text, however it does not offer the functionality of the SoundingBoard application, which can read aloud recordings of the symbols which adds another level functionality. It is however, harder to navigate and the pictures are far too small, with words being the primary screen element, which doesn't fit the purpose of the application as the people using the application are more likely to recognise the picture representation.

The project goals include allowing the background of the application to be changed to make it easier to read, allowing the user to press on the card in order to read aloud the English representation of the card and a picture prediction function that will speed up the selection of symbols. These accessibility features and the transmission of messages between users will build upon the previous ideas and also aims to improve the implementations and possibilities of using PECS.

Feature Comparison

	Application				
Features		**SoundingBoard**	**Grace**	**PexPix**	**Spectrum**
	Read-Aloud	YES	YES (new)	YES[15]	YES
	Camera	YES	YES	YES	NO
	HCI Concepts	NO	YES	NO	YES
	Device-Device	NO	NO	NO	YES
	High Contrast	NO	NO	YES	YES
	Tutorials	YES	NO	NO	YES
	Animations	NO	NO	NO	YES
	Sentences	NO	YES	NO	YES

Table 1 - Feature Comparison between evaluated applications and Spectrum

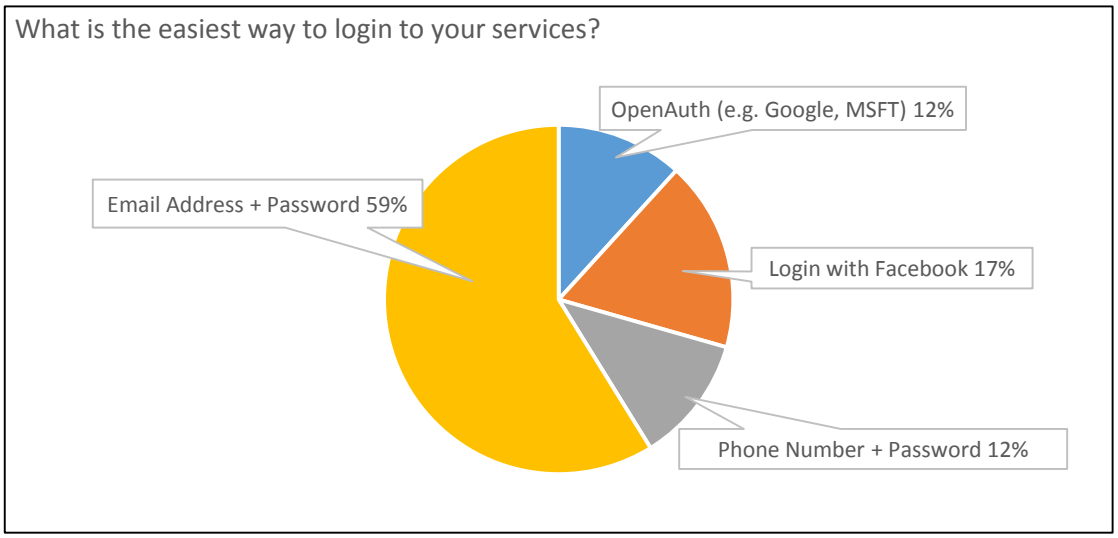
[15] PexPix does not come with this feature out-of-the-box, the user must record the sound for each card.

3.2 – Requirements Research

The research performed to gather requirements is detailed in this section. Several different research methods were employed for this report.

3.2.1 – Online Questionnaire/Survey

I designed an online questionnaire in order to get some opinions and information about how the general public use Instant Messaging software and what features are the most beneficial to the user. The survey was completely anonymous and utilised Google Forms to collect and collate the responses from 19 fellow informatics students and other people in the age range 18-24. This form can be seen in Appendix 1A and its corresponding data gathered is shown in Appendix 1B.



The survey influenced some of the decisions made when developing the application, one example is the research shows that most people prefer to use an email and password to register with their services and considering the children will not have any social accounts, the most likely identity method will be an email, as at least one of the child's guardians/carers will have access to an email account, this directly impacts objective 1[16] and resulted in this objective changing in order to better accommodate the target user. The email addresses that are registered with the system also allow email notifications regarding the status of the application (if the server is being taken down temporarily, then the user can be notified

[16] Objective 1 – "Users will be able to sign-in to the application using an existing account they have elsewhere, using OpenAuth, which will allow users access to their data while protecting their account credentials."

about this through email). The results from this questionnaire also affected the planned features such as read-receipts[17] and custom images were taken out of the objectives, as they were not widely requested and did not have a good fit with this particular application of Instant Messaging.

The survey provided some valuable insights and as it was performed at the beginning of the project, this meant that the results could have maximum impact on the finished product.

3.2.2 – Questionnaire

In order to best capture the requirements of the project, I designed a questionnaire for teachers/carers which is shown in Appendix 1C on page 89, it was used to capture more information about the target domain of the software. The questionnaire made use of the Likert Psychometric Scale[18] (Bertram, 2007), to ensure that the questions were balanced to prevent the participants from assuming there is a bias for a question. The answers provided guidance on what features of the application should be focused on, and one area especially considered was how to use the touch-screen to make children want to engage more with the application, so the Compose interface was made to exploit gestures and drag/drop to utilise the touch screen as much as possible and include animations that give feedback when a gesture cannot be done, such as when at the end of a list of cards.

The answers regarding the benefit of using digital systems as opposed to paper/card based ones and the suggestions were especially insightful.

[17] A Read-Receipt is a "notification delivered when a recipient opens the correspondence that you sent.
[18] e.g. [Strongly Disagree] [Disagree] [Undecided] [Agree] [Strongly Agree] – Prevents loaded questions/options.

3.3 – TARGET USERS

The target user is between the ages 6-12 and has an Autistic Spectrum Condition (ASC), which affects 6 out of every 1000 people on the planet (Newschaffer, et al., 2007), and encompasses Autism as well as Asperger Syndrome, which are neurodevelopmental disorders and causes problems in:

- Social Interaction[19]
- Communication[20]
- Patterns of Behaviour, Interests, Activities that are restricted and repetitive[21]

The application being developed hopes to help with the first two problems, by increasing interaction and communication with others in order to advance the users skills. As by having conversations with other children with Autism the application enables them to get some experience of having conversations without seeing the other person.

The user of my application will generally have a short attention span and will have to be supervised while using the application. Any equipment used will have to be properly safety checked and made sure to be solid enough to not break under the use of the children.

It has been proven that using computers and technology with autistic children can help to encourage learning (Leo & Leroy, 2008). Several features were developed specifically with ASC children in mind, for example, the 'Enhanced Visibility' mode was created as there has been a proposed link between Dyslexia and ASC conditions (Russell & Pavelka, 2013), so the development of a toggle that will turn the background of the application into the cyan colour with black text and emphasised controls with white text on a black background helps both these conditions inspired by the widely-used cyan-tinted ruler, shown in Figure 5.

Figure 5 - A Ruler used by people with Dyslexia to help read text

[19] "Diagnostic criteria for Autistic Disorder include qualitative impairment in social interaction and communication, a failure to develop peer relationships, and use of non-functional rituals and routines" (Kamps, et al., 2002)

[20] Children with ASC find it more difficult to engage in relationships - "Social Communication is a reciprocal, dynamic relationship based on mutual understanding, enjoyment and benefit"

[21] This is also known as Stimming – "A defining characteristic of children with autism is self-stimulatory behavior, or stimming, which can include rocking, hand waving, clenching of the fists, or nonword vocalizations" (Kientz, et al., 2007)

4. PROJECT PLAN

The phases of this project and the planned time of completion of each stage as well as the overlap are described in this section.

4.1 – PHASES

Several phases in this project had interdependencies, which involved planning the project out initially. The initial requirements analysis and design followed the Waterfall Model[22], as the only requirements analysis that had taken place was the survey and the teacher questionnaire, due to being unable to start participatory design/evaluation until DBS clearance was granted, this allowed the application to be developed to the point at which it was feature-complete using the Agile Software Development Lifecycle[23] to the specifications given in the Objectives.

Using the feature-complete application during the testing session meant that changes could be applied to the application quickly with the design and development stages taking place concurrently, using the information collected from the teachers and children to iteratively improve the design of the application/interface until it satisfies the goals of this project, which can be proven in the evaluation phase.

The testing and evaluation phases followed on from the participatory design and development phases and through using unit, load and manual testing methods, the client and server was tested to ensure that it can handle the different use cases.

The evaluation stage involved returning to a school and evaluating the effectiveness of the final design of the application and determining how effective the application was at completing its objectives, however this was proposed to be a Participatory Design session followed by a final testing session, but due to time-constraints, this could not be completed.

[22] Sequentially - Requirements Gathering, Analysis, Design, Coding, Testing, then Release. (Royce, 1970)

[23] Agile solves the problem that "Customers and users do not always know what they want at the outset of a software project, and we must be open to change during project execution" (Glass, 2001)

4.2 – GANTT CHART

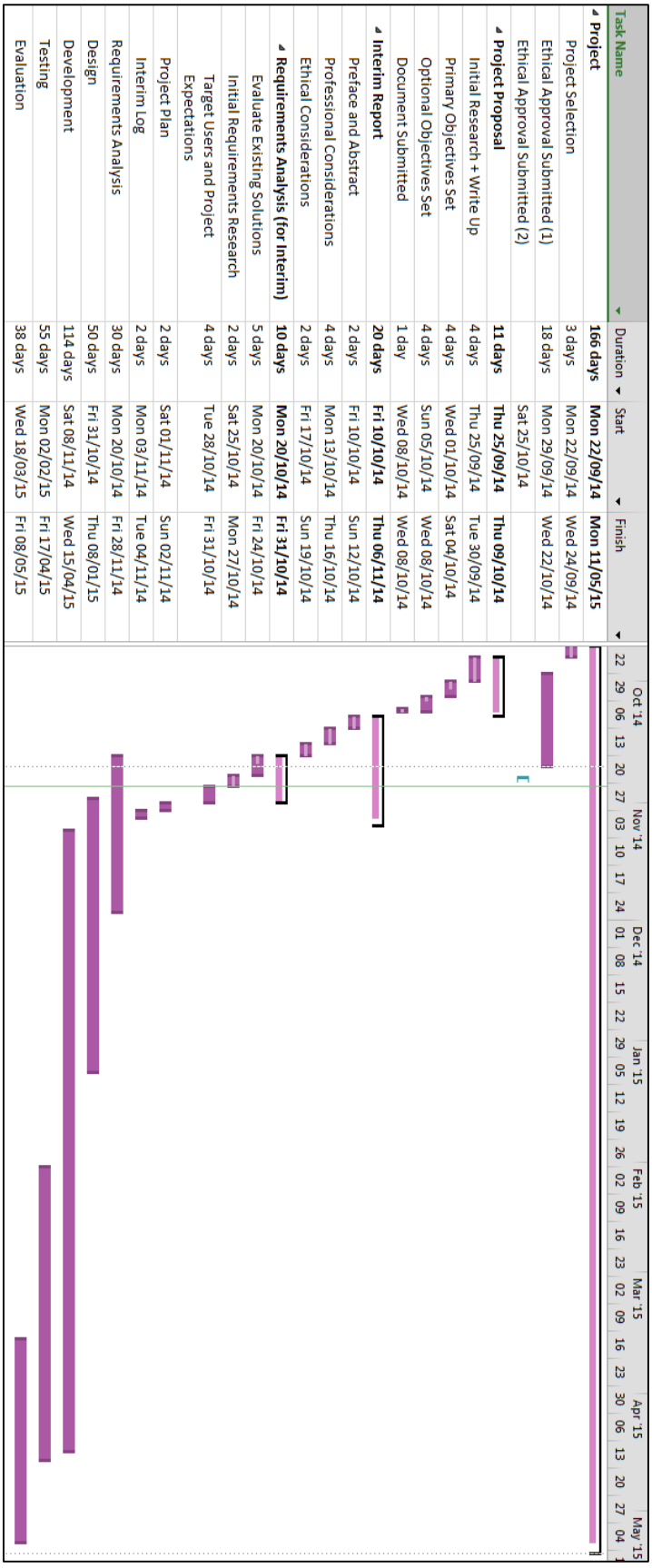


Figure 6 - Project Plan Gantt chart

4.3 – PROJECT EXPECTATIONS

This section underlines some of the expectations of the project, given the objectives specified in the Project Proposal.

4.3.1 – Primary Objectives

1	Users will be able to sign-in to the application using an existing account they have elsewhere, using OpenAuth, which will allow users access to their data while protecting their account credentials.	MEDIUM

Objective 1, to allow users to sign in using OpenAuth/OAuth was changed following the results from the online survey, which showed that the majority of people prefer to sign in with their email and a password, this combined with the requirement of OpenAuth/OAuth that you have an existing social account, meant that this method is not optimal, due to the target user being generally between 6-12 and carers, who will not want their social account linked to their work accounts.

Instead, an email and password will be used to sign-in and the credentials will be stored securely on the server in a database.

2	The interface will have a contact list as the main page, which contains other users they have added.	LOW
6	If a user receives a message via the application, their phone will make a sound and a notification will be created and displayed to alert the user in their Notification Center.	LOW

Objectives 2 and 6 are low risk objectives that impact the user interaction with the application, they are essential to the primary use of the application as in order to send messages you have to select a recipient and receiving messages from someone should show in a separate thread, instead of some form of unified inbox.

5	There will be a picture/symbol database that contains many of the PECS standard 'cards' such as the context cards like 'I want', 'thank you' or 'I see' and objects such as 'Apple' or 'Trampoline' and allow users to string these cards together to create sentences in the conversation view.	HIGH
7	A personalised Picture Prediction program will be included in the application, which makes suggestions for the next picture being added based on previous messages.	HIGH

The symbol database and picture prediction function (objectives 5 and 7) are high risk objectives and they will be considerably more complex to implement, however they are essential to the function of the application.

3	Each person that has had correspondence with the user will have its own 'conversation' in the conversation list and this will allow the user to see what has been sent in the past, this conversation window will scroll the images left-to-right as this is more logical for younger users and makes the conversations flow like normal sentences using the images/symbols.	HIGH

Objective 3 is going to be high risk, as it involves a custom layout being developed for the Android OS, in order to get the interface to look correct, with correct direction of cards (left to right) and scrolling functionalities as well as rendering the symbols, showing the time of the message and also showing the user whether the message is one that they sent or received from another person.

4	Users will have a way to add people to their contact lists, using a username for example.	MEDIUM

I envisage Objective 4 as a medium risk objective and will need to poll the server to see if the user exists and then add this to the local database, however it is essential to the functioning of the application.

4.3.2 – Extension Objectives

The extension objectives are objectives that are hoped to be completed, but not essential.

8	If each user could have a profile along with a status, this would make the application more immersive as it would provide a single place for users to see the status of their friends without moving to external services which may be unsafe for users with severe autism to be accessing such as Facebook and Twitter.	MEDIUM

This objective is an extension objective, which states that it would be beneficial for the application to give the user a way to personalise their account/profile, however, following research, the end-user of this application will not have fluent English and so providing a text profile is not useful, instead a Profile Picture function will be implemented, which allows each user to set a Profile Picture on Registering their account, which will be shown to all contacts through the picture appearing next to their name in the Contact List. The pictures will be pre-defined as to prevent any misuse.

9	Based on the coloured/tinted rulers that many people with dyslexia use I aim to have an option to tint the background of the application a certain colour such as magenta and cyan which should help children with dyslexia to see what is on the screen.	MEDIUM
10	I would also like to make it possible to get the phone to read out loud any messages received, by having alternate text for the built-in cards which can be read via Text To Speech (TTS) on the device.	MEDIUM

The accessibility features that make up objectives 9-10 are both medium risk and both affect the way the user interacts with the system and help the user to understand what is being shown/sent to the user. The TTS function is a medium risk, but has a dependency on the symbol database, as this needs to store the textual representation of the symbols in some form, and the symbol database is a high risk objective.

11	Location support would be useful to add and would provide users with a way of knowing how close the other person is to them.	MEDIUM
12	The ability to send a picture from the front or rear facing camera on the phone, or attach an image that is stored on the device memory should be built into the application so that users can include their own images if one is not available in the symbol database.	MEDIUM

Objectives 11 and 12 are objectives which will not be pursued, not due to development issues, but ethical and safety reasons which were not discovered until after the Proposal Document was submitted. Due to the target age group of this project being 6-12, sending locational data with messages is dangerous, and holds privacy issues. Objective 12 will also be dropped from this project, as it would be dangerous to allow children in this age group to send pictures from the camera on the phone.

5. DESIGN AND DEVELOPMENT

This section encompasses the design and development phases, as they are interdependent.

5.1 – INITIAL DESIGN

This section contains some early high-level designs for the application and the background processes that execute, most of the designs in this section are abstract enough to not impact the actual design stage.

6.1.1 – Initial Application Data Flow Diagrams[24]

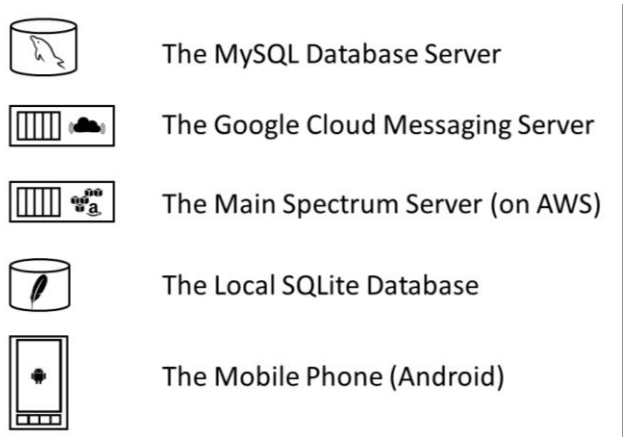


Figure 7 - Legend for Data Flow Diagrams

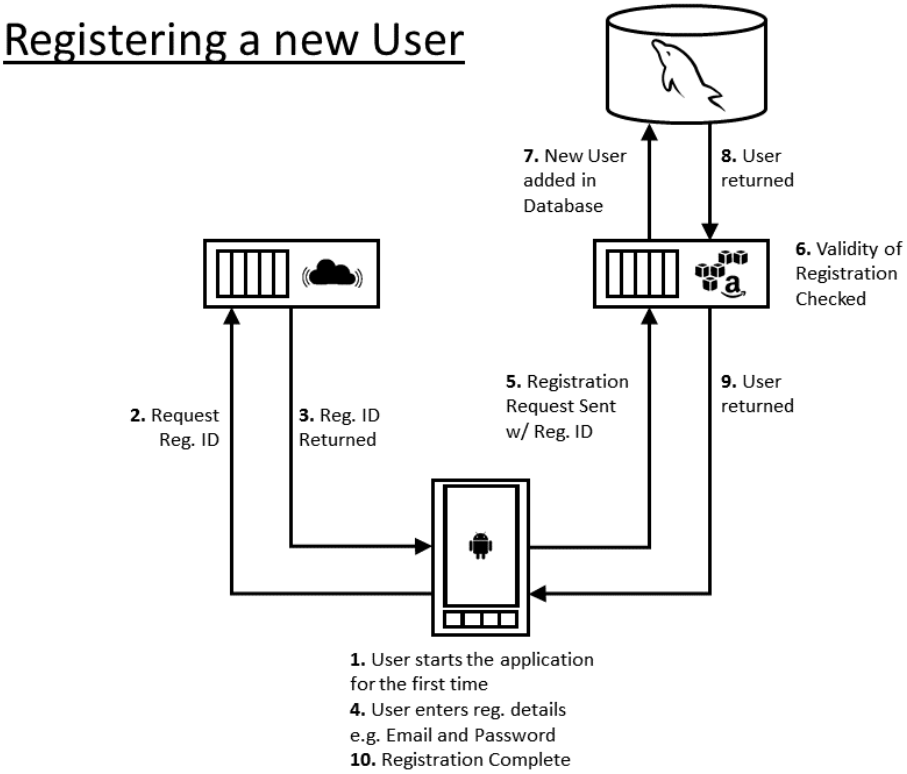


Figure 8 - The Data Flow that takes place when a new User is being registered

[24] The technologies chosen here are explained in the "5.2.3 – Application Design" section.

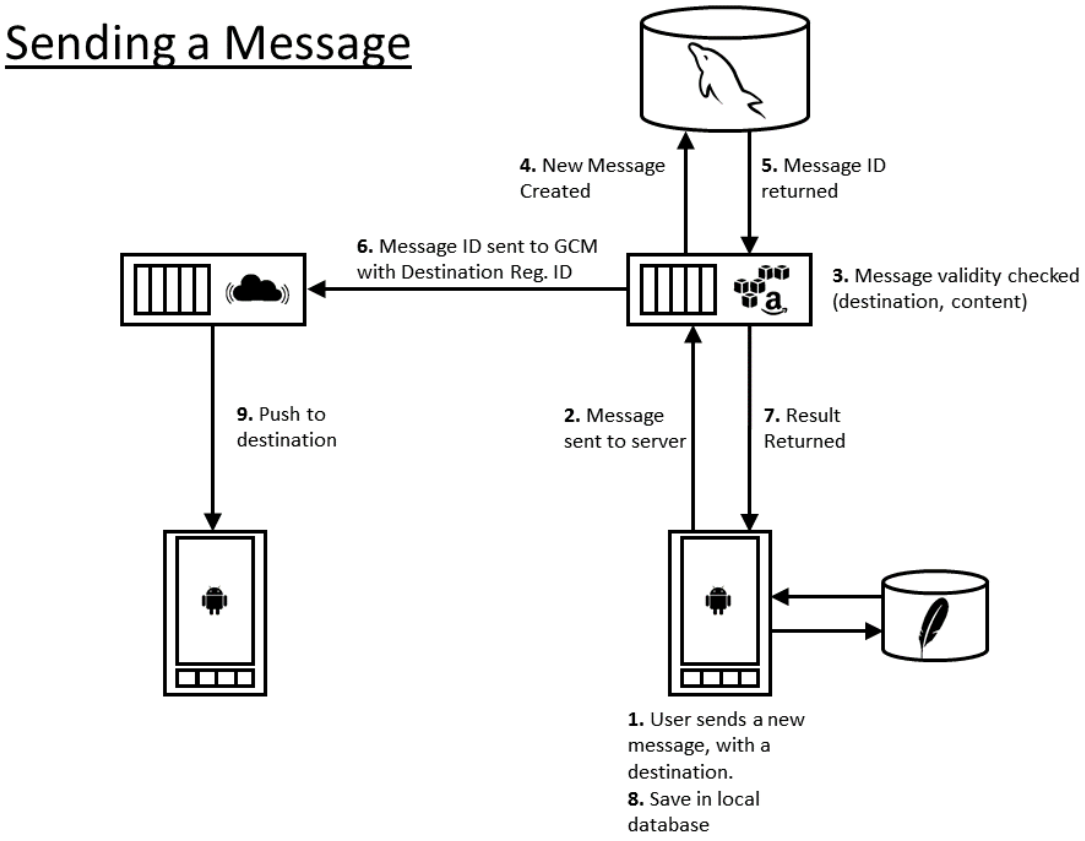


Figure 9 - The Data Flow that takes place when a message is being sent from to another device

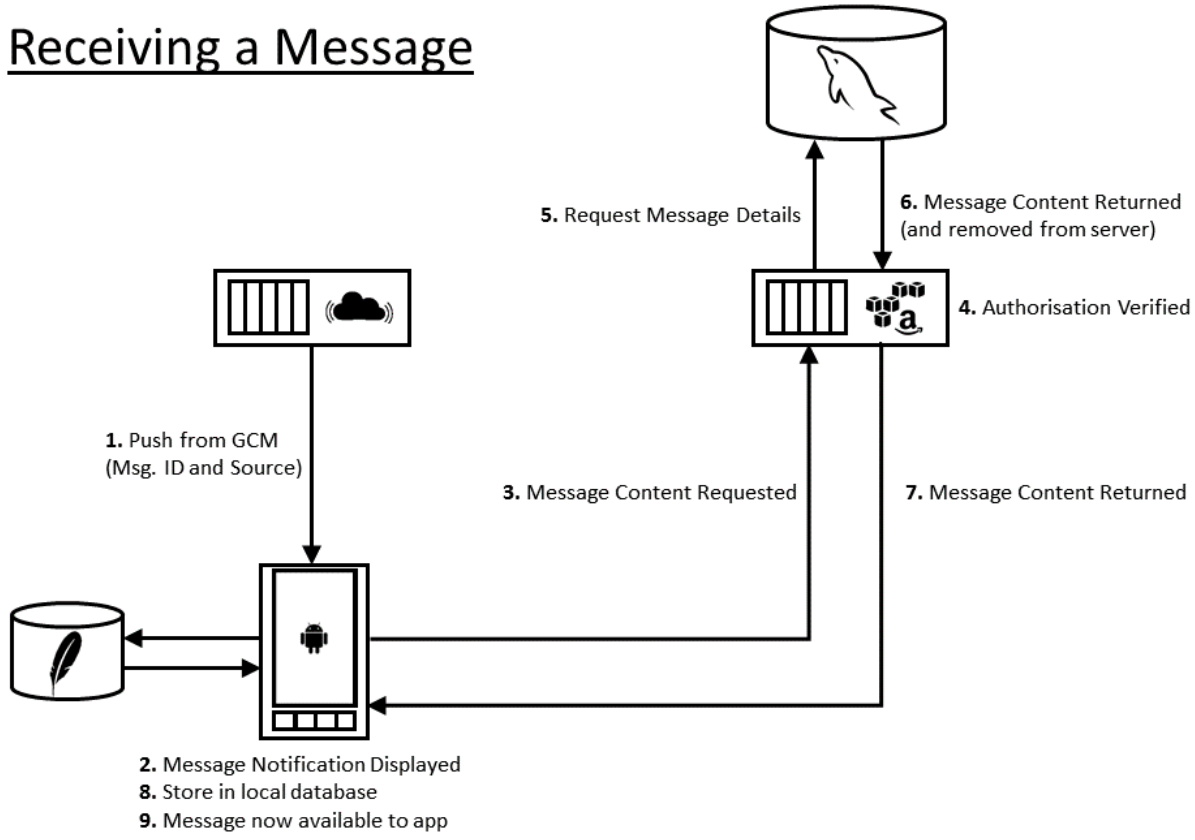


Figure 10 - Diagram showing the Data Flow of receiving a message on a device and retrieval

5.1.2 – Initial Application Interface Designs

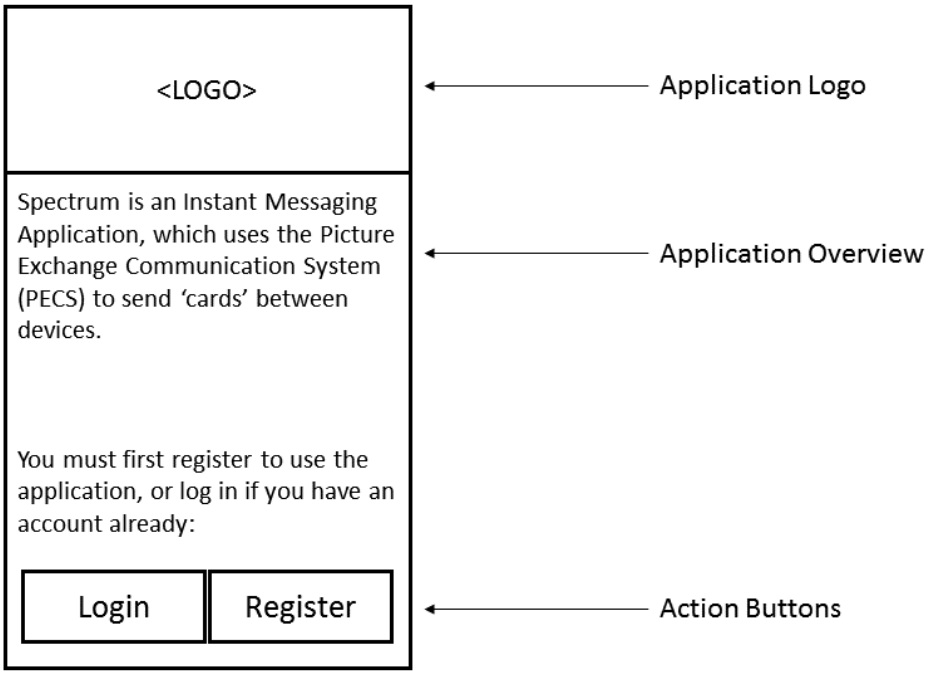


Figure 11 - Simple Wireframe of the Initial Design, showing the start screen, which is shown on the first run of the application

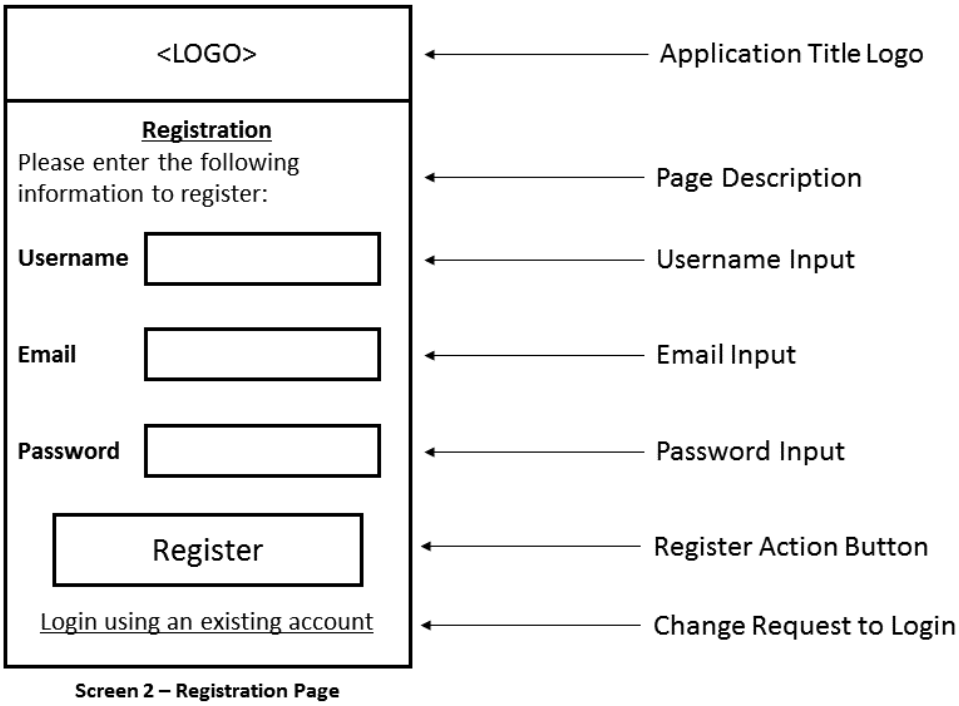


Figure 12 - Initial Design of the Registration Page

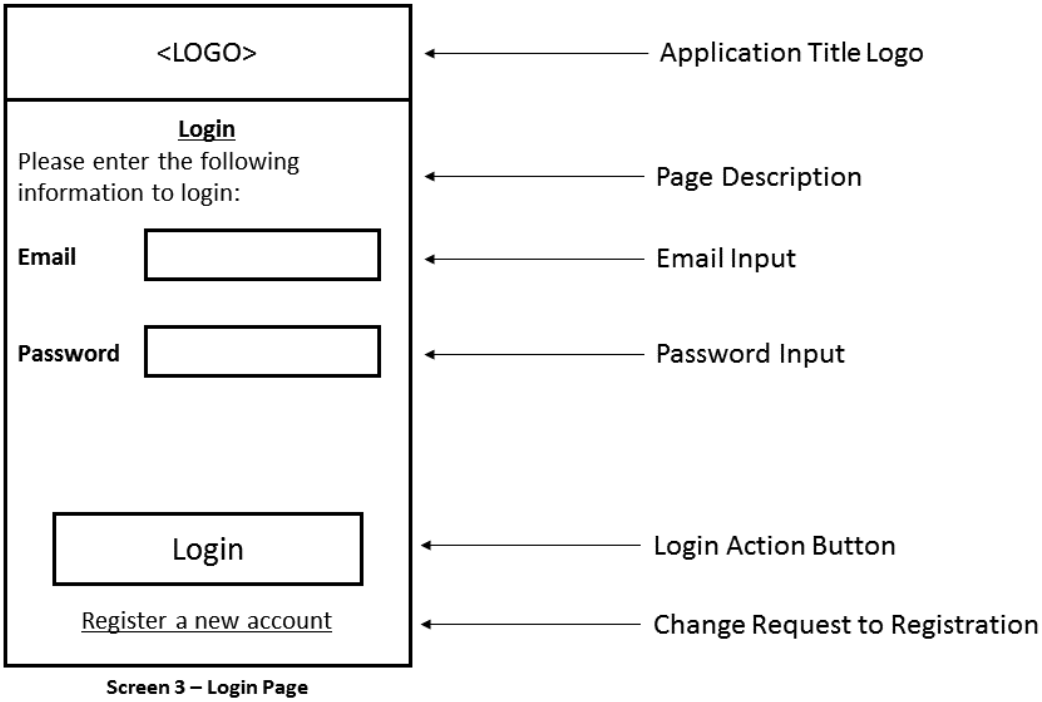


Figure 13 - Initial Design of the Login Page

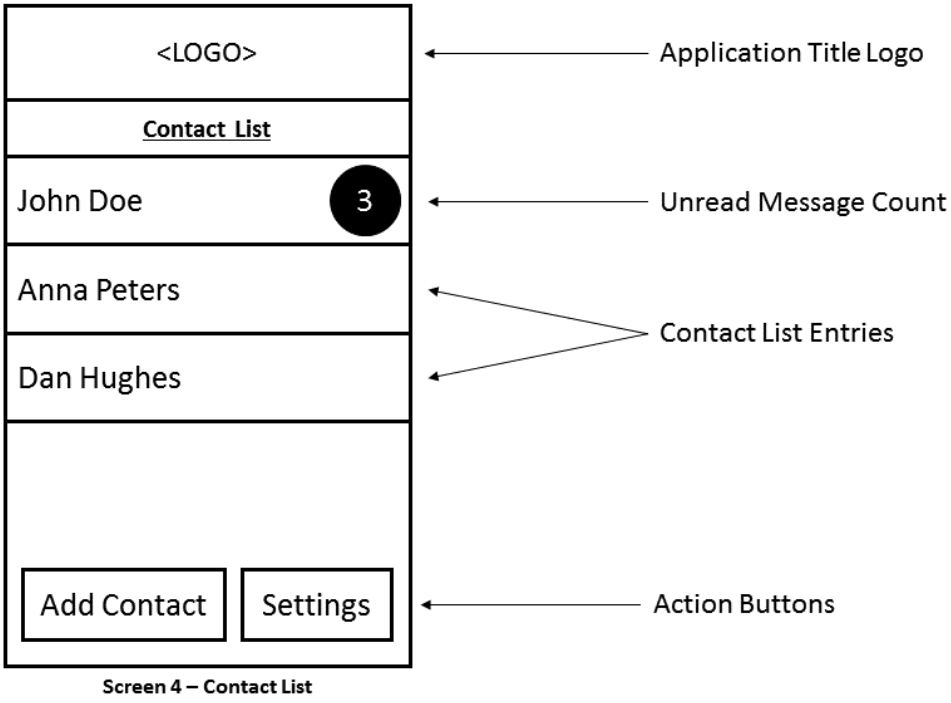


Figure 14 - Initial Design of the Contact List Page

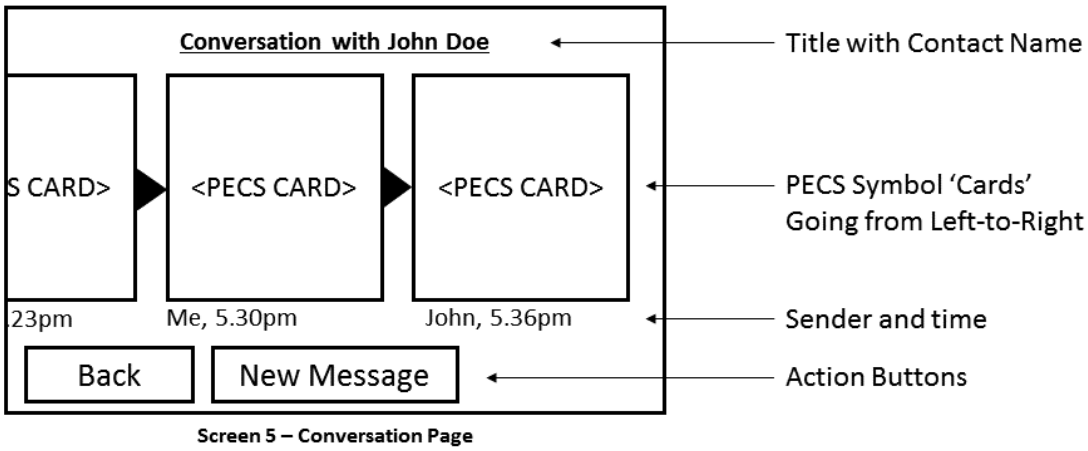


Figure 15 - Initial Design of a Conversation Window with a recipient

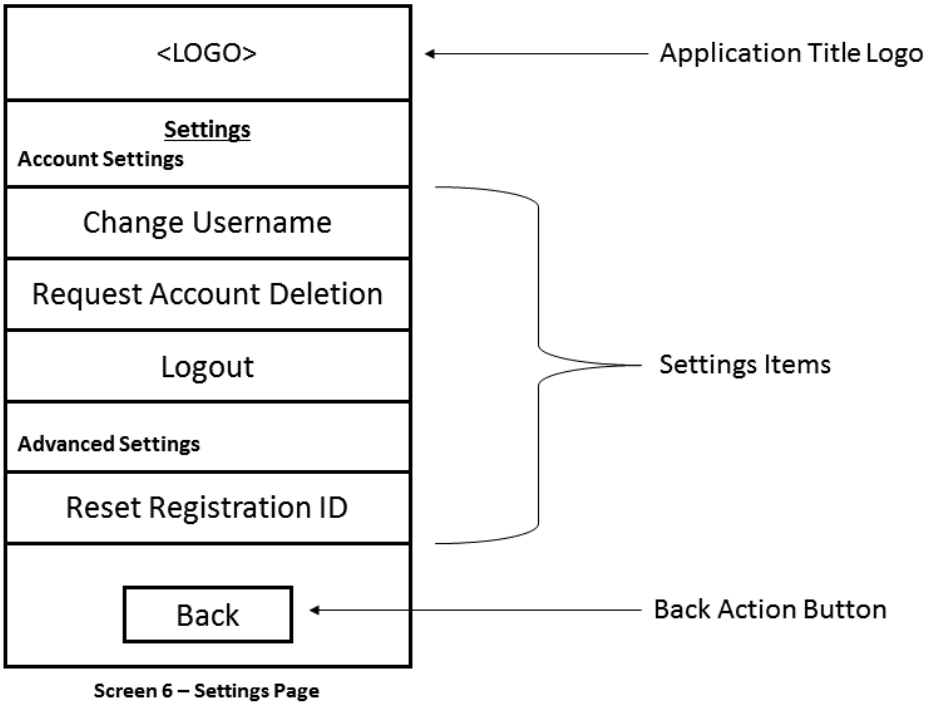


Figure 16 - Initial Design Wireframe of the Settings Page

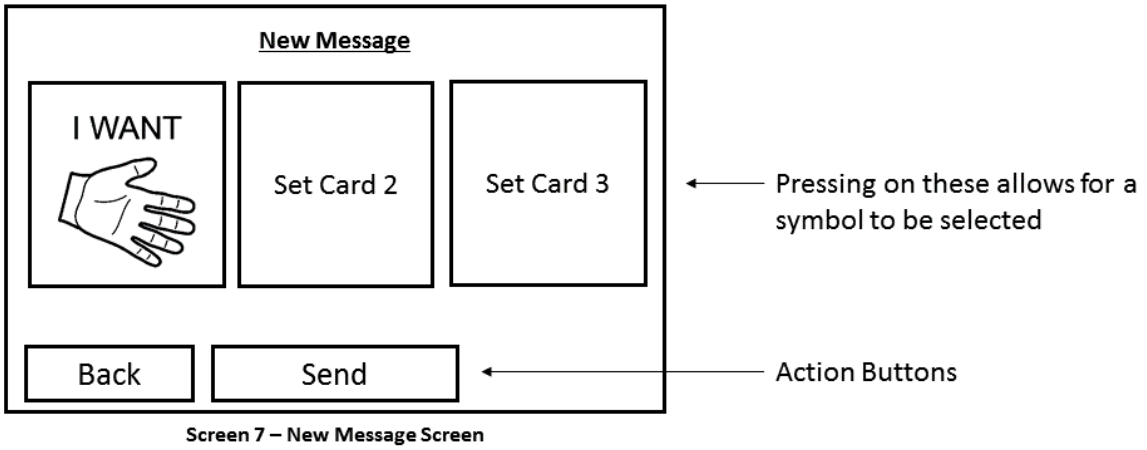


Figure 17 - Initial Design of the New Message screen, which is accessed from the Conversation Window using the 'New Message' Button

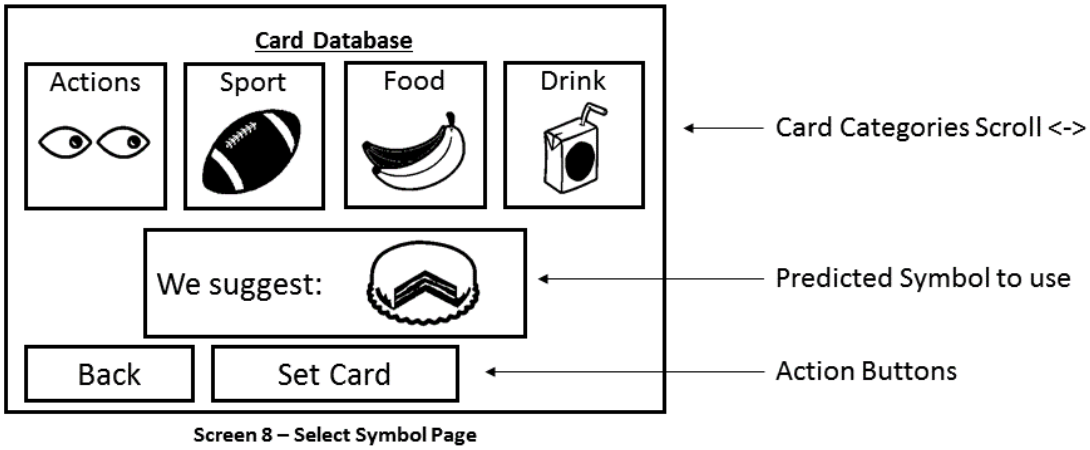


Figure 18 - Initial Design of the Card Database screen, which shows when one of the empty cards is tapped (in Figure 16)

The designs that have been drafted in this section contain considerations for people with ASC conditions, by being simplified and using high-contrast elements and simple navigational controls that are consistent across all interface screens.

5.2 – DESIGN

This section explains the design decisions made for the branding, colour scheme and architecture.

5.2.1 – Branding

5.2.1.1 – Colour Scheme

It was decided that the application should follow a consistent design throughout, this meant determining a suitable colour scheme from which the other assets such as icons and text colour would follow.

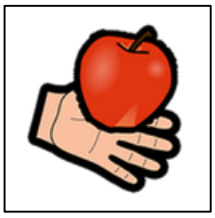
The colour chosen was light red, as it immediately set my application apart from others, is vibrant and using white icons and text worked well with it, which also helped when implementing the Enhanced Visibility mode for Objective 9, as by using white text, when a black background was applied to the titles it immediately increased the visibility of the elements.

Standard Colour Scheme

Enhanced Visibility Mode

5.2.1.2 – Icon

A simple, immediately identifiable icon was chosen to represent the application, which was based off one of the cards used in the symbol database and was later simplified to make it fit the Android Guidelines better as well as make the icon more recognisable when the silhouette is used in the title bar.

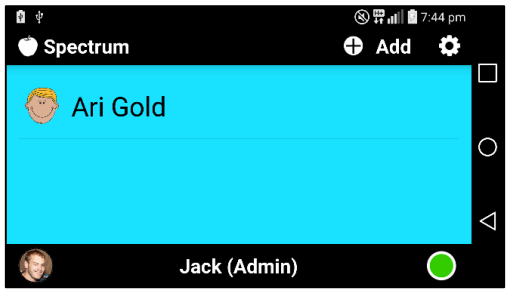


Initial Icon Design

Final Icon Design

5.2.1.3 – Enhanced Visibility Mode

The Enhanced Visibility Mode uses the concept of a dyslexia ruler and high-contrast to improve visibility.



5.2.2 – UX Design

The User Experience was very important in the design of this application, as the end-user may not have much prior knowledge of using handheld devices, so this aspect of the application was carefully considered and the designs from the initial wireframe drawings changed to simplify the interface as much as possible and make the navigation around the application simple enough that anyone could understand, this was done through Contextual Task Analysis (Graves, 2014).

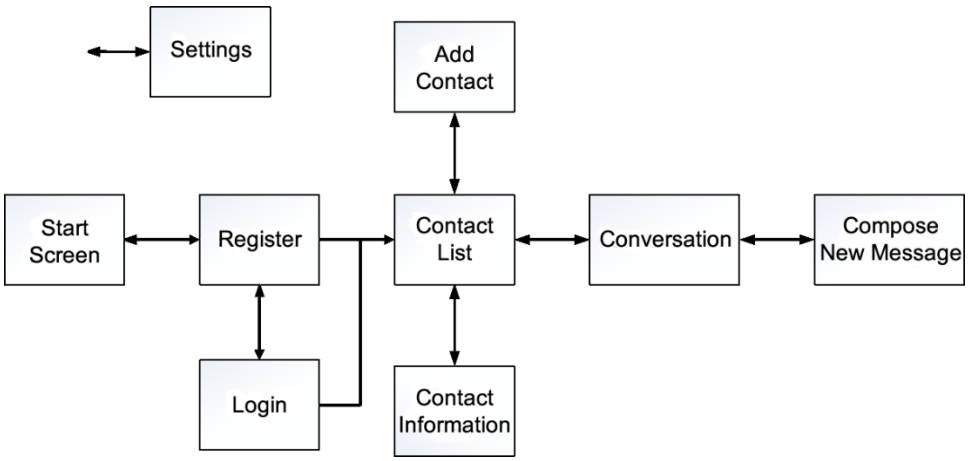
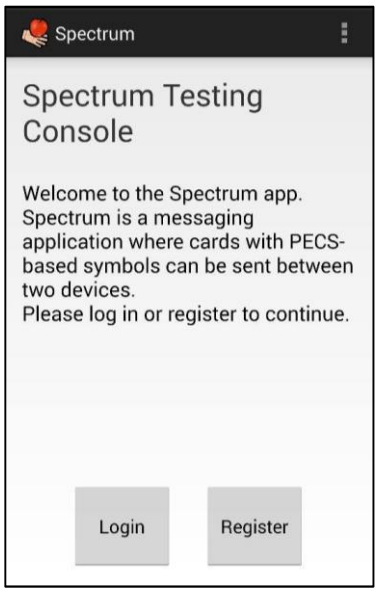


Figure 19 - The Navigation Map of Spectrum

The process of simplifying the interface was done iteratively, as each feature was added, the interface that it was accessed from was evaluated to determine its effectiveness, a good example of this is the start screen, shown below in three iterations, which reduced the amount of buttons by half and made it more obvious to the user how to start using the application.



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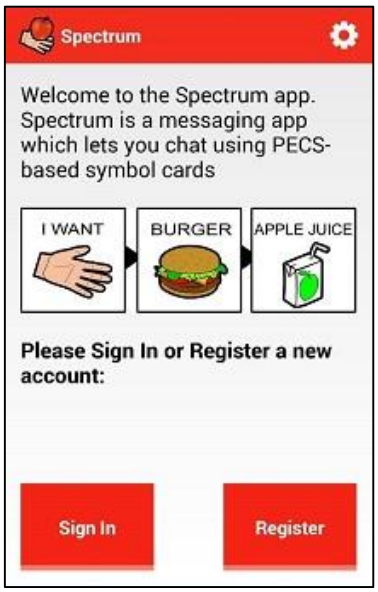

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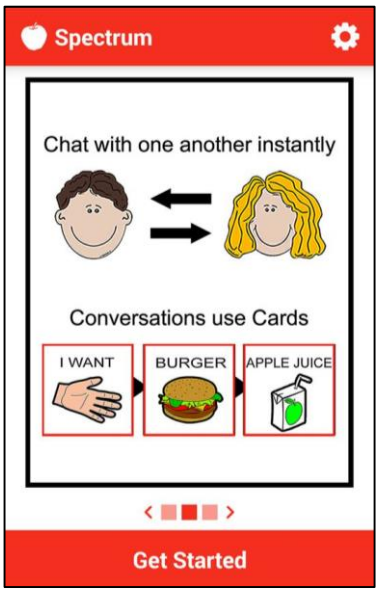


20/01/2015

5.2.3 – Application Design

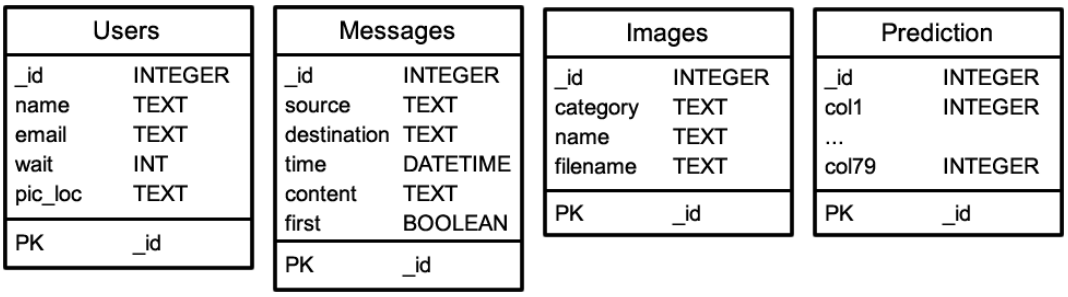
The various back-end technologies that drive the Spectrum system were chosen to best align with the aims of the project and make an efficient system.

5.2.3.1 – Database Design

Client

When deciding what database technology to use for the client, to store contact, message, prediction and picture tables, SQLite(3) was the obvious choice, due to its reliability through having 100% test coverage[25]. It is also the default and pre-installed database technology on Android, which allows the logic of CRUD[26] operations to be quickly implemented using a ContentProvider class[27], which "encapsulates the data, and provides mechanisms for defining data security".

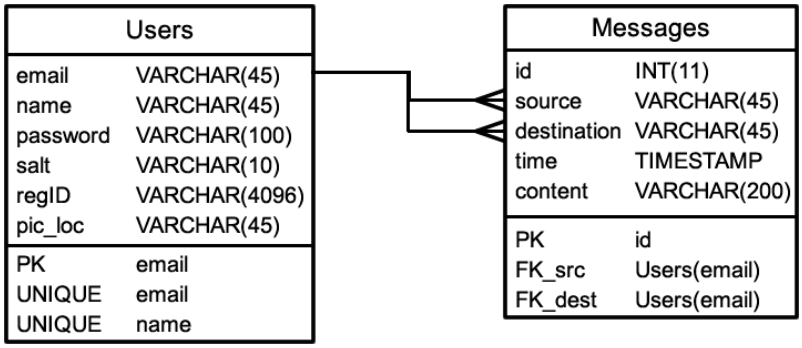
The structure of the client database is as follows:



Server

The database technology chosen for the server was MySQL, due to it being reliable, lightweight and PHP has built-in methods to facilitate connecting to and manipulating tables in a MySQL database.

The server database is designed to be simple and quick, with that in mind, the PHP scripts handle the consistency, validation and verification of data being handled by the server.



[25] https://www.sqlite.org/testing.html#coverage
[26] Create, read, update and delete (Heller, 2007)
[27] http://developer.android.com/guide/topics/providers/content-providers.html

5.2.3.2 – Messaging Technology

There are two technologies that facilitate the transmission of data to/from the server to the client, these being:

- JavaScript Object Notation (JSON) over HTTP (IETF, 2014)
- Google Cloud Messaging API (GCM)

The direct communication between the Server and Client utilises simple JSON which is transmitted over HTTP using POST to send the data inside the body of the request/response, this was chosen as it is quick, human-readable and doesn't require much processing to get the key/value pairs, especially compared to XML.

The client application is used on mobile devices, with finite battery life, to that end, Push Notifications are used, so when the phone is idle and the application is closed, the phone can still receive new messages and friend requests.

In order to determine the best push technology to use, a research paper which evaluated the different technologies response times and battery life was referred to as it contained in depth results (Hansen, et al., 2012).

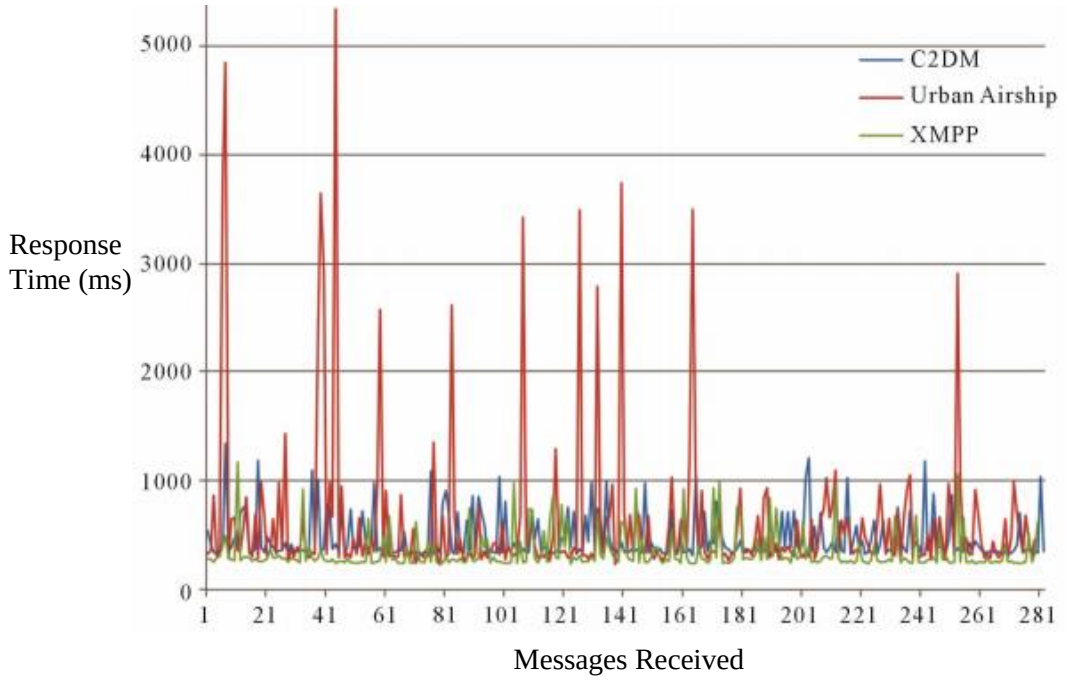


Figure 20 - Response Times for C2DM (GCM), XMPP and Urban Airship (Hansen, et al., 2012)

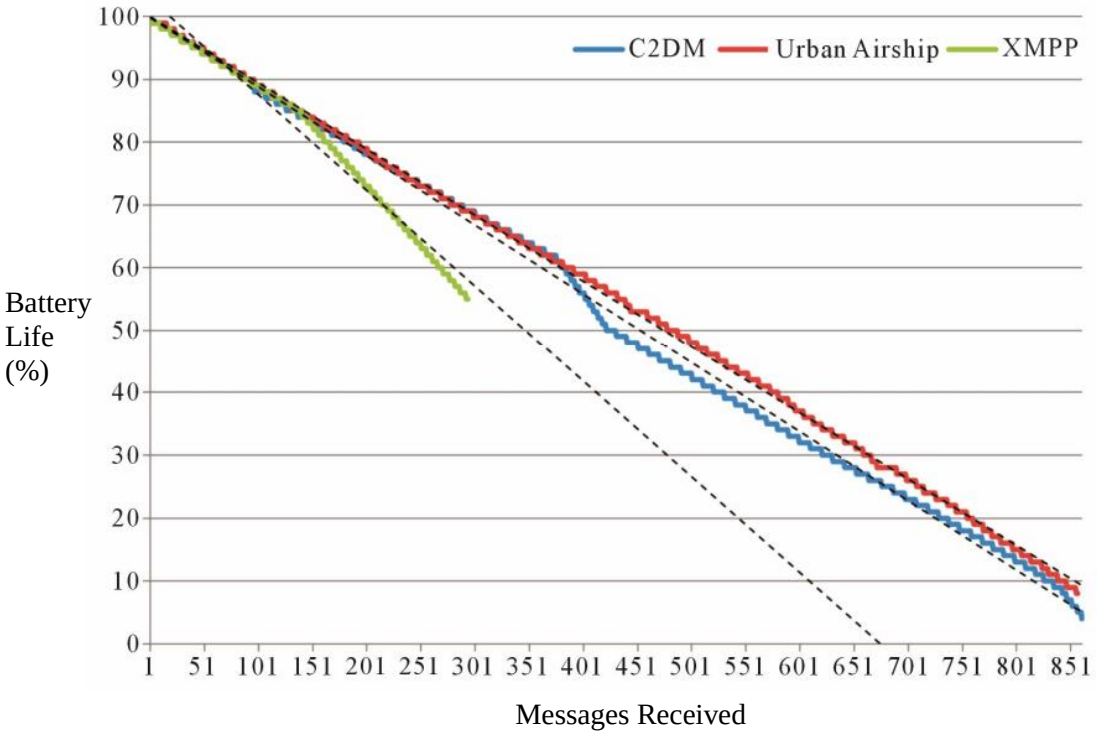


Figure 21 - Battery Drain of C2DM (GCM), Urban Airship and XMPP (Hansen, et al., 2012)

It can be determined from this report that while Urban Airship used less battery, it also had the highest response times and while XMPP had the lowest response times, it had substantial battery drain, the writers of this report conclude that "Overall, when including all aspects of the test from the three technologies we were able to test thoroughly, we found that C2DM provides the best results."

Therefore, GCM was chosen, as overall, when battery and response times are taken into consideration, it has the best balance, and the only drawback to using GCM is that the devices must have Google Play Services installed on them (which all Androids which have Google Play have).

When a message is sent and the server receives the data, it is inserted into the database and then a push notification is sent (using the php_gcm library) to the GCM server, which contains the Message ID and sender, which is then forwarded to the destination device, which fetches the message content using HTTP POST w/ JSON as shown in Figure 10 (Page 33).

5.2.3.3 – Server-side Scripting Technology

When choosing the server-side scripting language that acts as an API for the Client application, which sits between the client and the database, the requirements where that it must be lightweight and able to be written procedurally, and use minimum resources when idle. With these requirements in mind, PHP was chosen over Java Servlets for implementation, as PHP makes writing code for concurrent users and database connections easier, especially MySQL. The disadvantage to using PHP over a Servlet is that it can't handle as many concurrent users (Wu, et al., 2000), as is shown in the diagram below taken from a report on servers. However, Java Servlets along with JPA (Java Persistence API) were the first option considered. Apache was chosen as the host as it supports easy deployment of PHP.

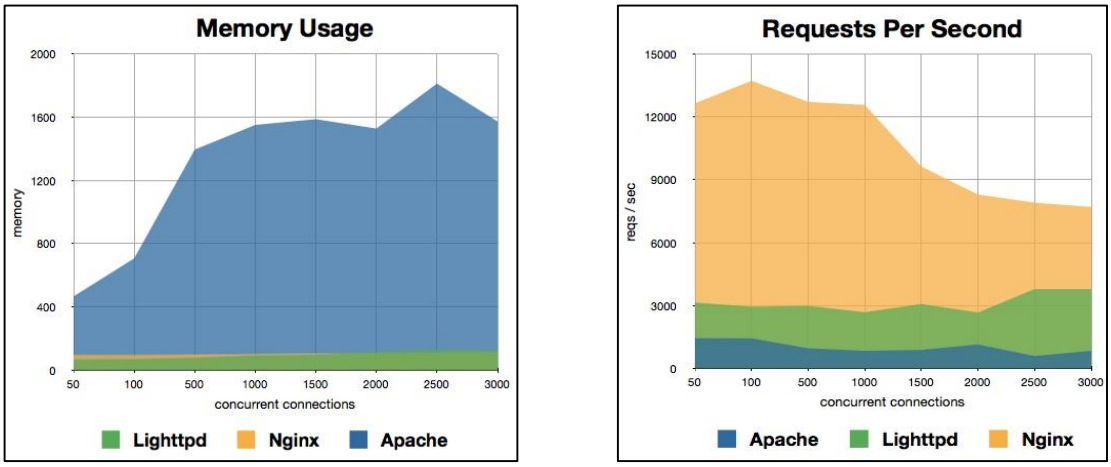


Figure 22 - Performance comparison of Servers (DreamHost, 2015)

The server logic was designed in layers, first there are front-end scripts that are accessible by the public, which handle verification checking and output to the user and work as an Application Programming Interface to the client application and are abstracted from the client code to make coding additional clients possible: login.php, pull.php, register.php, send.php, fetch.php, email_check.php.

These scripts then communicate with the DatabaseManager.php script which handles conversion of the verified input into a form that can be inserted into the MySQL database, it also handles sending push messages through Google Cloud Messaging.

Despite the shortcomings of using Apache, it is the only server-application that supports AWS scaling with a Load-Balancer, an essential feature for a web service.

5.2.3.4 – Prediction Engine

The prediction engine is powered by an IntentService[28], which has two possible 'Actions' that can be executed, which are both used by the Compose activity to add the values for sent messages and to get a prediction for the next symbol based on the current composed message.

Action	Description
ACTION_APPEND	Adds the specified string of comma-separated values (Symbol ID's) to the Prediction Database. Complexity is constant - O(1).
ACTION_PREDICT	Given a Symbol ID, predict what the next symbol will be using the Prediction Database. Complexity is constant - O(1).

The Prediction Engine makes use of a Markov Chain, where the probability distribution of the next state depends only on the current state and not on the sequence of events that preceded it (Norris, 2008).

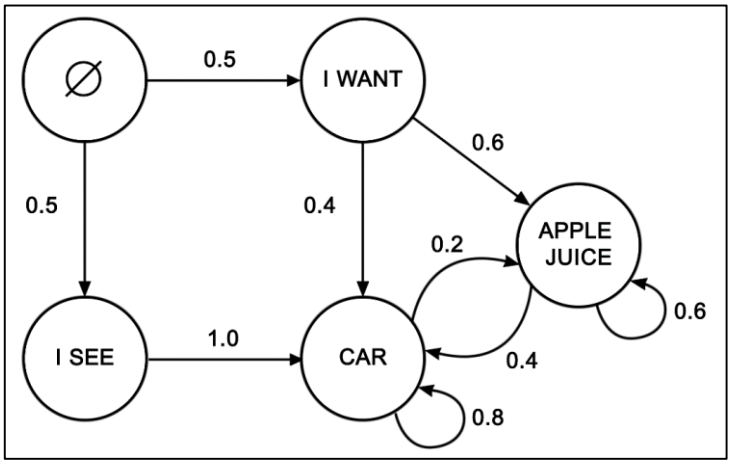


Figure 23 - Diagram showing a possible way in which the Predictor represents the Markov Chain (∅ represents an empty input)

In order to persist the prediction data, a table is created using SQLite when the application is first set up, where the row represents the initial symbol and each column in that row represents another symbol (or the same symbol) and the value of each cell is how many times the symbol has been used after the initial symbol. This data structure makes it easy to predict what the next symbol is based on manipulating the data found in the table which is structured as shown in Table 2.

Initial Symbol	I Want	Cat	Elephant	Dog	Sheep	Chicken
Empty (∅)	12	2	1	4	0	0
I Want	0	4	0	1	0	1
Cat	0	1	0	3	0	0

Table 2 - Example of the Prediction Table showing the first few entries. Highlighted are most probable transitions

Performance testing for the Prediction Engine is shown in Appendix 8, checking both append and prediction functions that the service provides.

[28] The "5.3.1 – Development Methods" section of this report details what an IntentService is.

5.3 – DEVELOPMENT

This section details the development phase, primarily the issues faced, how the application was developed using the facilities that Android provides and Android API short-comings.

5.3.1 – Development Methods

Developing for Android has a considerable learning-curve and some of the terminology and methods of calling procedures that are Android-specific are detailed in this section.

5.3.1.1 – Passing Data between Activities/Fragments

When an action is performed in the Android application that requires a new Activity/Fragment or Service to be instantiated, in order to pass parameters to it we add data to the Intent that we create to open the component. This functionality is used to pass the recipient to the Conversation Activity.

```
// Create new Intent for Conversation
Intent i = new Intent(this, Conversation.class);

// Add extended data to the intent (Contact ID and Email)
i.putExtra("id",    contact_id);
i.putExtra("email", contact_email);

// Start the Activity with Intent
startActivity(i);
```

Code 1 - Creating and Executing an Intent

However, we cannot pass complicated objects (unless they were Serializable/Parcelable, but this gets complicated) and the target activity will still have to fetch data from the Database (through a Content Provider) to populate the display, this is why the database ID of the contact is passed to the Conversation Activity, this process is similar for instantiating Fragments.

This system of passing ‘extras’ with Intents is used throughout the application, including opening a notification for adding a contact/receiving a new message – they start Intents directly to the correct screen, so that when that action is complete, going back will go back to the users’ previous activity.

5.3.1.2 – Performing Network Tasks

Any task that takes time to complete, such as network operations or loading data from a database on Android must be run in a different thread to the UI thread, this is to prevent lag and freezes, in order to satisfy the Android guidelines, Spectrum makes use of the classes which extend:

- **IntentService**
  - Used for tasks which start and finish.
  - Can be called/binded to the Main Thread, using Broadcasts.
  - e.g. Prediction Service.
- **Service**
  - Used for tasks with no UI.
  - Runs in the background.
  - e.g. Process a received Push Message.
- **AsyncTask**
  - Short Tasks which occur and are bound to the Activity that called them.
  - e.g. Sending Messages

The IntentService is used for the Logging In and Prediction logic, as these tasks must be accessed from the UI through binding the service to the Activity, which return a result on completion (useful for progress dialog and making predictions after each input.

AsyncTasks are used for other tasks which don't require feedback or where the result is written directly to the database and the UI updates automatically, such as Sending a Message, Adding a Contact or Checking for messages (which write changes to database).

Services are used extensively in the Spectrum Client, as they enable tasks to be completed separately to the application, they are used for the Push Messaging Receiver Service and the Fetch/Pull Services which facilitate message retrieval without needing the UI open.

5.3.1.3 – Accessing and Updating Database

Android provides the ContentProvider[29] abstract class for managing access to structured sets of data. It encapsulates the data and provides mechanisms for defining data security, this is usually only used by applications that allow data to be accessed externally, but as this project has 4 tables, it was useful to provide a single method of retrieving data given a URI which identifies each table.

The class 'LocalDBProvider' in Spectrum is an implementation of the ContentProvider class and is defined as a provider in the AndroidManifest file, it creates and manages insertion, deletion, updating and querying of all data structures.

The application then uses the getContentResolver() method to get a ContentResolver object which interfaces with the ContentProvider to provide the basic "CRUD" (create, retrieve, update, and delete) functions of persistent storage.

The method used most is the ".query" method, which is used to retrieve data and then use this data in the UI somehow, this method returns a Cursor object, which represents rows and columns that correspond to the query parameters.

```
// Get the Cursor
Cursor c = getContentResolver().query(
      Uri.withAppendedPath(LocalDBProvider.CONTACT_URI, id),
      null, null, null, null
);
// Move to the first (and only) row and retrieve data
if (c.moveToFirst()) {
      name  = c.getString(c.getColumnIndex(LocalDBProvider.CON_NAME ));
      email = c.getString(c.getColumnIndex(LocalDBProvider.CON_EMAIL));
}
// Close Cursor – Frees Memory etc.
c.close();
```

Code 2 - Retrieving Data from the Database

[29] ContentProvider - http://developer.android.com/reference/android/content/ContentProvider.html

5.3.2 – Application Architecture

The standards, principles and overall architecture of the application are discussed thoughrouly.

5.3.2.1 – Code Style

Writing Short Methods - Each class was written with clearly separated methods, to make the code readable and easier to debug, with variable, method and field names being named clearly. The Android guidelines state that in general a method should be below 40 lines of code (Google Inc., 2015).

```
void acceptSuggestion(int position) {
	// Get selected tag and the relevant suggestion
	TagObject tag = (TagObject) symbols[position].getTag();
	TagObject sug = suggestions[position];

	// If selected place is empty and there is a suggestion then:
	if(sug != null && tag.getTag().equals("Empty")) {
		// Add the symbol and make a new suggestion
		addSymbol(String.valueOf(sug.getId()));
		suggestions[position] = null;
		clearSuggestions();
		makeSuggestion();
	}
}
```

Code 3 - Clear and Separated Logic

Exceptions - All exceptions that are caught by the application cause the stack to be written to the log as well as log a reason why the exception occurred.

Javadoc Standard Comments - Where possible, every method that does not override another class has JavaDoc standard comments to describe the parameters and the function of it.

Limit Variable Scope - Using Android Lint, it was possible to inspect the code and change any fields that were not needed to be class variables into local variables - Each variable should be declared in the innermost block that encloses all uses of the variable.

Limit Line Length - Line length was kept to below 100 characters, with Android Guidelines, this makes the code easier to read.

Fully Qualified Imports - In general, the use of asterisks in imports is discouraged, so fully qualified imports are used where possible.

Logging – Logging is used throughout the application, under the appropriate D (debug) and I (info) tags in order to filter out the various levels of logging available. An application tag identifies log entries – e.g. "`com.jgraves.spectrum.ComposeFragment`".

5.3.2.2 – Version Control

The Version Control system used for both the Client and Server source code is Git, as this is industry standard and there are several providers of repository systems which are free:

- **BitBucket** (https://bitbucket.org/)
- **GitHub** (https://github.com/)
- **Google Code** (https://code.google.com/)

However, GitHub (free account) and Google Code do not allow for private code repositories and due to the nature of this project, having a private repository was essential, so BitBucket was used and synced with the local Git provider built into Android Studio, with the source code committed to the master BitBucket repository when the application was in a stable state.

The commits to the main repository can be found in "Appendix 2 – Repository Commits" and each one contains a description of what has changed with this commit – However the text included does not cover all aspects of the code that have changed, just noticeable changes, as the development was continual.

5.3.2.3 – Design Principles

The application follows the Android Guideline[30] patterns closely, as it provides a consistent interface which people with ASC will be able to quickly grasp, as it follows every other application on Android:

Action Bar – The application uses the Action Bar extensively for navigation and action items, the spinner navigation widget is also used on the Compose screen to select which Category is being viewed.

Figure 24 - Action Bar showing (a) Title and (b) Settings Action

Figure 25 - Action Bar showing (a) Back Navigation (b) Title and Subtitle (c) Actions

Figure 26 - Action Bar showing (a) Back Navigation (b) Spinner for Category Selection (c) Send Action

App Structure – The application is structured so once signed-in, there are only three activities that are generally accessed, the Contact List, Conversation and the Compose activities, which are nested.

Selection – On the Contact List, holding down a Contact will open the context menu, which is custom to make it easier to understand the actions.

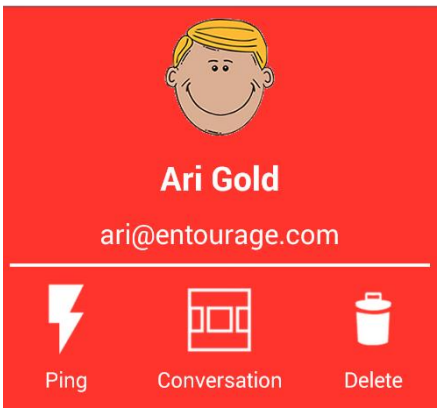


Figure 27 - The Context Menu for a Contact

Gestures – Gestures are used throughout the application, on the Start activity, you can swipe between the tutorial slides. The Compose activity makes heavy use of gestures to remove, add and rearrange (drag and drop) a message being composed and the Card Database uses left/right swipes to change page.

[30] http://developer.android.com/design/get-started/principles.html

Confirmation – Deleting a Contact requires confirmation to prevent accidental deletions.

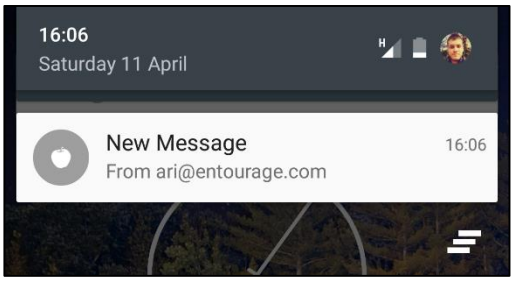
Settings – The settings page in this application conforms to the Android Guidelines, using Preferences and storing settings in an Application Specific Storage Area (Secure).

Compatibility – The application will work on any recent Android device with Google Play Services.

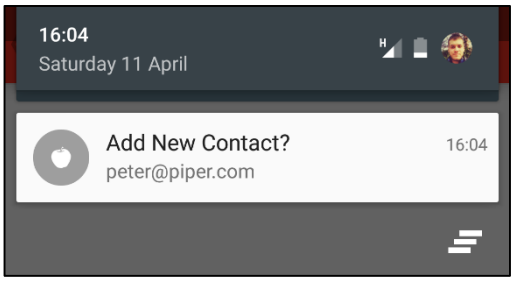
Accessibility – The application contains built-in accessibility features and all UI elements are labelled, the Enhanced Visibility Mode is the main accessibility feature.

Notifications – Uses Standard Android Notifications and appear in the Notification Center and which perform actions when they are pressed:

- New Message
  - Shows who sent the message
  - Takes the user to the relevant Conversation screen when pressed on.
- Add New Contact?
  - Shows who wants to add you as a friend.
  - Takes you to the Add Contact page and fills in the field.

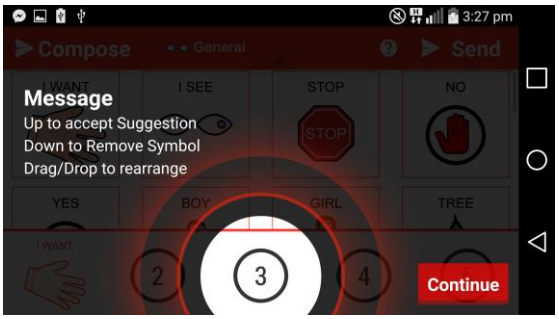


A 'New Message' Notification



An 'Add New Contact' Notification

Help – In order to provide a help system that provided guidance to potential users, the ShowcaseView library was used to give the guidance the same style that is used across the board in the Android system.



5.3.2.4 – External Libraries

php_gcm

The php_gcm library, by Luke Korth, was used in the server implementation to send push notifications to the destination device when a message is composed and sent to the server by the source device.

This library is a loose port of the Google Cloud Messaging Cloud Connection Server (CCS), a library had to be used as Google only provide a Java implementation of this module[31], and in order to make the server as efficient as possible, a PHP library was needed, to avoid any overhead that would come from having to run 2 application servers on the AWS Instance.

The code needed to push the message to the destination device was not complicated, the following function was written to facilitate the messaging and the only parameters needed are the Registration ID, which is sent to the server whenever a Registration or Send request is made by the device and the packet of data that is to be sent to the device.

However, the Registration ID, in general will not change[32], unless the user has changed devices, in which case the messages will then be sent to the new device.

```
/**
 * Pushes an appropriate message to the destination device using GCM
 * @param array  $packet  The packet of data to send (From, To, ContentID)
 * @param string $regid   The registration ID of the destination.
 */
public function pushToGCM($packet,$regid) {
	$this -> writeToLog("I ".time()." pushToGCM: Pushing Message...");
	$sender = new PHP_GCM\Sender(GCM_API_KEY);
	$message = new PHP_GCM\Message('', $packet);
	// Try sending the message
	try {
		$result = $sender -> send($message, $regid, 5);
	} catch (InvalidArgumentException $e) {
		$this -> writeToLog("W ".time()." pushToGCM: regID is null");
	} catch (InvalidRequestException $e) {
		$this -> writeToLog("W ".time()." pushToGCM: Resp not 200/503");
	} catch (Exception $e) {
		$this -> writeToLog("W ".time()." pushToGCM: Message not sent");
	}
}
```

Code 4 - Pushing a Message to the GCM server using php_gcm

[31] Google Cloud Connection Server - https://developer.android.com/google/gcm/ccs.html
[32] Registration ID is tied to an app running on a particular device https://developer.android.com/google/gcm/

HorizontalList

Please see the "5.3.3.5 – Horizontal (Left-to-Right) Conversation UI" section.

OnSwipeTouchListener

In order to accept swiping up and down on the Compose Fields, a library was used to abstract the code to recognise a swipe down and a swipe up, without needing to re-implement the positional logic so the small library developed by Sean O' Shea[33] was used.

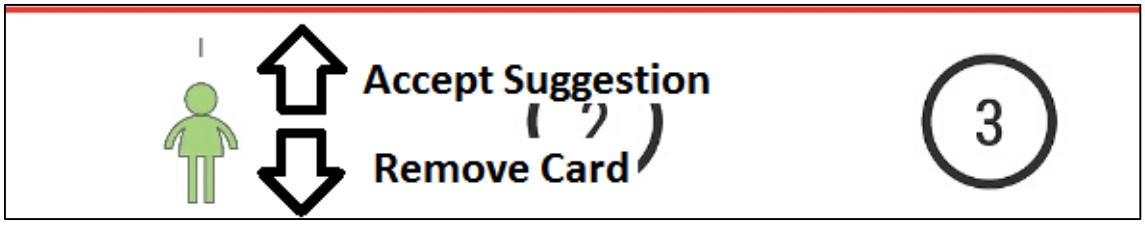


Figure 28 - The OnSwipeTouchListener in use for the Compose Field Fragment

JazzyViewPager/NineOldAndroids

JazzyViewPager by Jeremy Feinstein, which requires the NineOldAndroids library by Jake Wharton, is used for the page animations on the Start Page to show the Tutorial Slides using a tablet animation.

ShowcaseView

The ShowcaseView library, by Alex Curran, was used to create the tutorials that show the first time the Conversation and Compose screens are loaded by the user, this library allowed certain 'views' to be selected as the focus for instructions, Preferences are stored which are checked to see if the tutorial has been shown before and there is a Help button available at all times in the relevant screens if users need additional guidance. Google uses this library themselves for tutorials in their products (Google Inc., 2015).

Other

The org.json and org.apache libraries[34] are used by the application to enable transmission of data to/from the server (especially unpacking JSON responses from the Server) for all asynchronous tasks which use the JSONManager class. This class utilises the following HTTP and JSON libraries:

- org.apache.http
- org.json

[33] https://github.com/seanoshea/
[34] http://json.org/ and https://www.apache.org/

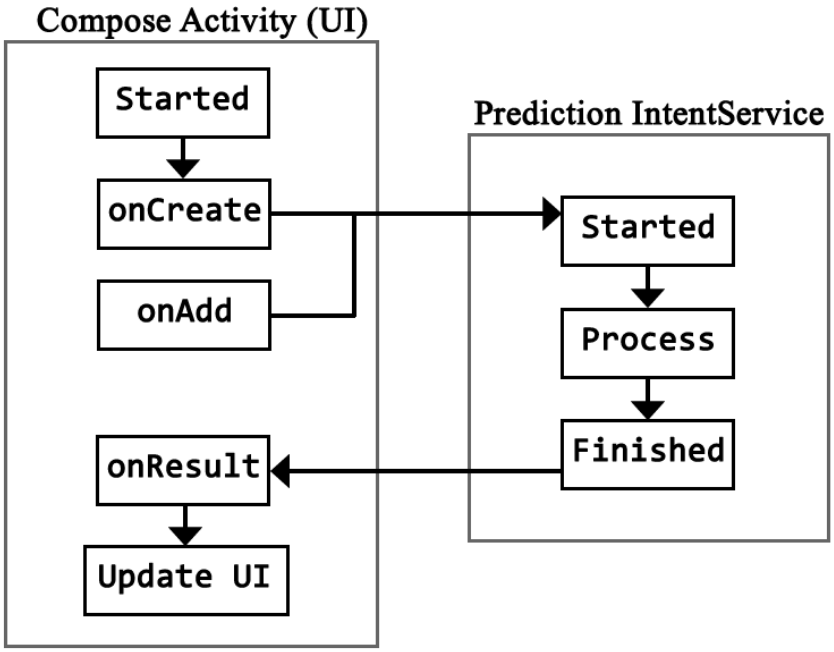
5.3.3 – Problems, Issues Faced and Optimisation

As opposed to detailing the development from end-end, the problems faced and solutions devised are discussed in this section.

5.3.3.1 – Keeping the User informed of Tasks being performed

Three background service types are used by Spectrum to perform tasks separately to the main UI thread, each was chosen based on how much data needs to be sent to the main UI:

- IntentServices can be binded to the UI Activity, so the UI thread can use data from the service, using a ResultReceiver to inform the user of progress (Uses Broadcasts).
    - Used by the Login and Prediction system



- Services are used for background tasks which don't require the UI thread to be aware of progress, as the database can be updated without informing the UI, as the UI will receive updates automatically using Cursors
    - Used for the Fetch, Pull and Google Cloud modules
- AsyncTasks are tasks that run asynchronously to the UI, similar to an IntentService, but do not inform the UI while they are executing – written procedurally and are useful for writing short-timed processes.
    - Message Sending, Adding a Contact and Pinging.

5.3.3.2 – Memory Issues

The method used to package the symbol database was a major problem, as the time/memory complexity of handling ~70 pictures caused a lot of problems with the application. The methods attempted are shown below:

Initial Process

Creating a SQLite database before the application was compiled, containing columns for the id, name and category, as well as a Binary Large Object field (BLOB) which contained a Bitmap of each symbol inside the database itself. A dump was made of the database (raw insert text) and then when the application was started the first time, this dump file was used to recreate the database on the device by uncompressing the dump file and running the commands, however:

a. The unpacking took ~10 seconds to complete and stuttered the UI thread, the space needed was also double, as the dump file and the unpacked database were present on the target device and it not being possible to delete the dump file.
b. The cursors used to query the database were taking up a large amount of memory, as they stored the BLOB's (Lundh, 2003) and every time an image needed to be shown, the bitmap needed to be decoded. (memory intensive)
c. One way of offsetting (b) was to use a Bitmap Cache (from a LruCache[35]) and try to find the bitmap in the Cache instead of decoding the bitmap again, however, this still caused crashing due to OutOfMemory exceptions (Bhardwaj, 2013)

Final Process

The second and final method of unpacking and storing each image along with its category, ID and the name (used for Text-To-Speech) was to directly store the bitmaps as Drawables[36] inside the application package, and then use a database to store references to the images. This method had a lot of benefits:

a. Stored images in several resolutions for different screen sizes
b. Passed the responsibility of processing the bitmaps to the Android system.
c. Allowed the use of the Android Garbage Collector
d. Initial installation only required creating a database with reference strings to Drawables (no BLOB)

[35] Least Recently Used (LRU) Cache (http://developer.android.com/reference/android/util/LruCache.html)
[36] Abstraction for "something that can be drawn." (http://developer.android.com/reference/android/graphics/drawable/Drawable.html)

5.3.3.3 – Representing Messages for Transfer

The message data is stored as follows when being transferred between the server and the client, after authentication has occurred, the table represents a JSON (IETF, 2014) object:

Message	
id	732
source	jack@spectrum.com
destination	emma@gmail.com
time	2015-01-28 11:40:31
content	1,2,3,4,5

Figure 29 - Message Data for Interchange

This format was chosen as it contains all the elements required to describe the message. The server will store this data in a table until the destination device retrieves the message, either from being pushed through GCM[37], or through a Pull request (Using PullService). The GCM component on the server only sends the value of the 'id' field which is then used by the client application to retrieve the message, without the GCM server receiving any identifiable information.

Additional processing takes place on the client-side to split each message and add data such as which symbol was the first in the sentence (in this instance the image 1 will be flagged as the first message in the series).

5.3.3.4 – Server Development

The password is stored as a hashed value in the database by using the following method which makes a hash and a salt and returns them in an array:

```
private function hashifyPassword($pass) {
            $salt = substr(sha1(rand()), 0, 5);
            $base = sha1($pass . $salt);
            $password = base64_encode($base . $salt);
            return array("pass" => $password, "salt" => $salt);
      }
```

The database is accessed through the DatabaseManager.php class as follows, using "mysqli_query".

```
$insert = $this-> database -> query(
      "INSERT INTO Messages(source,destination, time, content)
       VALUES('$source','$destination',now(),'$content')");
```

[37] Google Cloud Messaging (Hansen, et al., 2012)

5.3.3.5 – Horizontal (Left-to-Right) Conversation UI

Due to Android not including a Horizontal ListView object (only Vertical), a library had to be used, initially, the VariableHorizontalListView library was used, written by Alessandro Crugnola[38], however issues where encountered with the consistency of the list, so alternatives had to be investigated.

Next, the HorizontalList library was used, written by Paul Soucy[39], however this had problems with it being out of date and using a lot of deprecated methods and another problem was allowing the view to be programmatically moved to its right-most position, due to the requirement that the conversation show the most recent messages first, on the right side.

Finally, the solution was found, by using the MAComponents library written by Martin Appl[40] as this was using stable, up to date code which also didn't have problems with rendering or flinging the view to its right-most position and did not have the performance impact (lag) that the other two libraries had.

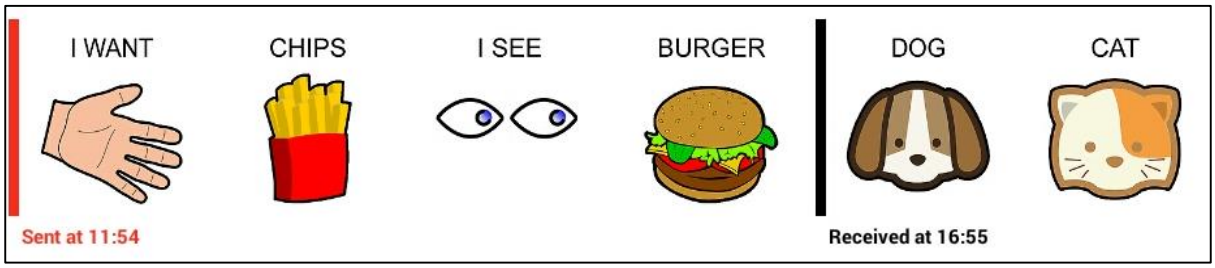


Figure 30 - The Horizontal List View implementation

An adapter is used to inflate each item in the list, setting the image, its corresponding string/tag representation (used for Text To Speech) and if the message is the first in a series (the first sent/received) then it also places a left border and the time at which the message was sent or received.

A red line represents messages sent and a black line represents a block of received messages. This colour coding makes reading the conversation easier.

Further Details for these libraries can be found in "Appendix 3 - Third-Party Libraries Used":
[38] https://github.com/sephiroth74/HorizontalVariableListView
[39] https://github.com/dinocore1/DevsmartLib-Android
[40] https://github.com/applm/ma-components

5.3.4 – Interface and HCI

5.3.4.1 – Handling Different Sized Devices

Designing the interface for the application took a considerable amount of time, as there are up to three layouts needed for each activity - portrait, landscape and x-large for tablets. Accommodating an array of different screens in the range 5 – 10 inch was the goal for the application, as this is the range of sizes I expect to be the most commonly used devices.

The images that make up the content of the application are stored as several bitmaps, which equates to about 4 different sized images per image included in the application and are split into sizes within folders for each resolution, shown in Figure 31.

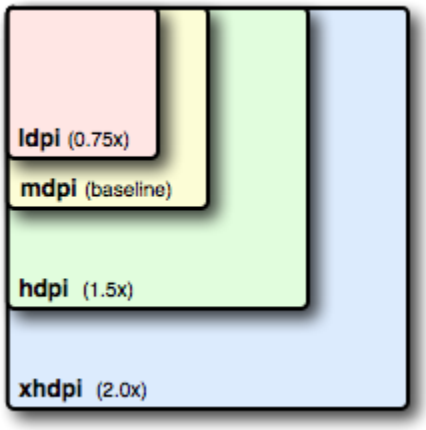


Figure 31 - Relative sizes for bitmap Drawables that support each density.[41]

The memory impact of storing separate sized images is not substantial and the processing saved by storing the images in separate sizes is noticeable, as was discovered when the bitmaps were stored as BLOB (Binary Large Object) items for the image extractor and then processed on-the-fly which is explained in the "5.3.3.2 – Memory Issues" section.

[41] Android Screens Support - https://developer.android.com/guide/practices/screens_support.html

5.3.4.2 – Animations

It was determined through several reports that children prefer interfaces that make use of animation, as they found that "animated interfaces rated more 'likeable'" and "task completion times using the animated interface were consistently lower" (Dyer & Adamo-Villani, 2008) which points to animation not only making the user experience smoother, but also improving the time of task completion.

The ways that animation is used was carefully considered, as it should not be over-the-top, but should make use of several non-intrusive animations which help the user understand the navigation structure of the application – e.g. Login and Register are on the same level so they slide left/right appropriately. When you open a conversation, it slides in from the right and closes to the left, to make it appear that it's a page that is being displayed over the Contact List.

Type	Location	Animation
Transition	Login to Contact List	Slide out to Bottom
Transition	To Settings Screen	Fade in/out
Transition	Between Login and Register Screen	Slide on from Right/Left
Transition	Conversation	Slide in from Right/out Left
Transition	Compose	Fade In
Animation	Contact List – Refresh (Figure 32)	Rotate status icon
Animation	Contact List – Status Bar	Slide in from Bottom/out Bottom
Animation	Login/Register/Add Contact Field Empty	Shake Left/Right
Animation	Start Page Tutorial ViewPager	'Tablet' animation (JazzyViewPager)

Table 3 - Animations used in the application

The animation on the Contact List is subtle, but gives the user some indication that there is some progress occurring in the application (in this case the pull request to the server/refresh).

Figure 32 - Screenshot showing progress animation and static icon

5.3.5 – Complex Development Areas

5.3.5.1 – The Compose Field Fragment

The Compose Field Fragment code that deals with showing predictions, handling adding new symbols and deleting symbols all within less than 1/3 of the screen space is complicated and it also handles storing the current state of the message and what is included in the message for when it is ready to be sent.

```
// ImageViews
private ImageView[]     symbols     = new ImageView[5];
// Drag Behaviour
private int             symbolFrom  = 0;
private int             symbolTo    = 0;
// Suggestions
private TagObject[]     suggestions = new TagObject[5];
```

Code 5 - Fields in the ComposeFieldFragment class, responisble for holding current sequence, suggestions and drag/drop vars

For the suggestions, a POJO is used called TagObject, there is an array of 5 TagObject objects, which either store a recommendation or are null, meaning there is no suggestion. This class is also used to tag the current images in the ImageView array 'symbols' using the setTag() method. The variable called 'suggestions' stores current suggestions and when a suggestion is accepted by the user by dragging up on the symbol, the following method is called (Code 6):

```
void acceptSuggestion(int position) {
      // Find what the suggestion tag is.
      TagObject tag = (TagObject) symbols[position].getTag();
      TagObject sug = suggestions[position];
      if(sug != null && tag.getTag().equals("Empty")) {
            // Remove the Colour Filter – we're accepting this!
            symbols[position].setColorFilter(
                  getResources().getColor(android.R.color.transparent),
                  PorterDuff.Mode.ADD
            );
            // Add the Symbol + Then Clear Suggestions + Make new Suggestions
            addSymbol(String.valueOf(sug.getId()));
            suggestions[position] = null;
            clearSuggestions();
            makeSuggestion();
      }
}
```

Code 6 - The acceptSuggestion() method, called when a suggestion is swiped upwards on the Compose Screen

The ComposeFieldFragment class also contains a method which is called by the Compose class, the getCSV method which iterates over the current sequence of cards and returns a comma separated string of all the symbols, this is used when sending the message.

5.3.5.2 – Picture Prediction Most Probable Next Symbol

The Picture Prediction class contains the methods used for processing through the prediction database table and returning some useful data from it that can be actioned upon using the Compose Field Fragment, this code makes use of Statistical Probabilities to determine what the next symbol will be (Code 7):

```
/**
 * Work out the most probable next symbol based on
 * the current symbol. Returns -1 if no value known.
 * @param currentSymbol   The Current symbol (1,2,3, etc.)
 * @return                      The Most Probable Symbol
 */
public int mostProbableSymbol(String currentSymbol) {
	float[] probabilityRow = getProbs(currentSymbol);
	if(probabilityRow == null) {
		return -1;
	}
	float highestValue = 0;
	int mostProbableSymbol = 0;
	for(int i = 1; i < probabilityRow.length; i++) {
		if(probabilityRow[i] > highestValue) {
			highestValue = probabilityRow[i];
			mostProbableSymbol = i;
		}
	}
	return mostProbableSymbol;
}
```

Code 7 - The method responsible for returning the most probable symbol using Markov Properties

The getProbs() method simply returns an array of floats which represent the probabilities of going from the current symbol to another symbol (using the Markov Properties that are explained in the '5.2.3.4 – Prediction Engine' section) and this is then used to return an integer representing the symbol card as is stored in the database.

5.4 – Final Design of Application prior to Evaluation Session

The design of the application prior to the evaluation session is shown below:

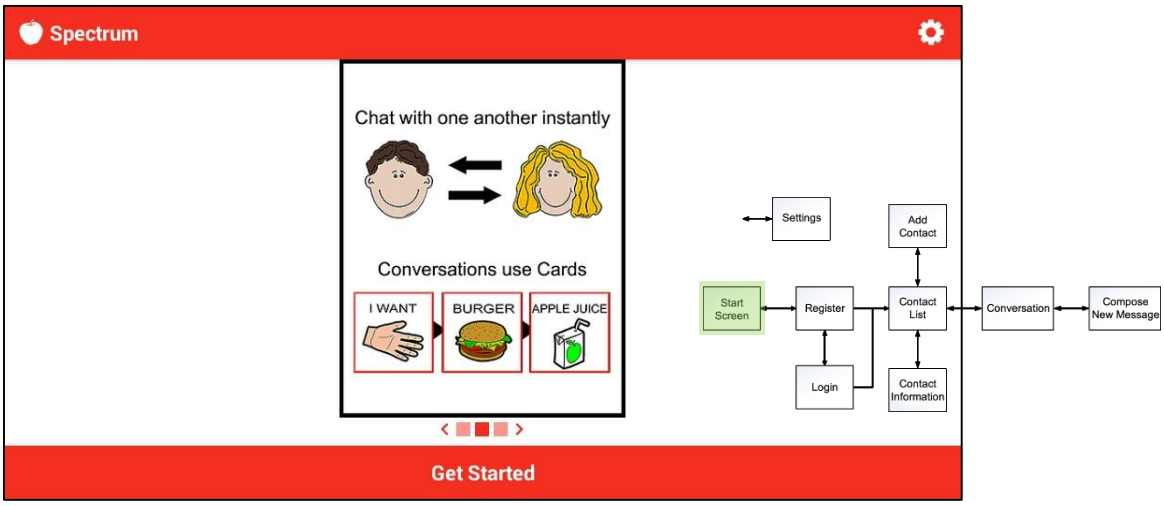


Figure 33 - Start Screen Interface Design

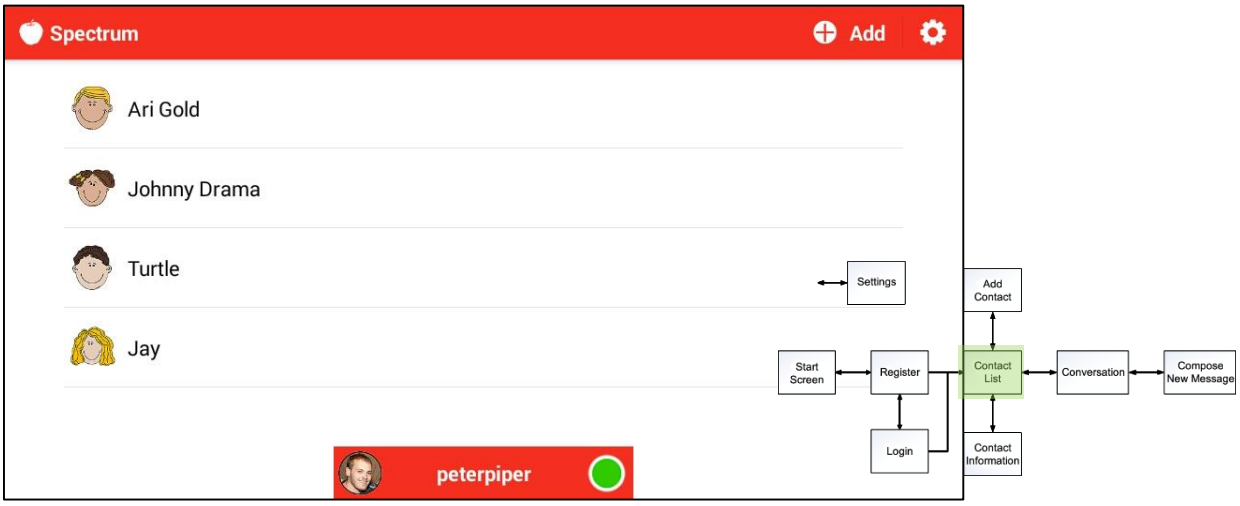


Figure 34 - Contact List Interface Design

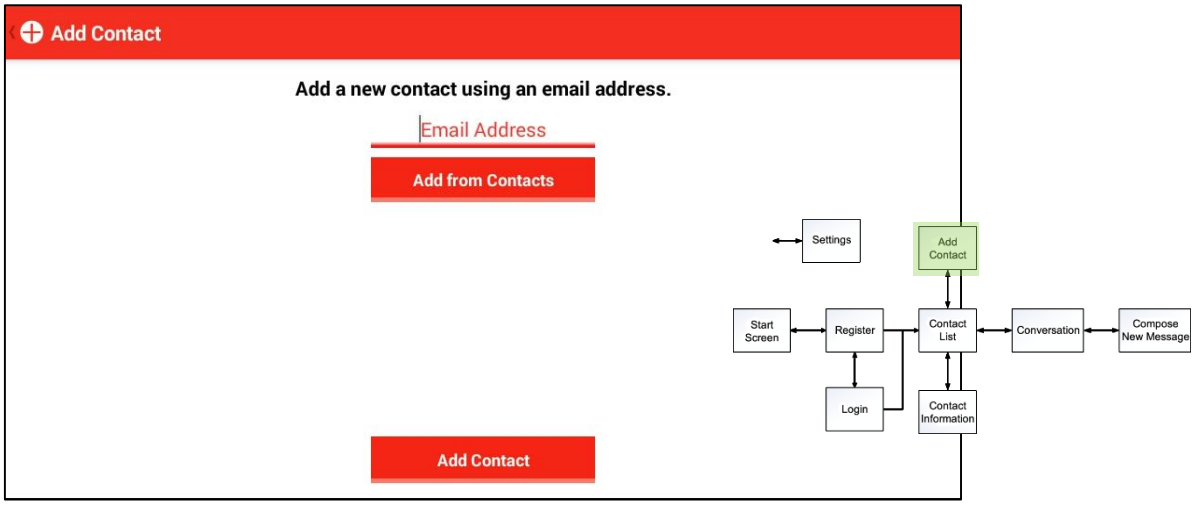


Figure 35 - Add Contact Interface Design

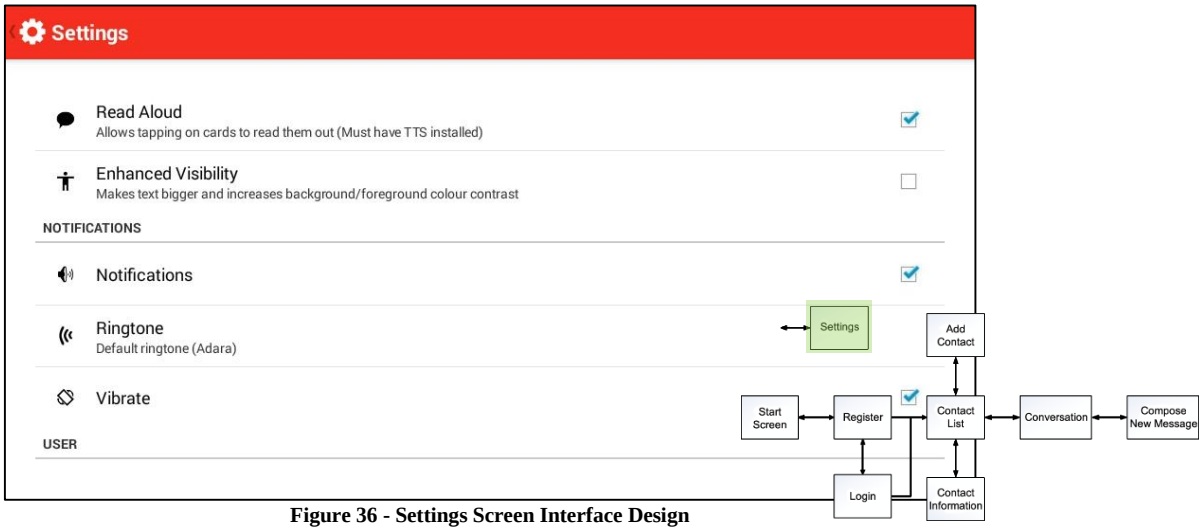


Figure 36 - Settings Screen Interface Design

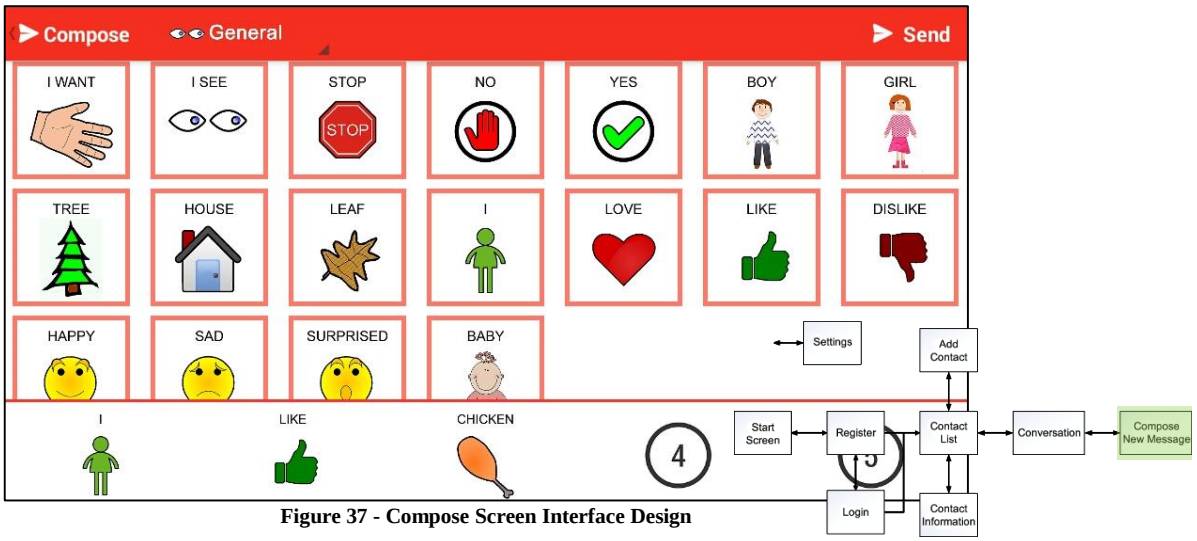


Figure 37 - Compose Screen Interface Design

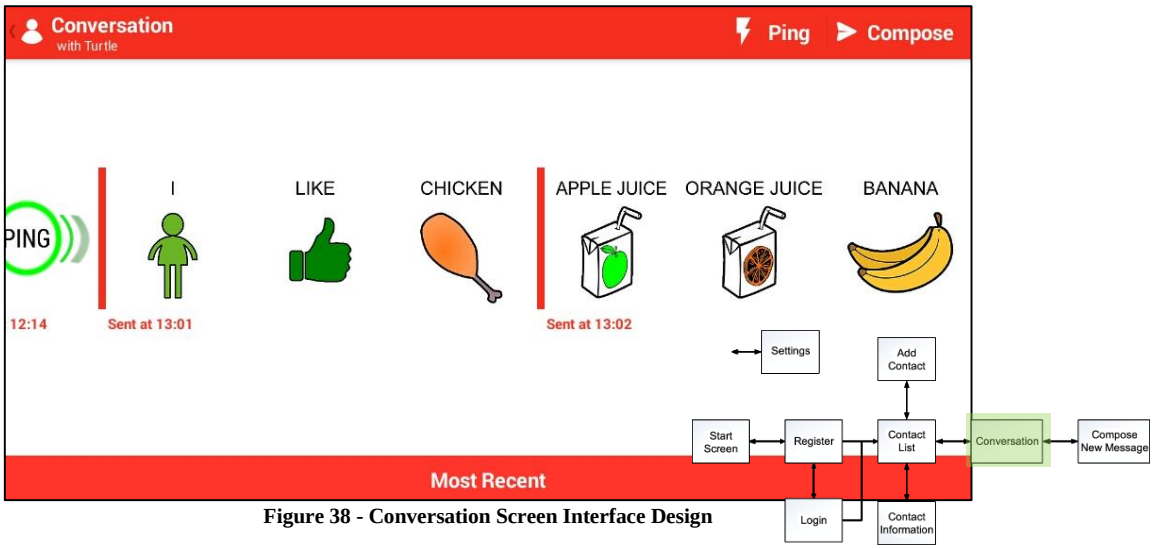


Figure 38 - Conversation Screen Interface Design

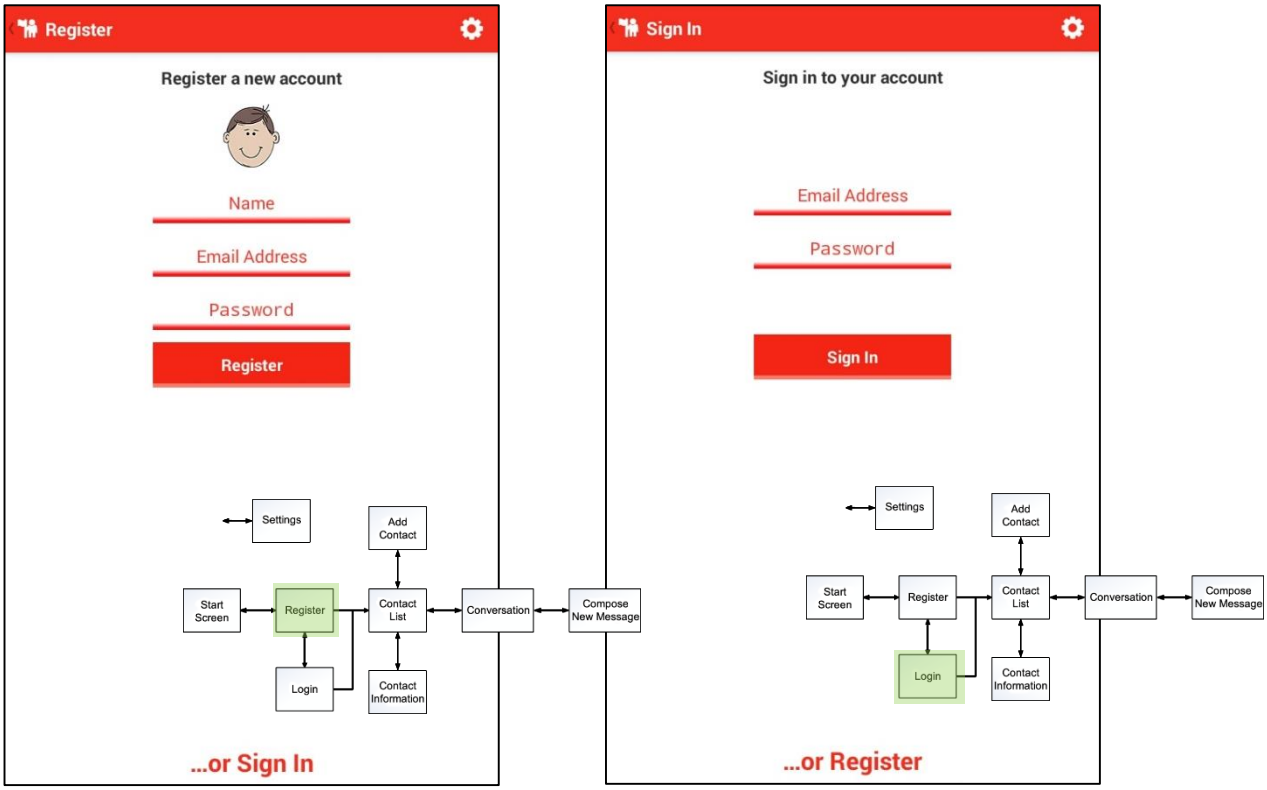
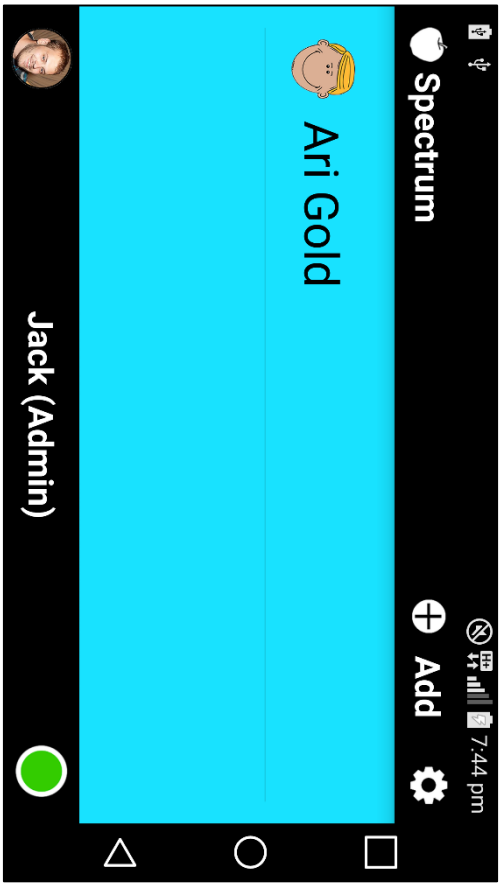


Figure 39 - Registration Screen Interface Design

Figure 40 - Login Screen Interface Design



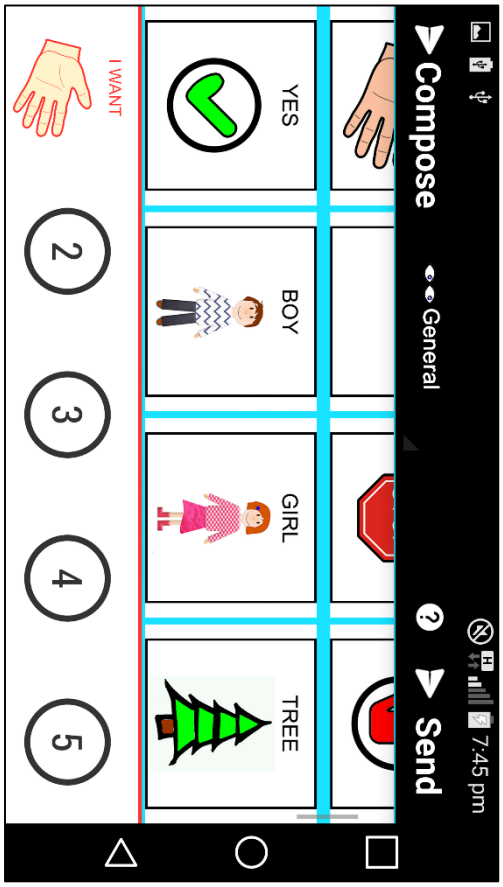


Figure 41 - 'Enhanced Visibility' Mode on the Contact List

Figure 42 - 'Enhanced Visibility' Mode on Compose

5.5 – EVALUATION SESSION

The evaluation of the application took place at Patcham House School and was used as the final test.

5.5.1 – Overview of Session

The evaluation session, previously planned to be Participatory Design (Iversen, et al., 2012) , but amended due to time constraints, for the application took place in the Patcham House School (Patcham House School, 2015) (Frauenberger, et al., 2011), a school for pupils aged 11-16 with complex needs. They cater for a large range of pupils needs including Autistic Spectrum Conditions, which is ideal for testing the Spectrum application as this is the target audience and the target location for use of the application.

Chris Fisher, the head of IT, was my liaison and helped to organise the study and chose the students taking part based on his previous experience as well as help to choose the structure that the session would take.

We met on the 18th March 2015 to meet one-another and to have a preliminary meeting regarding how to approach the study, in which I explained how the system worked and gave a demo. We decided the session should be hands-on and the best way to get opinions on the application was to show a small group of pupils the application (3 students, 1 teacher, 1 teaching assistant and myself), the concept and idea behind the application, how to use it and getting them started with registering new accounts and adding one-another to the Contact List.

After this initial set-up, I let the children chat to one-another using the application and guided them to try out all the features and after a 45 minute session, I began asking the students questions on how they found the application, if there were any specific parts of the application that they particularly disliked/liked and tried to get some constructive feedback, which is covered in the next section.

Time	Activity
8.30 – 9.00	• Arrival • Setting up the devices to work on the school Wi-Fi.
10.15 – 10.30	• Introduction to the pupils • Explanation of the application and premise • Showing pupils how to register and add each other as Contacts
10.30 – 11.10	• Pupils proceeded to test the application, by chatting to one-another and trying all the features available, with help available from me and staff.
11.10 – 11.20	• Asked questions about how the students found the application • Enquired about features they want to see or negatives, general feedback. • Thank the participants and liaison.

Table 4 - Schedule for School Session

5.5.2 – Problems Faced

There were several major problems that occurred on my second visit to the school, when the session was supposed to take place – one of the students taking part in the study was ill and so couldn't take part, it was discovered that the school internet connection was routed through a proxy (used for content filtering) and so the settings were input into the Android Settings, however, I found that Android has a major shortcoming in that the proxy settings you set for the system are not device-wide and only apply to web browsers – not applications. So an application called ProxyDroid (Lv, 2015), which requires root[42] access had to be installed on the devices I was planning to test with and only 5 of the devices I had were/could be rooted and later I found that three of the devices that I was using had the same MAC Address[43] so the school intrusion-detection system/wireless system would not allow more than one to be present on the network simultaneously, so I was left with 3 devices that worked:

- 1 Sony Xperia Z – Running Android 5.0
- 1 Samsung Galaxy Player 5.0 WiFi – Running Android 4.2.2
- 1 LG G3 – Running Android 5.1.1

This limited the breadth of my study, as the three Android tablets I had could not be used on the school Wi-Fi due to not being able to route the traffic through the proxy – I could have overcome this by building in proxy settings into the Spectrum application, but due to there being such limited documentation of this, I chose not to, as this would postpone the session even more and the decision was made to use the 3 devices described above. The solution to this was to come back the following day with the phones that could be rooted, rooted and with ProxyDroid setup, which worked well, but limited my study to a smaller number of people, and the group of Year 7 students were not available, so three Year 11 students were participants instead.

5.5.2 – Session Content

The session content and raw data can be found in "Appendix 3 – Session at School Data".

[42] "Rooting" your device means obtaining "superuser" rights and permissions, needed to run ProxyDroid (Lv, 2015), an application that lets you route all applications through the proxy as required. (A, 2011)

[43] Media Access Control (MAC) Address is a unique identifier for a device. However, some equipment manufacturers will use the same MAC address for multiple devices in order to save money, however, a wireless network (especially a school Wi-Fi with detection systems) will not let 2 devices on a network with the same MAC address, as this is suspected Spoofing – which is seen as malicious (Kirby, 2003).

5.5.3 – Results and Proposed Changes

The aim of this session was to determine areas where my application and its interface fell short of expectations, whether the navigational structure of the application was simple enough to understand and also features that pupils would like to see implemented in the application, things that didn't work well and also any other comments on the application from the students.

This session also made the basis for my evaluation for the application, in conjunction with the other testing, the poster event and the questionnaires. The majority of the suggestions that were made are things that I would like to develop and refine if I had more time. The suggestions are as follows:

#	Suggestion	Further Details
1	Improve the Help function with an animated mascot like a dinosaur or a cat who guides the user through the use of the application, as this appeals to children and will help keep them engaged.	This Mascot could also be extended to be a part of the cards, and give the application a 'personality', further improving the brand relationship.
2	The Read-Aloud function of the application needs a limit on how many presses on cards it will allow, as the children would press on the cards repeatedly which was distracting. The Toast that shows with a card press was staying on screen because of this.	This could be implemented as only allowing a press on a card once in a second or not allowing another Read-Aloud event to be queued while another is being read out and a cool-out period.
3	Adding Contacts could be made easier by allowing NFC to be utilised by tapping the backs of two phones together while they are running the Spectrum app, to Add each other as contacts.	This would make it a lot easier and fun to set up the devices and faster to get talking to one another using the application.
4	Holding down on a card in the Card Database could show other forms of the word – e.g. Long Press on Car to show Cars, or on Leaf to show Leaves.	This would be good to show plural cases in a pop-up.
5	Read Messages out-loud as they are received, in sentence form.	This might be an interesting option to include to make conversations more fluid and lifelike, however it could also hinder from distraction.
6	The Conversation screen does not automatically scroll – this would be helpful.	This is a noted limitation that has been known about, due to the implementation of the Horizontal List View.
7	More Cards should be available, such as connectors – AND, OR, ON, UNDER, A etc. and words such as PLEASE, THANK YOU.	These were widely suggested cards that were not included in the application. They would make the database more comprehensive.

Table 5 - Suggestions put forward by Students in the School Session

The full session details and suggestions can be found in "Appendix 3 – Session at School Data".

5.6 – Public/Acceptance Testing

Acceptance Testing is conducted to determine if the requirements of a specification have been met (the objectives set in the "4.3 – Project Expectations" section), and in order to acceptance test Spectrum, the final beta release of the application was manually tested by the public, made up of a group of people chosen because they owned a wide array of different Android devices, this sort of testing was useful to find bugs that the unit testing could not find, as when human interaction is introduced, it can reveal bugs and issues that would not be discovered otherwise. 5 testers were used, as it has been shown that ~75% of all usability issues can be found with 5 participants and the more participants you add, the less of a return you get on the time put in (Nielsen & Landauer, 1993), two participants didn't have Android devices so they were supplied one. The participants and devices, as well as issues are shown below:

Person	Device	Issues
Participant 1	HTC One (M8)	- No Issues
Participant 2	HTC One (M8)	- No Issues
Participant 3	OnePlus One	- No Issues
Participant 4	Samsung Galaxy Player (5.0)	- Compose Spinner (drop-down box) is temperamental but the left/right pager scroll is fine, it's just the category indicator that stops.
Participant 5	LG G3	- Text on Conversation screen showing time sent/received is too small (screen is QHD)

The Public/Acceptance Testing was managed through a Facebook Group page, where participants could get hold of the application file and share bugs that they encountered.

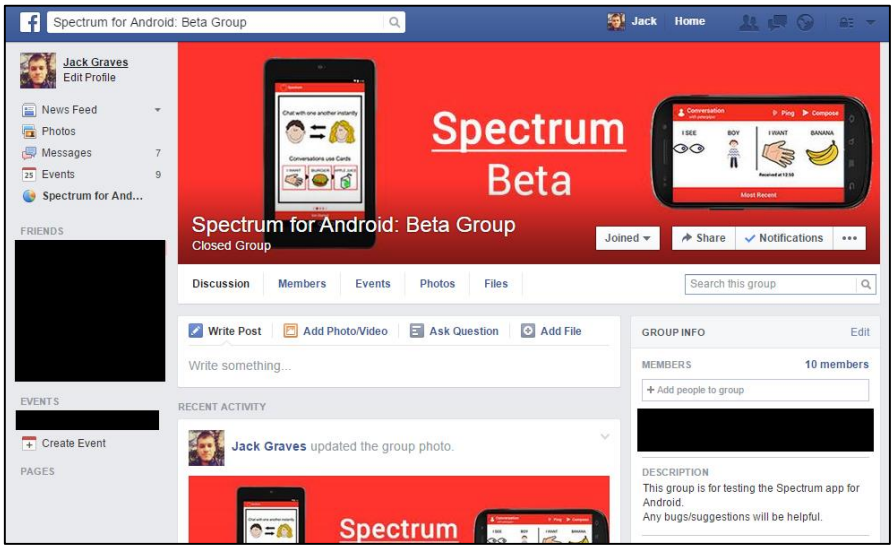


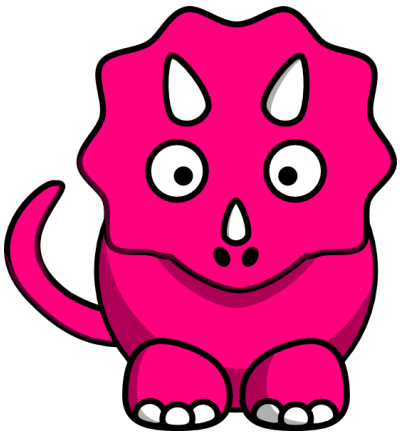
Figure 43- The Facebook Group for the Beta Testing

5.7 – Illustrations of Suggested Changes

5.7.1 – Animated Mascot

An animated mascot for the tutorial was suggested by one of the participants, where it would help keep the children interested in learning how to use the application and also would help with the brand identity of the application/brand – the mascot could be sold as an accessory and further help children to identify the Spectrum brand and engage them in using it to learn how to speak and use the PECS system.

It has been found that at age 6, children have a high rate of recognition for brand/character recognition as high as 96% (in the case of Mickey Mouse), so this is an effective method of reinforcement.[44]



The Mascot that would be in the application.

A Toy that could be sold alongside.

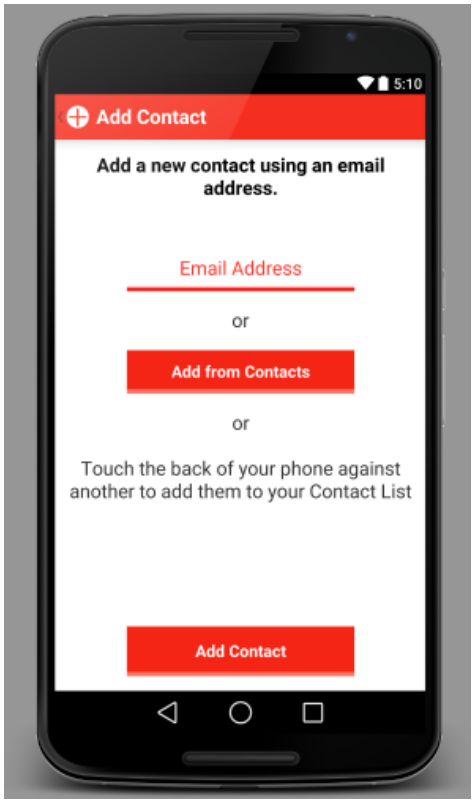
Figure 44 - An example of a possible mascot - the text would be read out.

[44] Taken from a study on children's recognition of brand cartoon characters (Mizerski, 1995, p. 66)

5.7.2 – NFC Add Contact Support

One feature request was being able to add a new contact simply by touching 2 phones together to add them to your Contact List.

An example of the interface that would be offered to users for this is shown below, as well as an example of how NFC would be implemented:



The augmented Add Contact screen.

The action the user would take.

6. TESTING

This section describes the various types of testing that took place during the project.

6.1 – LOAD TESTING

In order to test the load capacity of the server, stress testing software was used to test the scripts and ensure that they can handle multiple requests from a number of clients simultaneously. The tests stressed the server by issuing far more requests than would ever occur in normal operation. The clients connected to the server and sent a HTTP request for a login confirmation and then a pull request for new messages. The stress testing software load.io[45] was used (originally planned to use JMeter) and slowly increased the number of clients from 0 to 500 over a minute, out of 50,453 requests, 12 timed out starting at ~400 simultaneous clients.

Response Time		Response Counts		Bandwidth	
Average	197ms	Success	50,453	Sent	11.20MB
Min/Max	77/14585ms	Timeouts	12	Received	8.33MB

Table 6 - Load Test Results

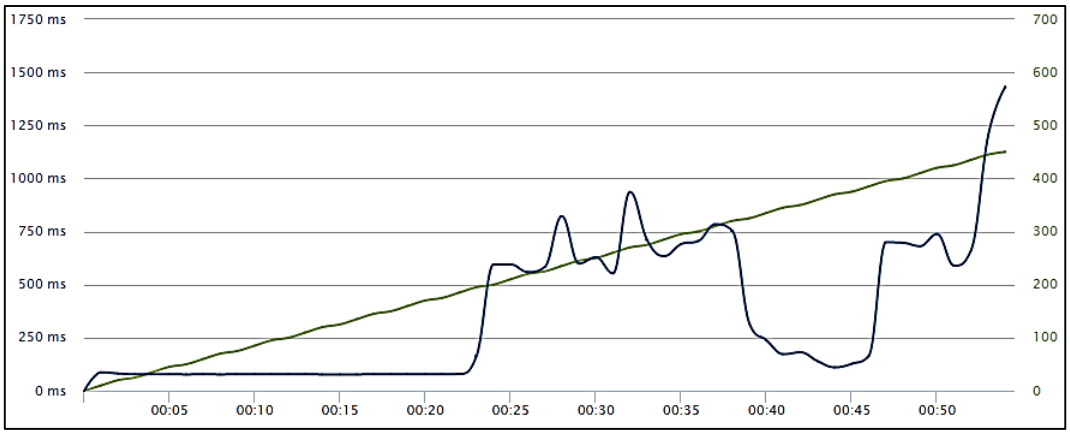


Figure 45 - Diagram showing Average Response Time in blue (Left Axis) and Clients connected in green (Right Axis)

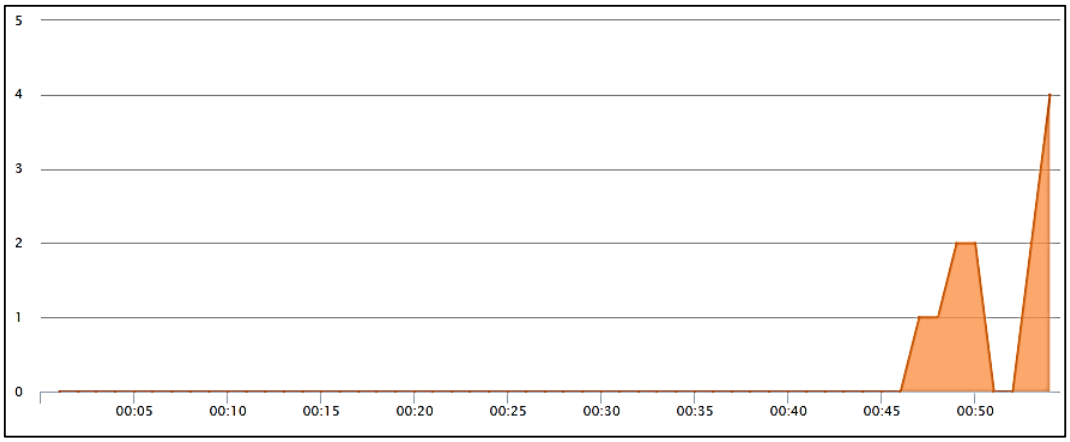


Figure 46 - Graph showing number of timeouts per second for the load test in Figure 45

[45] LoaderIO – Simple Cloud-based Load Testing (http://www.loader.io/)

As the Spectrum Server is a RESTful[46] service, these tests are not representative of actual transactions as a client can only make around 4 requests a minute (pull/send requests) and if the application is not open, due to using push messaging, it won't be in contact with the server at all until it needs to retrieve a message (see Figure 10 on Page 33).

It is also important to note that up to 200 clients, the response time is ~77ms and this would be very high load even if the service had 1,000 clients as they do not keep connections alive and each communication is separate from others.

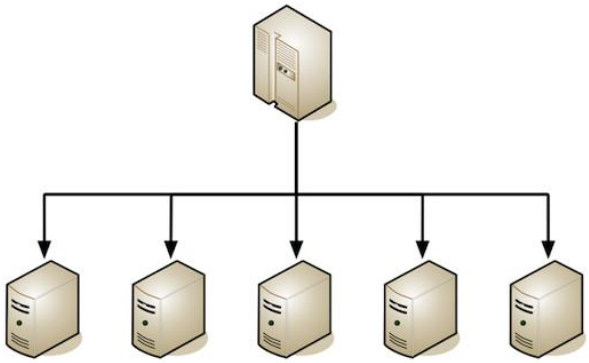
The server-side of the application can be easily scaled up using the Amazon AWS infrastructure, due to being modular and written in PHP utilising MySQL and being hosted on an ElasticBeanstalk instance – "PHP is especially well suited to horizontal scaling in this manner by simply adding more Web servers as needed." (White, 2011) and this was a consideration when choosing a server-side technology.

The Elastic Beanstalk application container will automatically provision instances of the following server according to demand:

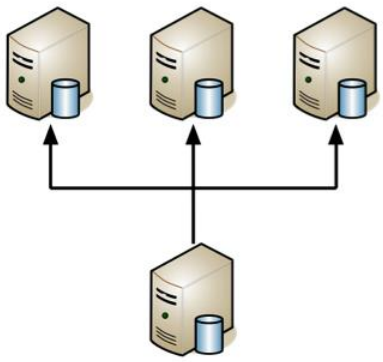
64bit Amazon Linux 2015.03 v1.3.1 running PHP 5.5	2015.03	PHP 5.5.22	Apache 2.4.12

This would be done through running a load-balancer which delegates tasks to different 'nodes' or 'instances' of the Spectrum PHP server, connecting to the same database.

The MySQL database can also be easily scaled using a Master-Slave setup with MySQL, shown below, with each PHP instance having its own slave database server, but due to the Spectrum server being lightweight and removing messages after they are received, this should not be necessary.



Load Balancing – PHP Server



Master-Slave Configuration - MySQL

[46] **RE**presentational **S**tate **T**ransfer (Heller, 2007)

6.2 – UNIT TESTING

This section contains details of the Unit Testing that took place on the server and client to ensure correct output for each input.

6.2.1 – Client-Side

The Android application was tested using J-Unit[47], extended for use with Android, several test suites were used, each which operates separately to one-another using Setup and Teardown methods:

- Database Operation Tests
- UI Input Tests
  - Add Contact Tests (Incorrect/Correct)
  - Login Tests (Incorrect/Correct)
  - Empty Inputs are Correctly Flagged
- UI Element Interaction Tests
  - Do all UI Elements correctly appear on the Start Screen
  - Do the correct Intents get sent according to interactions?
- Pull/Fetch Service Tests
  - Send a Message
  - Check it gets Received

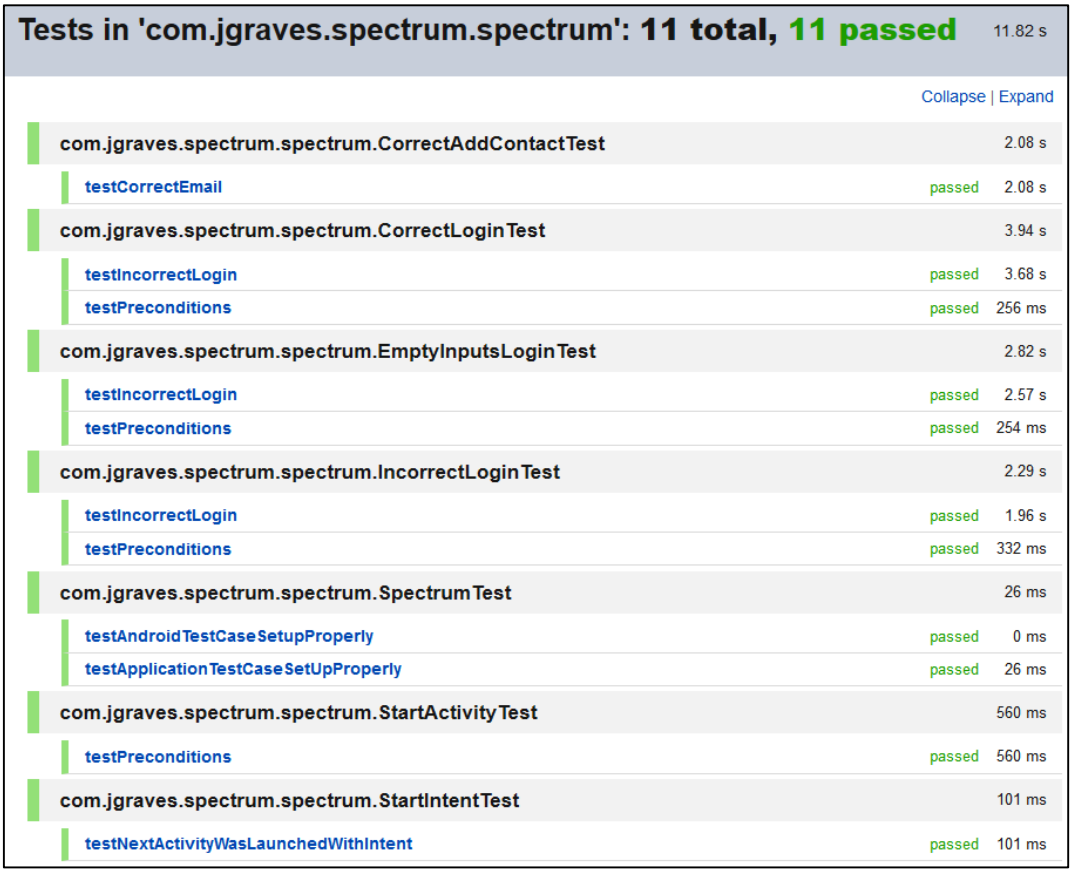


Figure 47 – An example of the J-Unit Test Results

[47] Junit Testing Framework - http://junit.org/

6.2.2 – Server-Side

The server code was unit tested using SoapUI (SmartBear Software, 2015), an open-source web service testing application for SOAP and REST Servers which allows Test Scenarios to be set up for each Server-Side Script and run on a number of inputs and checks that all inputs produced an appropriate output and that boundary cases were handled properly. See Appendix 7 – Performance Test Results for the test plan and load testing details.

In addition to using SoapUI, a simple REST HTTP Client was also used to test more elaborate functionality as well as the administration pages that were built on the Web Server which allow functionality testing, these pages made use of the JQuery library to enable quick development of an AJAX interface for testing the various scripts and showing the JSON response on the page with the form values, which made bug-testing and validation of the methods to be easily done.

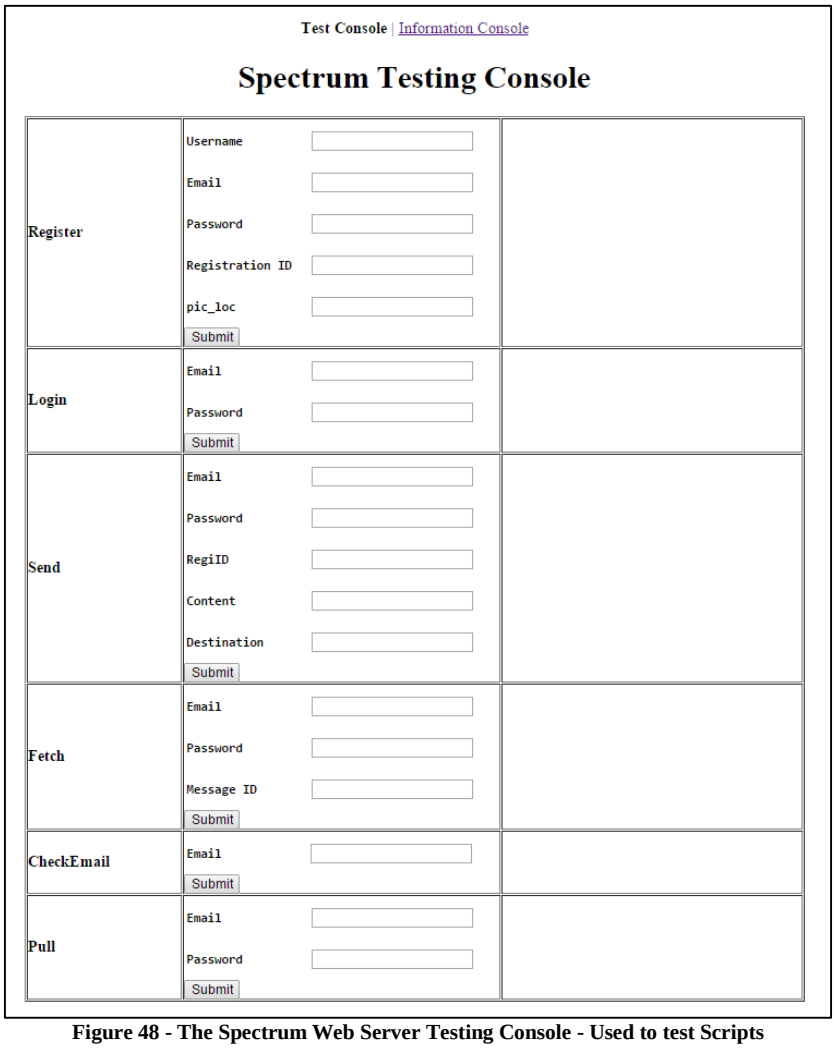
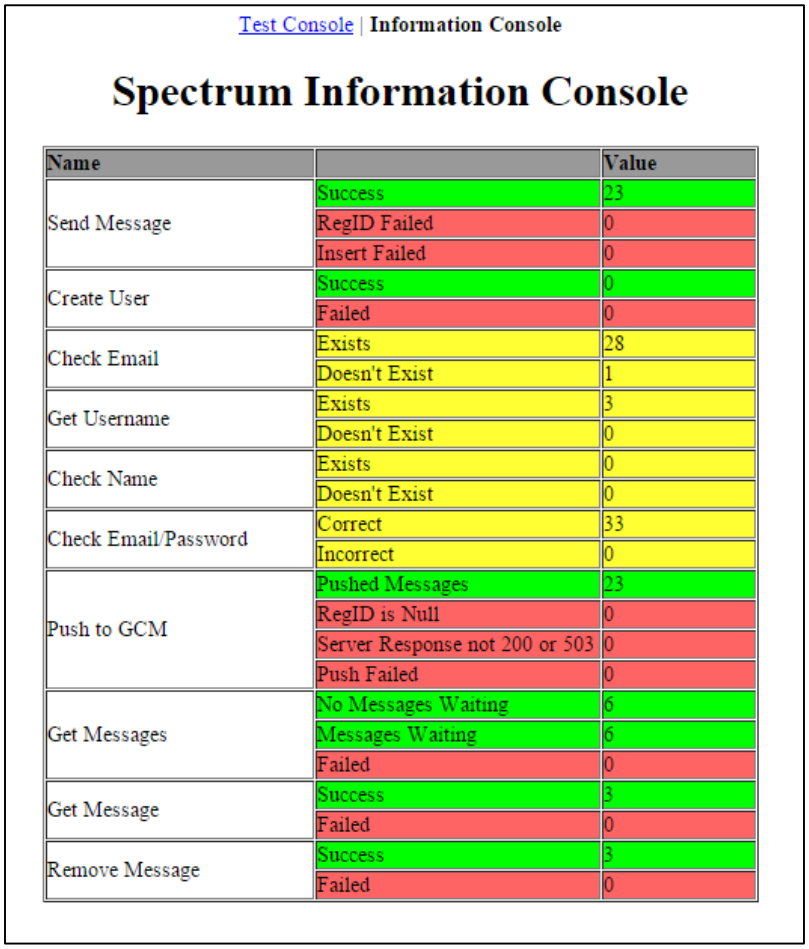


Figure 48 - The Spectrum Web Server Testing Console - Used to test Scripts



Test Console | **Information Console**

Spectrum Information Console

Name		Value
Send Message	Success	23
	RegID Failed	0
	Insert Failed	0
Create User	Success	0
	Failed	0
Check Email	Exists	28
	Doesn't Exist	1
Get Username	Exists	3
	Doesn't Exist	0
Check Name	Exists	0
	Doesn't Exist	0
Check Email/Password	Correct	33
	Incorrect	0
Push to GCM	Pushed Messages	23
	RegID is Null	0
	Server Response not 200 or 503	0
	Push Failed	0
Get Messages	No Messages Waiting	6
	Messages Waiting	6
	Failed	0
Get Message	Success	3
	Failed	0
Remove Message	Success	3
	Failed	0

Figure 49 - The Spectrum Information Console

These simple scripts/pages make testing the server simple, and display the resulting JSON that is received in-line on the page using the JQuery library and the information page shows a simple breakdown of the last ~300 log entries in the server. The scripts are in the following locations and were not made to be exhaustive or advanced, but to make developing the application easier:

- http://spectrumphp-env.elasticbeanstalk.com/index.html
- http://spectrumphp-env.elasticbeanstalk.com/info.php

7. EVALUATION AND CONCLUSION

The section contains a brief overview of how the project performed in relation to objectives, how it performed in real-life and closing statements on the project.

7.1 – EVALUATION

Early on in the project, it was stated that the aim of this project was "to develop a mobile (instant) messaging application designed specifically for children with Autistic Spectrum Conditions (ASC) in the age range 6-12 who find it difficult to learn to speak and learn language skills" and at this stage, following on from the testing that took place at the Patcham House School session and the user testing, it can be determined that the application and project succeeded in its goal.

The project has far exceeded the objectives outlined in the proposal document (Appendix 4), with all primary objectives completed, with a small amendment made to Objective 1, based on research gathered to use a more suitable sign-on method (explained in section 3.2.1).

Objective 8, to allow each user a profile with details about themselves was modified to better fit with the PECS-methodology, by introducing Contact Pictures making Contacts more recognisable to users without using text and keeping the focus on picture exchanges.

Extension Objectives 9 and 10 were also completed to the specification, but after several security and ethical considerations, Extension Objectives 11 and 12 (location and camera) were dropped from the objectives following the review.

In total, 7 of 7 Primary Objectives[48] and 3 of 5 Extension Objectives[49] where completed, a percentage of 83.3% objectives completed – however the amendments have better aligned the application with the target-user and the security and ethical problems.

The performance of both the server and client has been fully tested and are production-quality and capable of being scaled with growth in its use, utilising cloud infrastructure.

[48] Taking the amendment to Objective 1 into consideration (Changed OpenAuth Login to Email/Password Login)
[49] Taking the amendment to Objective 8 into consideration (Changed Profile Description to Profile Picture)

7.2 – CONCLUSION

In conclusion, the application developed has successfully completed its goal, as can be determined by the success of the evaluation session, where all the participants engaged in conversations using Spectrum and enjoyed using it (See Appendix 3C).

This project has allowed me to apply the knowledge that I gained from the Human Computer Interaction course, the machine-learning methods I learnt through the Artificial Intelligence courses, the development skills I learnt throughout university and finally the Testing/Test Automation skills I acquired during my placement year as an Application Test Engineer at BlackBerry[50].

One of the biggest skills developed through the project is time-management, including the importance of planning during the early stages of development and the amount of time that must be allotted to perform refactoring when knowledge improves at a later date.

Ideally, there would have been sufficient time to implement the best suggestions and feedback into the final product and evaluate the changes through Participatory Design – the changes which are described in Section 5.7 – Illustrations of Suggested Changes.

Following the release of the application on the Play Store, the deployment process has been shortened, with roll-outs/automatic updates it will be much easier to deploy any changes and also to use a staged roll-out system to test new features on a percentage of users at a time.

[50] See (Graves, 2014)

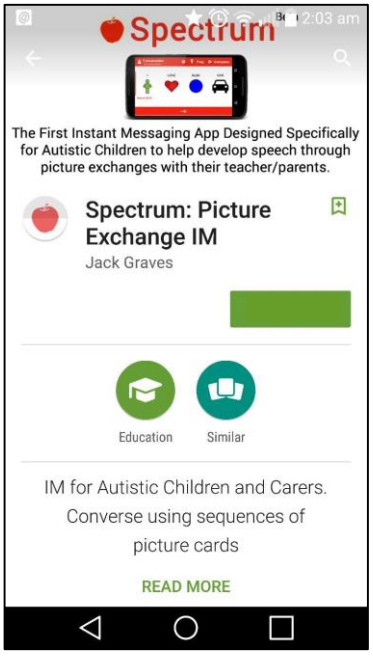
7.3 – FUTURE

The state of the Spectrum App is still a proof-of-concept in regards to the size of the picture database[51] (supported by the results from the school session), which has ~100 picture cards available currently, in the future I would like to implement the picture database using a modular system, where the picture database is distributed separately to the application, allowing it to be expanded separately to the application and additional 'picture packs' could be downloaded or sold as in-app purchases.

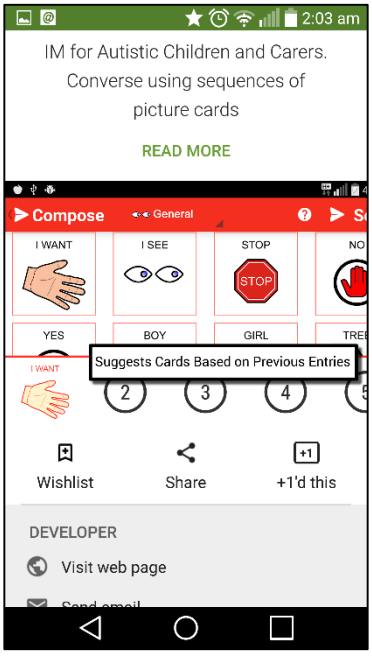
The prospective features discussed in Section 5.6, "NFC Support" and a "Mascot", as well as the suggestions to "long-press on a card in the database to bring up related/other forms" would be developed further.

One feature that would make the application more competitive against the existing solutions would be to allow accessing the picture database and reading the cards offline and would not take a considerable amount of development, as the Compose feature is written modularly with Fragments, so can exploit code-reuse.

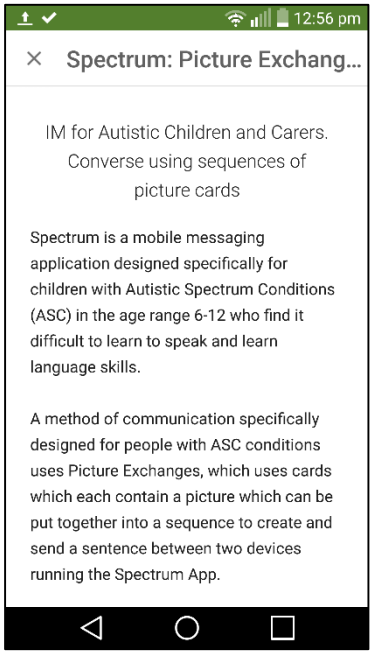
The application has been successfully been published to the Google Play store as of 30th April 2015.



The Header



Screenshots Section



Description Page

[51] There are many essential 'cards' that are missing from the application, but these are not architectural changes, merely content, which can be produced quickly and pushed to update all clients.

LOG

This table shows detailed scheduling information about the entire project and any applications/tasks that relate to the project.

Task	Timescale	Status
• Meeting with Bernhard Raus	23/09/2014	**Attended**
• Meetings with Supervisor		
○ Meeting with Chris Kiefer	24/09/2014	**Attended**
○ Meeting with Chris Kiefer	02/10/2014	**Attended**
○ Group Meeting with Chris Kiefer	22/10/2014	**Attended**
○ Meeting with Chris Kiefer	29/10/2014	**Attended**
○ Progress Meeting with Chris Kiefer	11/11/2014	**Attended**
○ Meeting with Chris Kiefer (Interim Results)	03/12/2014	**Attended**
○ Progress Meeting with Chris Kiefer	10/12/2014	**Attended**
○ Meeting with Chris Kiefer	26/01/2015	**Attended**
○ Meeting with Chris Kiefer (regarding Poster)	11/03/2015	**Attended**
○ Meeting with Chris Kiefer	13/04/2015	**Attended**
• Administrative Tasks		
○ Project Selection	22/09/2014 - 24/09/2014	**Completed**
○ Apply for Ethical Approval (1 – Low Risk)	29/09/2014 - 22/10/2014	**Not Approved ↓**
○ Apply for Ethical Approval (2 – High Risk)	25/10/2014 – 29/10/2014	**Not Approved ↓**
○ Apply for Ethical Approval (3 – High Risk)	29/10/2014 – 26/01/2015	**Approved**
○ Apply for DBS (CRB Check)	04/12/2014	**Attended**
▪ Meeting with Marc Williams for DBS	11/02/2015	**Attended**
▪ Submitted DBS Form with Evidence	21/01/2015	**Completed**
▪ Completed	13/03/2015	**Completed**
○ Emailed John Carroll regarding Android Tablets	10/03/2015	**Completed**
○ Met with Ian Wakeman to pick up devices.	18/03/2015	**Completed**
• Project Proposal (Detailed on Page 105)	**25/09/2014 – 09/10/2014**	**Completed**
○ Initial Research + Write Up	25/09/2014 – 30/09/2014	**Completed**
○ Primary Objectives Set	01/09/2014 – 04/10/2014	**Completed**
○ Optional Objectives Set	05/10/2014 – 08/10/2014	**Completed**
○ Document Submitted	09/10/2014	**Completed**
• Interim Report	**10/10/2014 – 06/11/2014**	**Completed**
○ Preface and Abstract	10/10/2014 – 12/10/2014	**Completed**
○ Professional Considerations	13/10/2014 – 16/10/2014	**Completed**
○ Ethical Considerations	17/10/2014 – 19/10/2014	**Completed**
○ Requirements Analysis	20/10/2014 – 31/10/2014	**Completed**
▪ Evaluated Existing Solutions	20/10/2014 – 24/10/2014	**Completed**
▪ Initial Requirements Research	25/10/2014 – 27/10/2014	**Completed**
▪ Target User and Project Expectations	28/10/2014 – 31/10/2014	**Completed**
○ Project Plan	01/11/2014 – 02/11/2014	**Completed**
○ Interim Log	03/11/2014 – 04/11/2014	**Completed**
○ Document Submitted	05/11/2014	**Completed**
• Design (Detailed on Page 38)		
○ Database Model designed	20/10/2014 – 27/10/2014	**Completed**
○ Layouts designed for Conversation, Compose and Contact List	20/11/2014	**Completed**
○ Interface overhaul	09/01/2015	**Completed**
○ Designed Tablet interface layouts	11/02/2015	**Completed**

• School Visit Organisation (Detailed on Page 65)		
○ Ethical Clearance Granted	26/01/2015	**Completed**
○ Contact with Chris Fisher at Patcham House	03/03/2015	**Completed**
○ Enquired with John Carroll and Chris Kiefer regarding obtaining Tablets for the visit	10/03/2015	**Completed**
○ DBS Clearance Granted	13/03/2015	**Completed**
○ Visited School (Chris Fisher) for Preliminary	18/03/2015	**Completed**
○ Visited School for Session	21/04/2015	**Completed**
○ Visited School for Session 2	22/04/2015	**Completed**
• Final Consent Forms obtained	01/05/2015	**Received**
• Development		
○ Client-Server Model Research	10/10/2014 – 15/10/2014	**Completed**
○ First server-side script written	15/10/2014 – 24/10/2014	**Completed**
○ Server-side scripts completed	28/10/2014 – 15/11/2014	**Completed**
○ Initial Android classes created (Start, Login and Register with login script completed	01/11/2014 – 05/11/2014	**Completed**
○ Register, Login, Send, Add Contact Asynchronous Tasks Completed	30/11/2014	**Completed**
○ Implemented Contact Pictures	24/01/2015	**Completed**
○ Redesigned Application Interface	24/01/2015	**Completed**
○ Fixed bug relating to Compose Tabs	04/02/2015	**Completed**
○ Added ShowcaseView Tutorials	08/04/2015	**Completed**
○ Added ViewPager and Animations to Start Page	10/04/2015	**Completed**
• Testing		
○ Load Testing of Server	01/02/2015	**Completed**
○ Manual Testing with Group	24/03/2015	**Completed**
○ Unit Testing		**Completed**
▪ Client	11/04/2015	**Completed**
▪ Server	18/04/2015	
• Poster		
○ Submitted Poster	22/03/2015	**Completed**
○ Poster Event	14/04/2015	**Completed**
• Draft Report		
○ Hand-in	13/04/2015	**Submitted**
• Evaluation and Conclusion		
○ Evaluation Complete	30/04/2015	**Completed**
○ Conclusion Complete	01/05/2015	**Completed**
○ Summary/Abstract etc. Completed	02/05/2015	**Completed**

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APPENDICES

APPENDIX 1 – USER RESEARCH

A. Online General Questionnaire

The following document shows the general questionnaire that was designed to be filled in by participants, it mainly deals with discrete questions, but some paragraph fields are included to allow for some additional feedback.

---Form Start---

Consent

The data gathered here will be used in my report and may impact the design of the application being developed. If any of the below questions is 'No', then none of the data gathered can be used by me (Jack Graves) in my report.

I confirm that I have read and understand the project information and have had the opportunity to ask questions.
□ Yes / □ No

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.
□ Yes / □ No

I agree to take part in the above study.
□ Yes / □ No

I agree to the use of anonymised quotes in presentations/publications.
□ Yes / □ No

Main Questionnaire

Which Mobile OS do you use primarily?
□ BlackBerry 10

□ Windows Phone

□ Android

□ Apple iOS

□ BlackBerry (Legacy)

How often do you use Mobile Instant Messaging software? (Such as WhatsApp, BBM, and Skype)

□ Hourly □ Daily □ Weekly □ Monthly □ Never

Which IM Software do you use on your mobile device? (Tick all that apply)

□ Viber □ Skype □ Facebook Messenger

□ BlackBerry BBM □ WhatsApp □ Snapchat

□ Other (please specify)

Do you use Instant Messaging more often than SMS (Text) Messaging?

□ Yes □ About the Same □ No

What are the main reasons you use IM for? (e.g. Price, Ability to send Media)

How comfortable are you with an IM service storing your conversation history on their servers?

□ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 □ 8 □ 9 □ 10

Not Comfortable **Very Comfortable**

What is the easiest way to login to your services?

□ OpenAuth (Google+, LinkedIn, Microsoft Account)

□ Facebook Connect (Login with Facebook)

□ Phone Number + Password

□ Email Address + Password

Do you think the ability to send photos from their device/camera is suitable for children? (Under 16)

What feature adds the most to your experience of messaging?

□ Location Support

□ Multimedia Attachments

□ Self-Destructing Messages

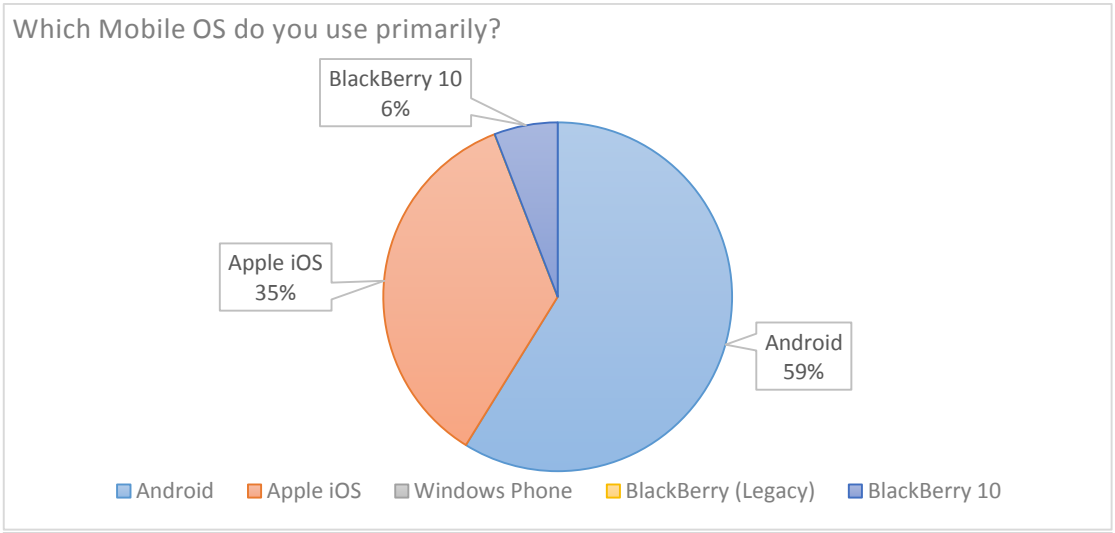
□ Read-Receipts

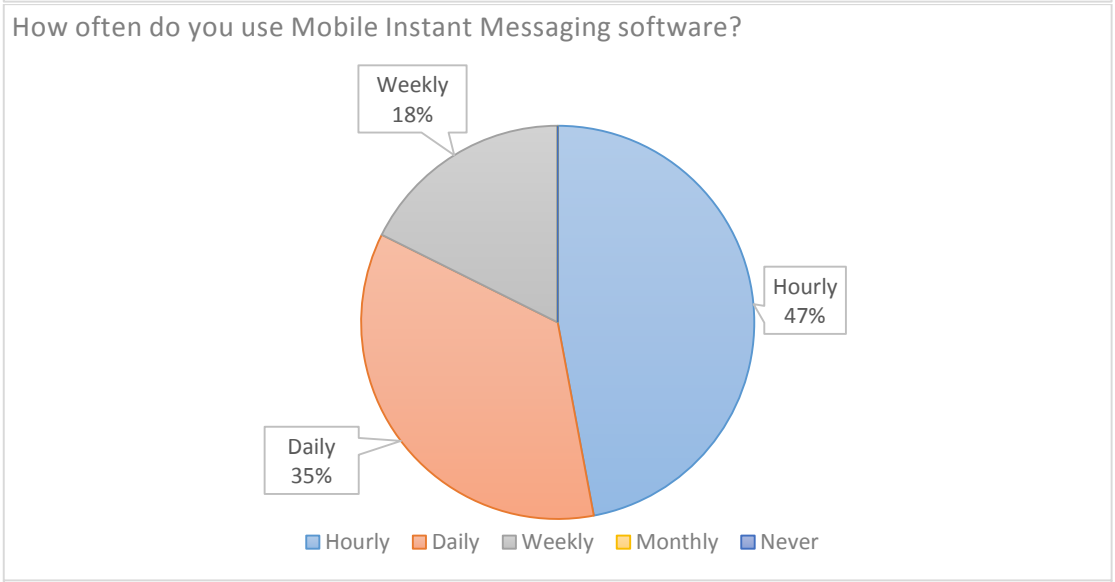
□ Other (please specify)

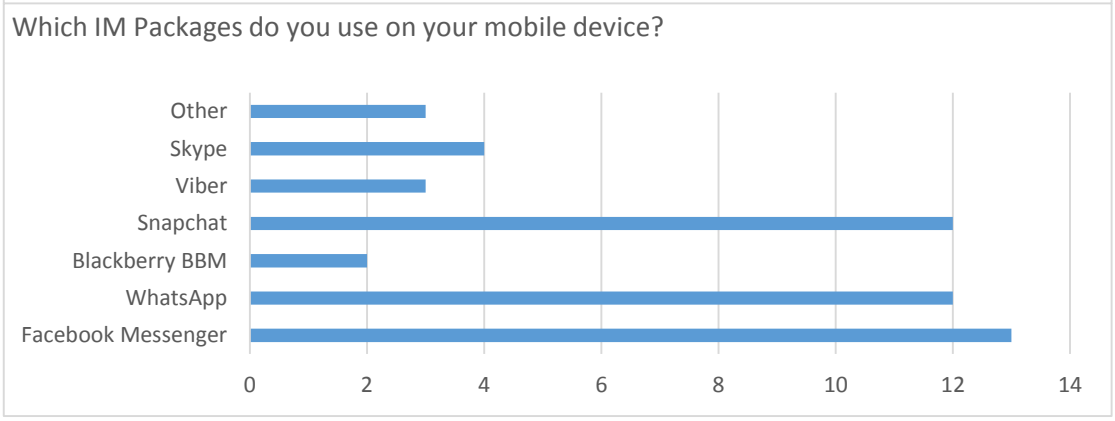
---Form End---

B. Data Collected from Online Questionnaire (shown in Appendix 1A)

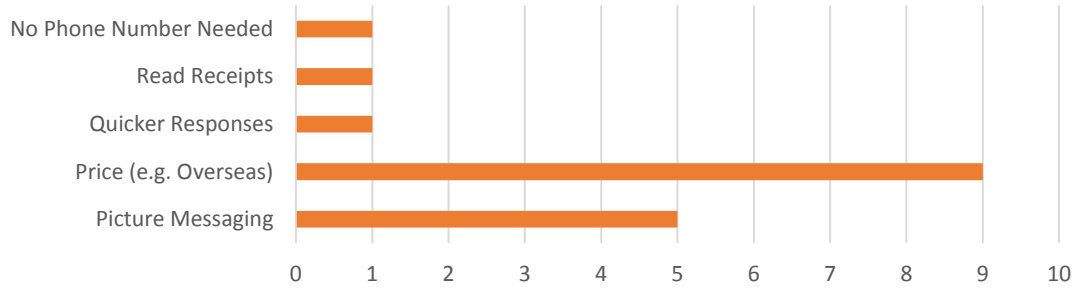
The data below has been collected from 17 people, who each agreed to have their data shown in this report.





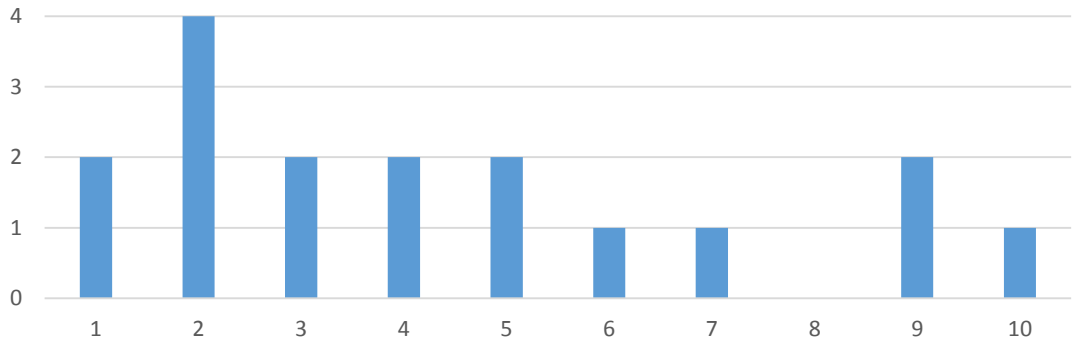


What are the main reasons you use IM for?

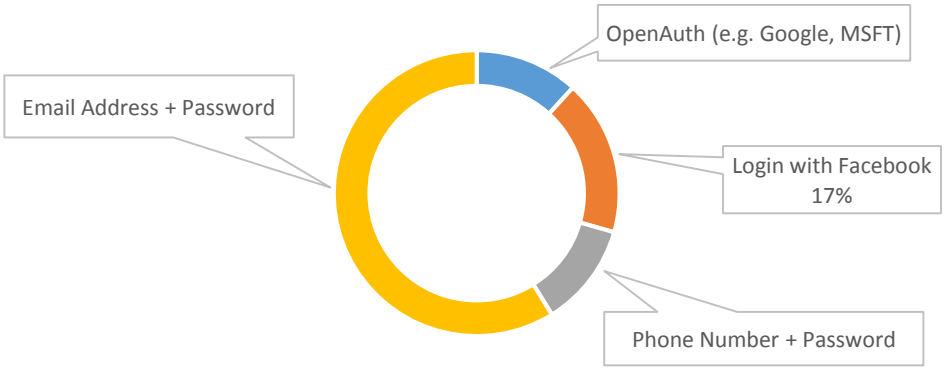


How comfortable are you with IM services storing your data/history?

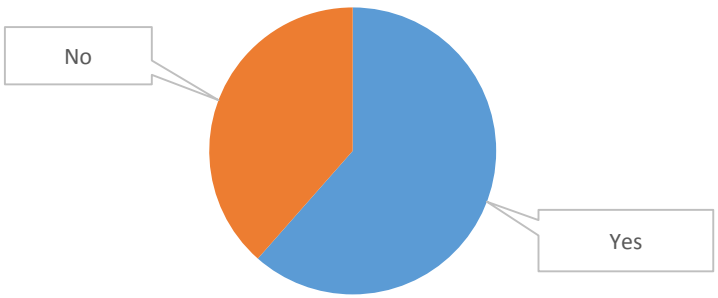
(0 = Least Comfortable, 10 = Most Comfortable)



What is the easiest way to login to your services?



Do you think that the ability to send photos is suitable for children?



C. Teacher Questionnaire Form

PARTICIPANT CONSENT FORM

Project Title
Spectrum: A PECS-based Messaging Mobile Application for People with Autism

Project Brief
This project is to develop a messaging application designed specifically for people in the age group 6-12 who have autism and find it hard to begin talking and understanding sentences at the younger ages. The application uses the Picture Exchange Communication System (PECS) which was developed to help autistic children improve their vocal/linguistic skills. PECS is mainly used currently using laminated cards, this project aims to develop an application that allows for the sending/receiving of these cards using Instant Messaging between devices, with the interface and experience of the application designed using Participatory Design, with potential target users, children who have autism and their carers/teachers.

The data gathered will be used to heavily influence the design/interface of the application in order to make it the most suitable for the target users and to improve the ease-of-use, the data gathered will also be used in the associated report to evaluate how successful it is.

Consent:

		Cross Out
1.	I confirm that I have read and understand the project information and have had the opportunity to ask questions.	Yes / No
2.	I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.	Yes / No
3.	I agree to allow myself to take part in the above study.	Yes / No
4.	I agree to the use of anonymised quotes in presentations/publications	Yes / No

Name _____ Date _____ Signature _____

Contact details:
Please contact me if you have any questions about the questionnaire.

Researcher: Jack Graves Email: jg337@sussex.ac.uk Phone: 0777 2842768

Supervisor: Chris Kiefer Email: c.kiefer@sussex.ac.uk Phone: 0127 3877986

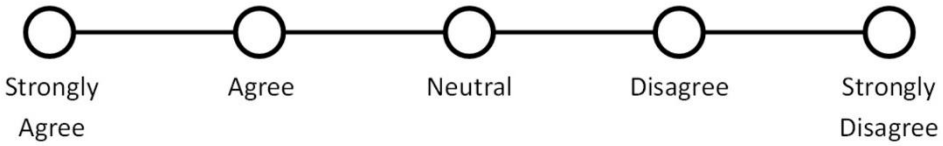
Spectrum (r3) **Teacher Questionnaire** Page 1/3

Please ensure you have completed and submitted the associated Consent Form for this Questionnaire.

1) **How often do you use the Picture Exchange Communication System (PECS)?**

☐ Daily ☐ Weekly ☐ Monthly ☐ Rarely

2) **PECS is an efficient communication method for children with Autism**



3) **Given your experience with PECS and it's use with children to communicate, how would you criticise/praise it?**

4) **In your opinion, are there any ways in which technology can improve PECS, through methods such as Text-To-Speech (TTS) which can read aloud the cards in English or through next card prediction?**

Spectrum (r3) **Teacher Questionnaire** Page 2/3

5) **Do you think that an Instant Messaging application where autistic users can send PECS symbols to each other will be beneficial to autistic children?**

Similar to WhatsApp, but instead of text, series of PECS cards are sent

6) **Are there any benefits/issues you see with such a system?**

7) **Do you find that children with autism are much more likely to engage in an activity if it involves technology?**

Such as phones, tablets and other interactive devices

8) **What are the best activities that keep the student from losing concentration/getting distracted when using technology?**

9) **What are the most important aspects of an Application Interface (e.g. on a Tablet) in relation to their use by disabled students?**

Such as background/foreground colour, font size, navigation.

10) **If there were two tablets, one for the student and one for the teacher, each with a PECS Instant Messaging client, do you think this would improve collaboration and engagement with Students?**

11) **Do you have any further comments that were not included in this questionnaire?**

~End of Questionnaire~

PARTICIPANT CONSENT FORM

Project Title
Spectrum: A PECS-based Messaging Mobile Application for People with Autism

Project Brief
This project is to develop a messaging application designed specifically for people in the age group 6-12 who have autism and find it hard to begin talking and understanding sentences at the younger ages. The application uses the Picture Exchange Communication System (PECS) which was developed to help autistic children improve their vocal/linguistic skills. PECS is mainly used currently using laminated cards, this project aims to develop an application that allows for the sending/receiving of these cards using Instant Messaging between devices, with the interface and experience of the application designed using Participatory Design, with potential target users, children who have autism and their carers/teachers.
The data gathered will be used to heavily influence the design/interface of the application in order to make it the most suitable for the target users and to improve the ease-of-use, the data gathered will also be used in the associated report to evaluate how successful it is.

Consent:

		Cross out as appropriate
1.	I confirm that I have read and understand the project information and have had the opportunity to ask questions.	Yes / ~~No~~
2.	I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.	Yes / ~~No~~
3.	I agree to allow myself to take part in the above study.	Yes / ~~No~~
4.	I agree to the use of anonymised quotes in presentations/publications	Yes / ~~No~~

Name [redacted] Date 31/1/15 Signature [redacted]

Contact details:
Please contact me if you have any questions about the questionnaire.

Researcher: Jack Graves Email: jg337@sussex.ac.uk Phone: 0777 2842768

Supervisor: Chris Kiefer Email: c.kiefer@sussex.ac.uk Phone: 0127 3877986

Revision 5 (21/01/2015)

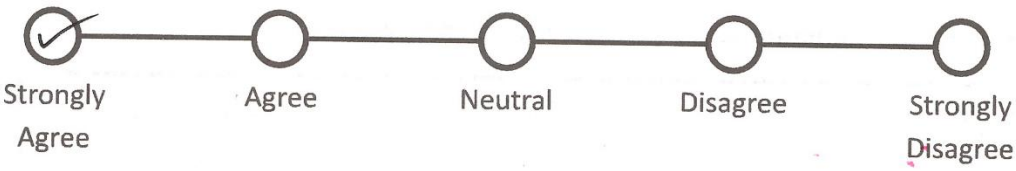
Spectrum (r3) **Teacher Questionnaire** Page 1/3

Please ensure you have completed and submitted the associated Consent Form for this Questionnaire.

1) **How often do you use the Picture Exchange Communication System (PECS)?**

☑ Daily ☐ Weekly ☐ Monthly ☐ Rarely

2) **PECS is an efficient communication method for children with Autism**



3) **Given your experience with PECS and it's use with children to communicate, how would you criticise/praise it?**

Gives the children opportunity to 'ask' or 'respond' to others - easy to understand simple.
- Can be problematic scrabbling around for picture cards / get lost / creased. Case for picture cards very cumbersombe - time consuming too!

4) **In your opinion, are there any ways in which technology can improve PECS, through methods such as Text-To-Speech (TTS) which can read aloud the cards in English or through next card prediction?**

Have knowledge of one system Proloquo2go app - allows speech from tablet.
Speaking voice much better - really allows children to have a 'voice' - much more inclusive when around their peers.
Although adult nearby can't talk' without interpreter.

5) **Do you think that an Instant Messaging application where autistic users can send PECS symbols to each other will be beneficial to autistic children?**

Similar to WhatsApp, but instead of text, series of PECS cards are sent

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

6) **Are there any benefits/issues you see with such a system?**

Will give the children more independence. Children with autism that I have worked with really respond to touch screen technology - so will be interested to engage with this method.

7) **Do you find that children with autism are much more likely to engage in an activity if it involves technology?**

Such as phones, tablets and other interactive devices

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

8) **What are the best activities that keep the student from losing concentration/getting distracted when using technology?**

Open ended materials - ones with multiple options so no right or wrong ways - ones that can be personalised

9) **What are the most important aspects of an Application Interface (e.g. on a Tablet) in relation to their use by disabled students?**

Such as background/foreground colour, font size, navigation.

Easy to navigate, quick access to frequently used areas.
Personalisation - ability to add own pictures/images to provide 'familiar' & 'safe' content for child.

10) **If there were two tablets, one for the student and one for the teacher, each with a PECS Instant Messaging client, do you think this would improve collaboration and engagement with Students?**

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

11) **Do you have any further comments that were not included in this questionnaire?**

Like the idea of two-way communication - puts child on an equal footing - very inclusive.
Could be a good way for child to engage with peers too so not just pupil/teacher. This would be great for personal social development.

~End of Questionnaire~

APPENDIX 2 – REPOSITORY COMMITS

Commit	5240104	Date	2014-11-14
Initial Commit Completed basic interface and navigation logic for Start, Registration, Login and Contact List. Conversation not functional, need to implement check for adding a contact, as adding the same contact twice crashes the application. Implemented the Settings screen, however does not work at the moment. No Compose or Conversation screen currently			
Commit	**5f02c0f**	**Date**	**2014-11-14**
Fixed bugs with screen rotation, login and registration screen rotating now functioning. CursorAdapters still pending implementation.			
Commit	**ecbe814**	**Date**	**2014-11-15**
Conversation implemented, without filtering on whose messages are shown – but working. CursorAdapter for Conversation partially done.			
Commit	**e647106**	**Date**	**2014-11-24**
Symbol Database deployment completed, with classes Symbol, SymbolDB, SymbolDBHelper and SymbolFetcher created. Fetch, JSON and Pull services written to receive and fetch new messages when a GCM message is received. Added a watermark of the application icon to the Contact List which rotates on action. Moved most of the hardcoded strings into the strings.xml file, as per Android Guidelines. Added waiting message ‘circle’ to the Contact List.			
Commit	**7d60dc9**	**Date**	**2014-11-25**
Refactored Code to fix errors/warnings. Problems with Memory Usage/Leakage still prevalent. Implemented the Symbol 1-5 places and filling/removing symbols. Sending task changed and can send messages now. TODO: Implement Symbol Prediction Engine			
Commit	**f465735**	**Date**	**2014-11-28**
Add Contact logic refactored Using the ExpandableHListView library for L-T-R conversation implementation – But not working very well. Symbol Database code refactored to deal with bitmap memory requirements. Added ‘Add new Contact’ notification to app for allowing someone to send you messages.			

Commit	e264459	Date	2014-12-08

```
Added:      Accessibility Background Colours
            Fade on Compose Swipe
            CursorLoader on all Database Access
            Changed Information Screen to allow Accessibility Functions
Bugs:       Spinner in Compose is broken (crash on change)
            No portrait mode in Conversation and Compose Still
To Do:      Picture Predictor
            Custom Profile Picture
            Still need to replace HorizontalListView (crashes)
```

Commit	5d9e483	Date	2015-01-30

```
At Bug Fix Stage in Development. Feature Complete
Bug Fix needed Composed Tabs
Added Custom Display Picture which shows in Information screen, Contact
List, Status Bar and is chosen in the Registration Screen
Added shake animation to empty fields on various pages.
Changed Layout for Register, Start, Login pages.
Implemented 3 screens that can be tapped between on the Start page which
show how to use the application.
```

Commit	3df9a18	Date	2015-01-21

```
Removed Symbol Database – now images are stored natively as Drawables.
Implemented Compose Field Fragment
Compose Screen numerous improvements.
Now using HorizontalList by Martin Appl as the Horizontal List for
Conversation.
Settings screen now completely global with changes.
Added author image to Contact List if empty.
Information screen improved, with Cursor closing.
```

Commit	5d9e483	Date	2015-02-02

```
Bugfixes    Fixed Compose Tabs crashing application
            Fixed swiping on Compose
Improvement Decreased size of bottom 'status' bar of Contact List
            Added x-large layout sizes to support large tablets
            Added Category images to Compose
Changes     Set minimum screen size to 4.8 inches
            Added MIPMAP icon to fit better with Android Guidelines
Issues:     On cheap tablet screen, suggestions not clear (transparent)
```

Commit	22fc20b	Date	2015-04-11

```
Added the nineoldandroids and JazzyViewPager libraries and implemented
them on the Start Page to make it swipeable left and right as opposed to
just a tap-to-use from feedback received in the group testing.
Added ShowCaseView Tutorials, using the ShowcaseView library. These
tutorials appear on the Conversation and Compose Screens on first-run.
Made the feel of the Buttons the same throughout the interface with a
pressed, focused and default state.
The MIPMAP icon is now used for notifications on newer devices, but the
original icon used otherwise for the Launcher Icon.
```

APPENDIX 3 – SESSION AT SCHOOL DATA

A. Consent/Information Forms

PARTICIPANT PARENT CONSENT FORM

Project Title
Spectrum: A PECS-based Messaging Mobile Application for People with Autism

Project Brief
This project is to develop a messaging application designed specifically for people in the age group 6-12 who have autism and find it hard to begin talking and understanding sentences at the younger ages. The application uses the Picture Exchange Communication System (PECS) which was developed to help autistic children improve their vocal/linguistic skills. PECS is mainly used currently using laminated cards, this project aims to develop an application that allows for the sending/receiving of these cards using Instant Messaging between devices, with the interface and experience of the application designed using Participatory Design, with potential target users, children who have autism and their carers/teachers.
The data gathered will be used to heavily influence the design/interface of the application in order to make it the most suitable for the target users and to improve the ease-of-use, the data gathered will also be used in the associated report to evaluate how successful it is.

Consent:

		Cross out as appropriate
1.	I confirm that I have read and understand the project information and have had the opportunity to ask questions.	Yes / No
2.	I understand that my child's participation is voluntary and that I am free to withdraw at any time, without giving reason.	Yes / No
3.	I agree to allow my child to take part in the above study.	Yes / No
4.	I agree to the use of anonymised quotes in presentations/publications	Yes / No

Name of Child _____ Date _____ Parent/Carer Signature _____

Contact details:
Please contact me if you have any questions about the questionnaire.

Researcher: Jack Graves Email: jg337@sussex.ac.uk Phone: 0777 2842768

Supervisor: Chris Kiefer Email: c.kiefer@sussex.ac.uk Phone: 0127 3877986

Revision 5 (21/01/2015)

RESEARCH PARTICIPANT INFORMATION SHEET

Contact Details

Researcher:	Jack Graves	Tel: 0777 2842768	Email: jg337@sussex.ac.uk
Supervisor:	Dr Chris Kiefer	Tel: 0127 3877986	Email: c.kiefer@sussex.ac.uk
Research Ethics Committee:			Email: crecscitec@sussex.ac.uk

Research Title

Spectrum: A PECS-based Messaging Mobile Application for People with Autism

Research Description

What is the aim of the project?

This project aims to develop a messaging application designed specifically for people in the age group 6-12 who have autism and find it hard to begin talking and understanding sentences at younger ages. The application uses the Picture Exchange Communication System (PECS) which was developed to help autistic children improve their vocal/linguistic skills, currently PECS is mainly used using laminated cards and this project aims to develop a mobile application on the Android platform that allows for the sending/receiving of these cards using Instant Messaging between devices.

What research methods are being used?

This research is taking place in order to directly influence the application and its interface based on data gathered from children and their carers/teachers in order to make the application easy to use and simple.
Research will be done through a variety of methods, by performing Participatory Design (where the end-user is involved in the development by helping evaluate proposed solutions) in order to gather people's opinions and suggestions for improvements on the application through group sessions and interviews with possible target users, these sessions will be audio recorded in order to obtain responses without interrupting the session.
Other research methods will be used to gather data from the teachers and carers by using questionnaires, interviews and observation of use with the system.
The teachers/carers will be present throughout the session.

How will the data gathered be used?

The data gathered will be used to heavily influence the design/interface of the application in order to make it the most suitable for the target users and to improve the ease-of-use, the data gathered will also be used in the associated report to evaluate how successful it is.
For example, the way in which the user navigates through the system, or how certain screens are displayed to the user will be influenced through what data the research gives at each stage in the development of this application and again when it is evaluated after development.

The University of Sussex has insurance in place to cover its legal liabilities in respect of this study

---

B. Complete List of Suggestions

#	Suggestion	Further Details
1	Improve the Help function with an animated mascot like a dinosaur or a cat who guides the user through the use of the application, as this appeals to children and will help keep them engaged.	This Mascot could also be extended to be a part of the cards, and give the application a 'personality', further improving the brand relationship.
2	The Read-Aloud function of the application needs a limit on how many presses on cards it will allow, as the children would press on the cards repeatedly which was distracting. The Toast that shows with a card press was staying on screen because of this.	This could be implemented as only allowing a press on a card once in a second or not allowing another Read-Aloud event to be queued while another is being read out and a cool-out period.
3	Adding Contacts could be made easier by allowing NFC to be utilised by tapping the backs of two phones together while they are running the Spectrum app, to Add each other as contacts.	This would make it a lot easier and fun to set up the devices and faster to get talking to one another using the application.
4	Holding down on a card in the Card Database could show other forms of the word – e.g. Long Press on Car to show Cars, or on Leaf to show Leaves.	This would be good to show plural cases in a pop-up.
5	Read Messages out-loud as they are received, in sentence form.	This might be an interesting option to include to make conversations more fluid and lifelike, however it could also hinder from distraction.
6	The Conversation screen does not automatically scroll – this would be helpful.	This is a noted limitation that has been known about, due to the implementation of the Horizontal List View.
7	More Cards should be available, such as connectors – AND, OR, ON, UNDER, A etc. and words such as PLEASE, THANK YOU.	These were widely suggested cards that were not included in the application. They would make the database more comprehensive.
8	Have a search bar on the Contact List to enable searching for contacts.	For Carers/Teachers, this may be helpful for a large Contact List.
9	Long Press on a Conversation item to enlarge the picture to fill the screen up	This feature would be helpful for people with sight-problems, a useful extension to the Enhanced Visibility Mode.
10	Have some animated cards, for emotions, the happy card could have a face that smiles to the user in an animation.	This might help people recognise the emotions quicker and children would enjoy the animated cards. Unfortunately this would be hard to implement.

11	It would be nice to be able to change the colour theme used by Spectrum to any custom colour the user wanted – one suggestion was to provide this feature as easily-accessible button on the Contact List, in the Status Bar.	This would not be very difficult to implement, but it's not an essential feature and could make it more complex than it needs to be. E.g. Someone could set the background and foreground colours to be the same – crippling the application interface.
12	You should be able to change your Profile Picture after you have set it in the initial registration.	This would require the server to be updated to allow this and would require additional programming on the Android application.
13	Be able to change the Font Size from within the application – useful for dyslexic users.	This can already be done through the main Android settings and does apply to the application – but this would be a nice feature.
14	The Notifications need optimising – multiple notifications for a conversation for each message received.	These would be better if they collapsed into 1 notification for each contact.
15	The 'Back' needs to be more clearly marked on the application – or a tutorial that shows the users how to go back	The Android design might not be optimal and instead a clearer back button made visible.

C. Results of Evaluation

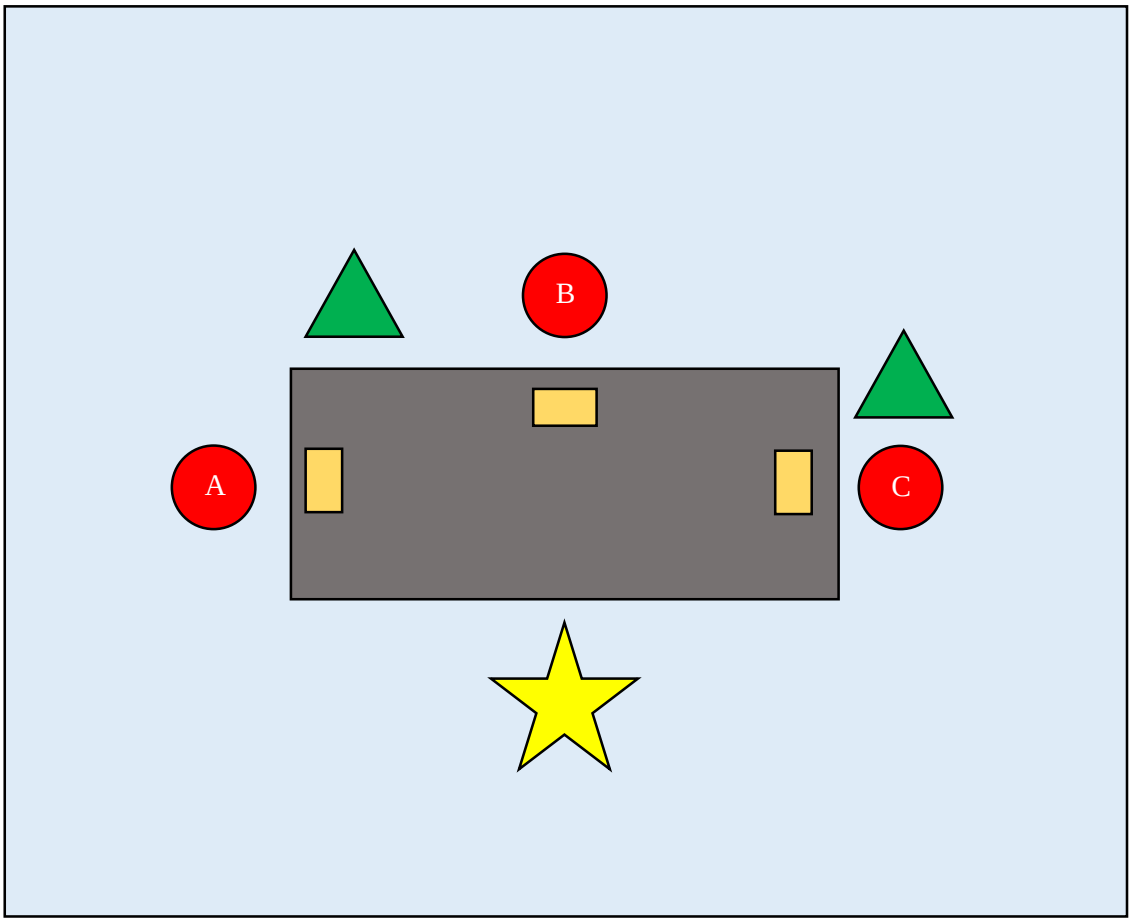
The ease-of-use of each feature was enquired about during the session on a range of features:

	Participant		
	A	B	C
Visual Design	10/10	8/10	9/10
Navigation	7/10	10/10	8/10
Add Contact	4/10	2/10[52]	4/10
Picture Library	9/10	7/10	4/10[53]
Compose Fields	2/10[54]	8/10	9/10
Touchscreen	10/10	10/10	10/10

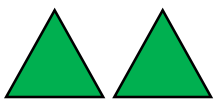
[52] Had trouble entering email address. Suggested the use of username or tapping-back of phone like NFC.
[53] Not enough pictures in the database and lack of connectors and plural words – participant had language skills far above the level the target audience for this application would have.
[54] Had trouble with the Drag/Drop feature.

D. Layout of Session

Diagram



Legend

Shape	Description
	Student Participants A, B and C
	Teacher, Teaching Assistant
	Me (Jack Graves)
	Devices • Sony Xperia Z • LG G3 • Samsung Galaxy Player 5.0 WiFi

APPENDIX 3 - THIRD-PARTY LIBRARIES USED

Name	Author	Website	Licence
Android API's	Google	https://developer.android.com/sdk/index.html	Apache License v2
HorizontalList	Martin Appl	https://github.com/applm/ma-components	Apache License v2
JazzyViewPager	Jeremy Feinstein	https://github.com/jfeinstein10/JazzyViewPager	Apache License v2
JQuery	The jQuery Foundation	https://jquery.org/	MIT license
NineOldAndroids	Jake Wharton	http://nineoldandroids.com/	Apache License v2
OnSwipeTouchListener	Sean O' Shea	https://github.com/seanoshea/krissytosi-android	Apache License v2
org.apache.http.*	Apache	https://hc.apache.org/	Apache License v2
org.json.*	JSON	http://www.json.org/	http://json.org/license.html
php-gcm (PHP port of GCM)	Luke Korth	https://github.com/lkorth/php-gcm	Apache License v2
ShowcaseView	Alex Curran	https://github.com/amlcurran/ShowcaseView	Apache License v2
Symbol Database Images	Various	https://openclipart.org/	Unlimited Commercial/Free Use

APPENDIX 4 - PROPOSAL DOCUMENT

Name Jack Graves
Supervisor Chris Kiefer
Project Title Spectrum: A PECS-based Messaging Mobile Application for People with Autism

Aims & Objectives

As a person with autism myself, my aim in undertaking this project is to develop an application for the Android Operating System that allows people with autism to message one another using the Picture Exchange Communication System (PECS), developed by Pyramid Educational Consultants.

PECS is a communication method designed for use by people with autism to communicate without voice or text and instead allow the users to choose from a database of pre-defined pictures/symbols to convey meaning.

The application will allow these users to have conversations by joining these symbols together in order to make structured sentences. A very important aspect of the application will be the interface design and I hope to use concepts that I have learnt through Human Computer Interaction (HCI) and by using participatory design develop an application that is tailored to users with Autism.

The project encompasses Software Engineering, Networking, Interface Design, Human Computer Interaction, AI and User Studies.

I hope to visit one/several schools and test some concept ideas for the interface and revisit at several different stages in the development of the application in order to do my interface design in an iterative manner.

Primary Objectives

ID	Objective	Risk
1	Users will be able to sign-in to the application using an existing account they have elsewhere, using OpenAuth, which will allow users access to their data while protecting their account credentials.	MEDIUM
2	The interface will have a contact list as the main page, which contains other users they have added.	LOW
3	Each person that has had correspondence with the user will have its own ‘conversation’ in the conversation list and this will allow the user to see what has been sent in the past, this conversation window will scroll the images left-to-right as this is more logical for younger users and makes the conversations flow like normal sentences using the images/symbols.	HIGH
4	Users will have a way to add people to their contact lists, using a username for example.	MEDIUM
5	There will be a picture/symbol database that contains many of the PECS standard ‘cards’ such as the context cards like ‘I want’, ‘thank you’ or ‘I see’ and objects such as ‘Apple’ or ‘Trampoline’ and allow users to string these cards together to create sentences in the conversation view.	HIGH
6	If a user receives a message via the application, their phone will make a sound and a notification will be created and displayed to alert the user in their Notification Center.	LOW
7	A personalised Picture Prediction program will be included in the application, which makes suggestions for the next picture being added based on previous messages. This will most likely use a Hidden Markov Model.	HIGH

Extension Objectives:

ID	Objective	Risk
8	If each user could have a profile along with a status, this would make the application more immersive as it would provide a single place for users to see the status of their friends without moving to external services which may be unsafe for users with severe autism to be accessing such as Facebook and Twitter.	MEDIUM
9	Based on the coloured/tinted rulers that many people with dyslexia use I aim to have an option to tint the background of the application a certain colour such as magenta and cyan which should help children with dyslexia to see what is on the screen.	MEDIUM
10	I would also like to make it possible to get the phone to read out loud any messages received, by having alternate text for the built-in cards which can be read via Text To Speech (TTS) on the device.	MEDIUM
11	Location support would be useful to add and would provide users with a way of knowing how close the other person is to them.	HIGH
12	The ability to send a picture from the front or rear facing camera on the phone, or attach an image that is stored on the device memory should be built into the application so that users can include their own images if one is not available in the symbol database.	HIGH

Relevance

This project is relevant to my course, Computer Science and Artificial Intelligence, as it involves Software Engineering in order to develop the application using Java for the Android platform, Human Computer Interaction, as the interface is very important in an application designed for disabled and young users, the communication between the client (phone) and the server involves knowledge of Networking between devices and knowledge of Database technologies is needed to engineer the data storage of information.

The Picture Predictor will use an AI concept to predict pictures that will be sent next, this will most likely use a Hidden Markov Model in order to predict.

I hope to use the skills that I learnt Software Testing at BlackBerry in my placement year to rigorously test the software

Resources Required

Resource	Source	Details
An Android Handset	Own	Sony Xperia Z (C6603)
An Android Virtual Machine	Own	Allows Compatibility Testing
An Android Development Environment	Own	Eclipse IDE w/ ADB
A Server for running Servlets	Available Free	Offered by Amazon and Google

Interim Log

Date	Work Performed
23/09/2014	• Meeting with B. Reus regarding project selection
24/09/2014	• Meeting with C. Kiefer about project and selected project • Sent project proposal to Chris via the web system
25/09/2014	• Project Proposal accepted by C. Kiefer • Read three journals on autistic use of PECS
26/09/2014	• Primary and extension objectives added
27/09/2014	• Researched the use of the C2D/GMS service from Google, which supports push messaging which can be used to 'ping' the destination device to poll the server for new messages on the server • Researched use of OpenAuth to support sign-in and to protect users credentials
29/09/2014	• Ethical Approval Application approved by C. Kiefer
02/10/2014	• Read two journals on designing interfaces for autistic people
05/10/2014	• Added Artificial Intelligence HMM concept into report. • Started application to get CRB checked in order to do Participatory Design

Bibliography

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Timetable

	Monday 29 Sep	Tuesday 30 Sep	Wednesday 1 Oct	Thursday 2 Oct	Friday 3 Oct
09:00		*Final Year Project Allotted Time*			
10:00				*Knowledge & Reasoning*	*Final Year Project Allotted Time*
11:00	*Knowledge & Reasoning*		*Human-Computer Interaction*	*Final Year Project Allotted Time*	
12:00	*Human-Computer Interaction*				
13:00			*Web Computing*		
14:00	*Web Computing*				
15:00					*Knowledge & Reasoning*
16:00					
17:00				*Web Computing*	
18:00					

APPENDIX 5 – ETHICAL APPLICATION

Ethical Review Application (ER/JG337/2) Jack Graves	
Parent Application: ER/JG337/1	
Project Title:	PECS-based Messaging App for Android
Status:	Approved
Department:	Informatics
Email:	jg337@sussex.ac.uk
Applicant Status:	UG
Phone:	07772842768
Supervisor:	Kiefer, Chris
Project Start Date:	29-Sep-2014
Project End Date:	17-Aug-2015
External Funding in place:	No
External Collaborators:	No
Funder/ Project Title:	
Name of Funder:	

Ethical Review Application ER/JG337/2 (continued)
Project Description
My aim in undertaking this topic is to develop an application for the Android Operating System that allows people with autism to message one another using the Picture Exchange Communication System (PECS), developed by Pyramid Educational Consultants, which is a communication method used by people with autism to communicate without voice or text and instead use pictures/symbols in sequence to convey meaning. It will be a messaging app which allows users to have conversations with images. I am getting in touch with teachers (2 at the moment at separate schools) in order to perform participatory design where I can understand what is working well with the application and what is not and improve the application interface through Participatory Design. A DBS application is in the process of being sent in order to allow this. The participants will be a group of fewer than 10 children and their teacher/teaching assistant, the inclusion criteria will be that the children must be between the ages of 6-12 and preferably have experience with the PECS communication system/are on the Autistic Spectrum. They will be contacted through the teacher/staff at the school. Teachers AND Children will be involved in the data collection. I aim to perform two sessions of visiting a school, one to perform an evaluation of the current state of the application and to determine ways in which it can be improved, and another session to evaluate the final version of the application. The activities performed during the initial Participatory Design session will be sending messages between students and teachers/carers/myself and evaluating the system during performing these conversations to find areas of improvement and suggestions that can be included in the final product. There will be several differing designs that will be tried out and it is possible to change elements of the application during the session if they are possible. A small group of children and carers is the best session size, as this lets the problems faced be looked into better and having a group size that allows the teachers/carers to discuss their evaluations with myself will help to discover the main issues with the application. The final session (2/2) will make up my final evaluation of the application and draw conclusions as to the effectiveness of the system.

Ethical Review Form Section A (ER/JG337/2) (cont.)

Ethical Review Form Section A (ER/JG337/2)	
Question	**Response**
>> Checklist	
A1. Will your study involve participants who are particularly vulnerable or unable to give informed consent or in a dependent position (e.g. people under 18, people with learning difficulties, over-researched groups or people in care facilities)?	Yes
A2. Will participants be required to take part in the study without their consent or knowledge at the time (e.g. covert observation of people in non-public places), and / or will deception of any sort be used?	No
A3. Will it be possible to link identities or information back to individual participants in any way?	No
A4. Might the study induce psychological stress or anxiety, or produce humiliation or cause harm or negative consequences beyond the risks encountered in the everyday life of the participants?	No
A5. Will the study involve discussion of sensitive topics (e.g. sexual activity, drug use, ethnicity, political behaviour, potentially illegal activities)?	No
A6. Will any drugs, placebos or other substances (such as food substances or vitamins) be administered as part of this study and will any invasive or potentially harmful procedures of any kind will be used?	No
A7. Will your project involve working with any substances and / or equipment which may be considered hazardous?	No
A8. Will financial inducements (other than reasonable expenses, compensation for time or a lottery / draw ticket) be offered to participants?	No
>> Risk Assessment	
A9. If you have answered 'Yes' to ANY of the above questions, your application will be considered as HIGH risk. If however you wish to make a case that your application should be considered as LOW risk please enter the reasons here:	

Ethical Review Form Section C (ER/JG337/2) (cont.)

Ethical Review Form Section C (ER/JG337/2)	
Question	**Response**
>> C.1 Risk Checklist - Participants	
C1. Does the study involve participants who are particularly vulnerable, or unable to give informed consent, or in a dependent position (e.g. children (under 18), people with learning difficulties, over-researched groups or people in care facilities, including prisons)?	Yes
C2. Is Criminal Records Bureau clearance necessary for this project? If yes, please ensure you complete Section C.6.	Yes
C3. Will participants be asked to take part in the study without their consent or knowledge at the time (e.g. covert observation of people) or will deception of any sort be involved? Please refer to the British Psychological Society Code of Ethics and Conduct for further information.	No
C4. Could the study induce psychological stress or anxiety, or produce humiliation, or cause harm or negative consequences beyond the risks encountered in normal life?	No
C5. Are alcoholic drinks, drugs, placebos or other substances (such as food substances or vitamins) to be administered to the study participants?	No
C6. Can you think of anything else that might be potentially harmful to participants in this research?	A DBS Certificate (Disclosure and Barring Service) has been applied for to ensure that permission is given for working with children. Any work with children/school will not take place until this has been received.
>> C.2 Risk Checklist - Researcher(s) Safety and Wellbeing	
C7. Does the project involve working with any substances and/or equipment which may be considered hazardous? (Please refer to the University's Control of Hazardous Substances Policy).	No
C8. Could the nature or subject of the research potentially have an emotionally disturbing impact on the researcher(s)?	No
C8a. If yes, briefly describe what measures will be taken to help the researcher(s) to manage this.	
C9. Could the nature or subject of the research potentially expose the researcher(s) to threats of physical violence and / or verbal abuse?	No
C9a. If yes, briefly describe what measures will be taken to mitigate this.	
C10. Does the research involve any fieldwork - Overseas or in the UK?	Yes
C10a. If yes, where will the fieldwork take place?	Participatory Design and Evaluation of the Application will take place in a school classroom under supervision by teacher(s).
C11. Will any researchers be in a lone working situation?	No
C11a. If yes, briefly describe the location, time of day and duration of lone working. What precautionary measures will be taken to ensure safety of the researcher(s)?	

Ethical Review Form Section C (ER/JG337/2) (cont.)

C12. Can you think of anything else that might be potentially harmful to the researcher(s) in this research?	
>> C.3 Data Collection and Analysis (Please provide full details)	
C13. PARTICIPANTS: How many people do you envisage will participate, who they are, and how will they be selected?	Working with a group of 10 or fewer children at a school, as well as their associated teacher/teaching assistant. The selection will be made by the teacher that supervises the class, with a focus on having a larger amount of autistic children.
C14. RECRUITMENT: How will participants be approached and recruited?	
C15. METHOD: What research method(s) do you plan to use; e.g. interview, questionnaire/self-completion questionnaire, field observation, audio/audio-visual recording?	I hope to interview the teacher and get opinions about the interface of the application.
C16. LOCATION: Where will the project be carried out e.g. public place, in researcher's office, in private office at organisation?	In a school classroom
>> C.4 Ethical Considerations (Please provide full details)	
C17. INFORMED CONSENT: Please describe the process you will use to ensure your participants are freely giving fully informed consent to participate. This will usually include the provision of an Information Sheet and will normally require a Consent Form unless it is a purely self-completion questionnaire based study or there is justification for not doing so. (Please state this clearly).	All participants who are over 16 and have the capacity to give consent will be asked to read the information sheet and also complete a consent form in order to be included in the research, if anyone over 16 with a developmental disability were to be included in the study, then they must have parental consent as well. Any participants under 16 (such as the majority of participants) or unable to give consent themselves will have the research explained to them by their carer and asked if they want to participate and consent given by the teacher/associated carer.
C18. RIGHT OF WITHDRAWAL: Participants should be able to withdraw from the research at any time. Participants should also be able to withdraw their data if it is linked to them and should be told when this will no longer be possible (e.g. once it has been included in the final report). Please describe the exact arrangements for withdrawal from participation and withdrawal of data for your study.	The information sheet that is handed to participants includes an email address and phone number for contacting in order to withdraw. If any of the participants indicate a non-verbal desire to cease participation for example, fidgeting, disengaging or acting like they don't want to be included will be allowed to leave the study and any research that they give will be removed from the dataset. In addition to the researchers monitoring for signs of distress, the teacher/teaching assistant who will be taking part in the participatory design session will also be asked, in advance, to monitor the children and indicate whether they feel that a particular child is exhibiting any signs of negative affect.

Ethical Review Form Section C (ER/JG337/2) (cont.)

C19. OTHER ETHICAL ISSUES: If you answered YES to anything in C.1 you must specifically address this here. Please also consider whether there are other ethical issues you should be covering here. Please also make reference to the professional code of conduct you intend to follow in your research.	Throughout this project, a strong regard for the health, privacy, security and wellbeing of everyone involved in the research for report will been paramount. As the application will facilitate the sending and receiving of messages over the internet by users, any data that is sent or stored using the application must be handled in conformance with the Data Protection Act 1998, which has specific requirements on the way data is handled by this application such as the location of any web servers that are storing users data (which must be within the European Economic Area). The act also includes requirements on how long data is stored for, who can access this data and that it is properly secured and well-protected. At any points when this project uses third party software or libraries, the party will be referenced and credit given. There shall be discrimination between people and equal access to IT will be promoted whenever possible. As this project is a part of my undergraduate studies, the main goal is to develop professional knowledge, skills and competence on a continuing basis, maintaining awareness of technological developments, procedures, and standards that are relevant to the field. (BCS, 2014). No part of the application developed will mislead the user into thinking that it performs any other function than the one set out in this report, along with this, all legislation appropriate will be complied with and any evaluations of the application/project, including criticism will be seeked out and respected. In addition to this, every effort will be made to avoid injuring others, their property, reputation, or employment by false or malicious or negligent action or inaction. and I will reject and will not make any offer of bribery or unethical inducement. All work carried out in this project and the application that is developed will in no way break any UK or EU laws and will adhere to the University of Sussex requirements. With respect to this, any requests for information from these relevant authorities will be complied with in full accordance of the law and any requests to disclose information from any party other than these will be denied. Every effort will be made to carry out my professional responsibilities with due care and diligence and as the author of this project, Jack Graves, I accept professional responsibility for all work performed in this report. To Clarify: The application sends REAL messages, over the internet to the Amazon server based in the European Economic Area (EEA) as required by law, these messages are stored SECURELY on the server and nobody is able to access the contents/credentials (the server actually only contains messages as comma separated numbers and the user accounts are encrypted and salted.)

Ethical Review Form Section C (ER/JG337/2) (cont.)

>> C.5 Data Protection, Confidentiality, and Records Management	
C20. Will you ensure that the processing of personal information related to the study will be in full compliance with the Data Protection Act 1998 (DPA)?	Yes
C20a. If you are processing any personal information outside of the European Economic Area (EEA) you must explain how compliance with the DPA will be ensured.	
C21. Will you take steps to ensure the confidentiality of personal information?	Yes
C21a. Please provide details of anonymisation procedures and of physical and technical security measures here:	All user passwords will be securely stored on the server by creating a SHA1 hash (obsfucated password) and will also be 'salted' which means the password will be stored in such a way that even if the password data was leaked, without the password salt, the information is useless. All message data will be deleted from the server when it has been received by the destination device, and if this has not been collected in a certain time-frame (e.g. a month), then the message will be deleted from the server. All people who participate in this project will be anonymised when any opinions or data is used in the report, especially when concerning audio recordings, which will be destroyed once the accuracy of transcripts has been verified to respect the anonymity of participants. Data will be stored in the EEU on secure servers.
C22. Will all personal information related to this study be retained and shared in a form that is fully anonymised?	Yes
C22a. If you answered "no" to the above question you must ensure that these arrangements are detailed in the Information Sheet and that participant consent will be in place. If relevant, please outline arrangements here:	
C23. Will the Principal Investigator take full responsibility during the study, for ensuring appropriate storage and security of information (including research data, consent forms and administrative records) and, where appropriate, will the necessary arrangements be made in order to process copyright material lawfully?	Yes
C23a. If you answered "no" to the above question, please give further details:	
C24. Who will have access to personal information relating to this study?	There will be no outside people with access to the data relating to this study.
C25. Data management responsibilities after the study. State how long study information including research data, consent forms and administrative records will be retained, in what format(s) and where the information will be kept.	Any consent forms and administrative records will be retained in paper form in a locked drawer which will be stored until 1 December 2015 and at the University of Sussex.
>> C.6 Other Ethical Clearances and Permissions	
C26. Are any other ethical clearances or permissions required?	Yes

Ethical Review Form Section C (ER/JG337/2) (cont.)

C26a. If yes, please give further details including the name and address of the organisation. If other ethical approval has already been received please attach evidence of approval, otherwise you will need to supply it when ready.	A DBS Certificate is needed, which has been applied for and a photocopy of this will be included in the final report.

Responses for Ethics Approval (21/01/15)

1] Overall, more information is needed on the participatory design activities. It is important to spell out the number of sessions, who will be involved in each session, how long they will take and what the activities will be. How many sessions will the children be involved in? One or more than one? If one, are they evaluating a finished system or a prototype? Will there be 10 prototypes for each child to use? Is a group session the most appropriate way to evaluate the use of a system?

I have updated the main description of the project to include more details of the Participatory Design.

2] The project description mentions that the study will be conducted in children with autism aged 6-11. However, item c17 refers to consent procedures for participants aged over 16. Item c17 presumes that the participants over 16 are the teachers and able to give informed consent, while those under 16 are children with developmental disabilities. This should be made clear, as the response only considers age. If anyone over 16 with a developmental disability were to be included in the study, then they should have parental consent as well (particularly since the use of PECS suggests that the individual in question may not write or speak).

Have further clarified this answer.

3] In relation to the response at item c18, in addition to the researchers monitoring for signs of distress, the teacher/teaching assistant who will be taking part in the participatory design session should be asked, in advance, to monitor the children and indicate whether they feel that a particular child is exhibiting any signs of negative affect.

Have added this phrase to the response and will follow this guideline.

4] At item c19 clarify whether any data will actually be sent by the internet or whether this is a "proof of concept" that will develop prototype systems (and/or use local intranets only)

Rectified this answer with a clarified response.

5] In the questionnaire, Question 6 shows up twice (in slight different formats).

Removed the redundant question from the questionnaire.

6] In the information sheets, provide some background on participatory design: what it is, how it works, and why it may be useful (especially in the case of children with disabilities)

I have included more information about the participatory design in the Information Sheet.

7] Check for and correct typographical errors (e.g., "these sessions may have the audio recorded")

Have replaced with 'these sessions will be audio recorded'

8] Use neutral language where possible, e.g. replace "suffers with autism" with "has autism"

I have replaced this language on the Information Sheet with neutral language

9] Please add the following to the participant information sheet: "The University of Sussex has insurance in place to cover its legal liabilities in respect of this study"

I have added this quote to the end of the information sheet.

University of Sussex

Certificate of Approval	
Reference Number:	ER/JG337/2
Title Of Project:	PECS-based Messaging App for Android
Principal Investigator (PI):	Chris Kiefer
Student:	Jack Graves
Collaborators:	
Duration Of Approval:	7 months
Expected Start Date:	29-Sep-2014
Date Of Approval:	29-Jan-2015
Approval Expiry Date:	17-Aug-2015
Approved By:	Richard de Visser
Name of Authorised Signatory:	Richard de Visser
Date:	29-Jan-2015

*NB. If the actual project start date is delayed beyond 12 months of the expected start date, this Certificate of Approval will lapse and the project will need to be reviewed again to take account of changed circumstances such as legislation, sponsor requirements and University procedures.

Please note and follow the requirements for approved submissions:

Amendments to protocol

* Any changes or amendments to approved protocols must be submitted to the C-REC for authorisation prior to implementation.

Feedback regarding the status and conduct of approved projects

* Any incidents with ethical implications that occur during the implementation of the project must be reported immediately to the Chair of the C-REC.

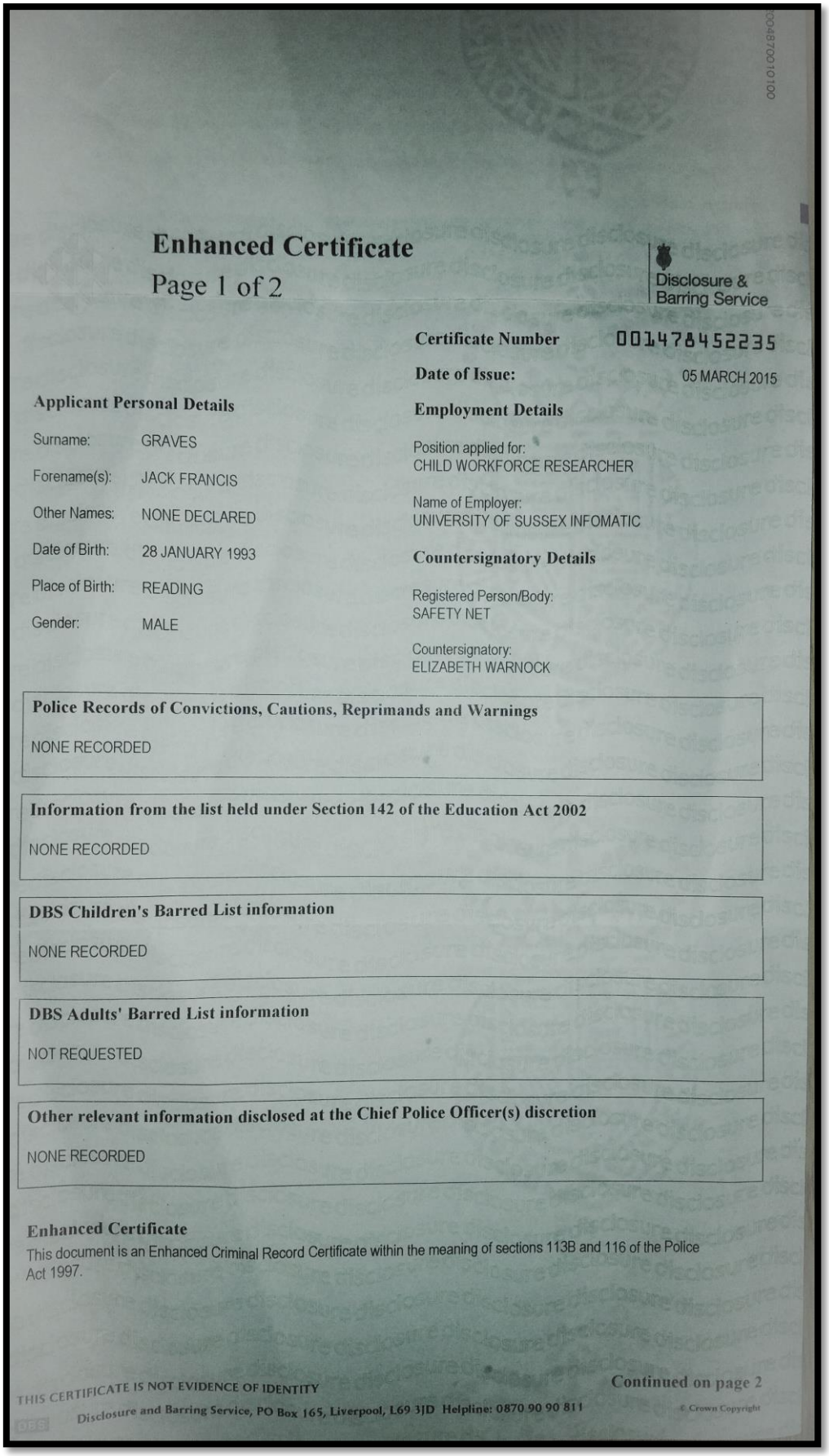
Feedback regarding any adverse and unexpected events

* Any adverse (undesirable and unintended) and unexpected events that occur during the implementation of the project must be reported to the Chair of the Social Sciences C-REC. In the event of a serious adverse event, research must be stopped immediately and the Chair alerted within 24 hours of the occurrence.

For Life Sciences and Psychology projects

* The principal investigator is required to provide a brief annual written statement to the committee, indicating the status and conduct of the approved project. These reports will be reviewed at the annual meeting of the committee. A statement by the PI to the C-REC indicating the status and conduct of the approved project will be required on the Approval Expiration Date as stated above.

APPENDIX 6 – DBS APPROVAL



004870010100

Enhanced Certificate
Page 1 of 2

Disclosure & Barring Service

Certificate Number 001478452235

Date of Issue: 05 MARCH 2015

Applicant Personal Details

Surname: GRAVES

Forename(s): JACK FRANCIS

Other Names: NONE DECLARED

Date of Birth: 28 JANUARY 1993

Place of Birth: READING

Gender: MALE

Employment Details

Position applied for:
CHILD WORKFORCE RESEARCHER

Name of Employer:
UNIVERSITY OF SUSSEX INFOMATIC

Countersignatory Details

Registered Person/Body:
SAFETY NET

Countersignatory:
ELIZABETH WARNOCK

Police Records of Convictions, Cautions, Reprimands and Warnings

NONE RECORDED

Information from the list held under Section 142 of the Education Act 2002

NONE RECORDED

DBS Children's Barred List information

NONE RECORDED

DBS Adults' Barred List information

NOT REQUESTED

Other relevant information disclosed at the Chief Police Officer(s) discretion

NONE RECORDED

Enhanced Certificate

This document is an Enhanced Criminal Record Certificate within the meaning of sections 113B and 116 of the Police Act 1997.

THIS CERTIFICATE IS NOT EVIDENCE OF IDENTITY

Continued on page 2

Disclosure and Barring Service, PO Box 165, Liverpool, L69 3JD Helpline: 0870 90 90 811

APPENDIX 7 – PERFORMANCE TEST RESULTS

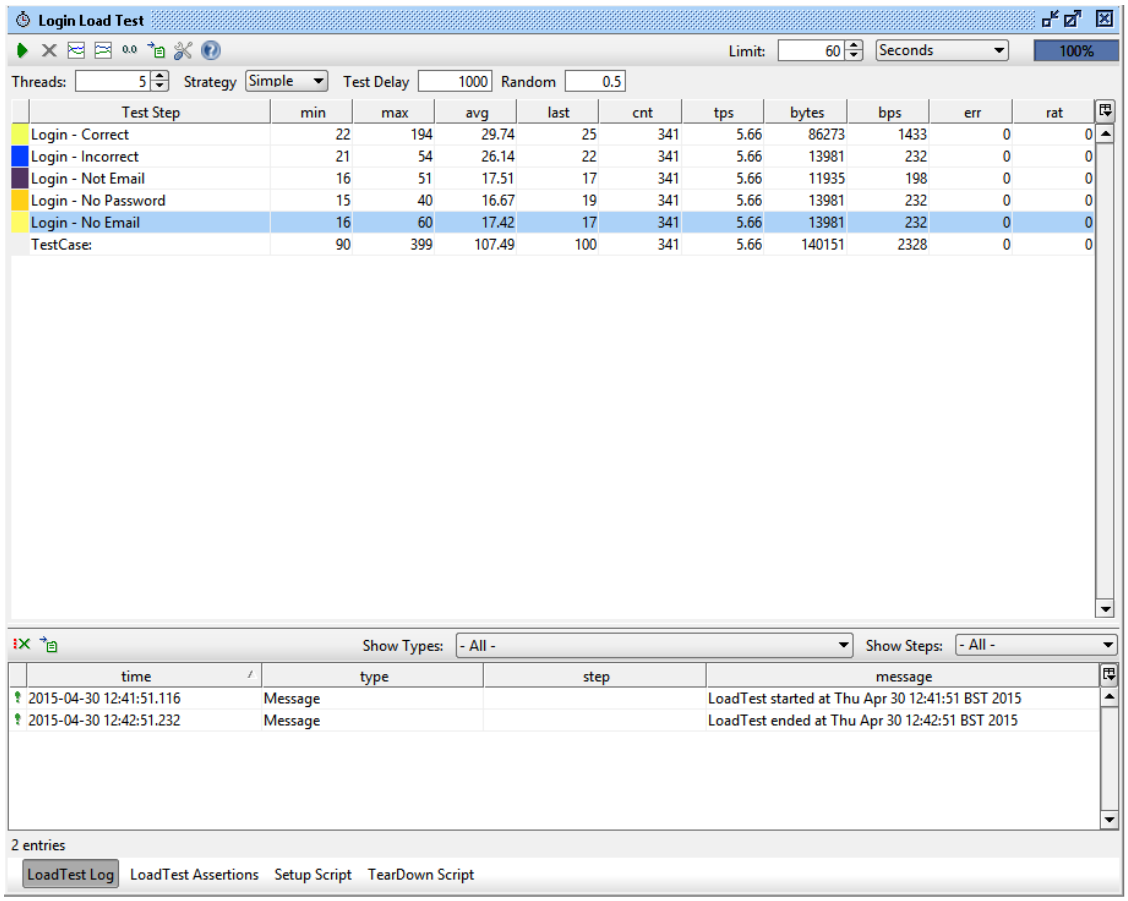


Figure 50 - SoapUI Login Load Test

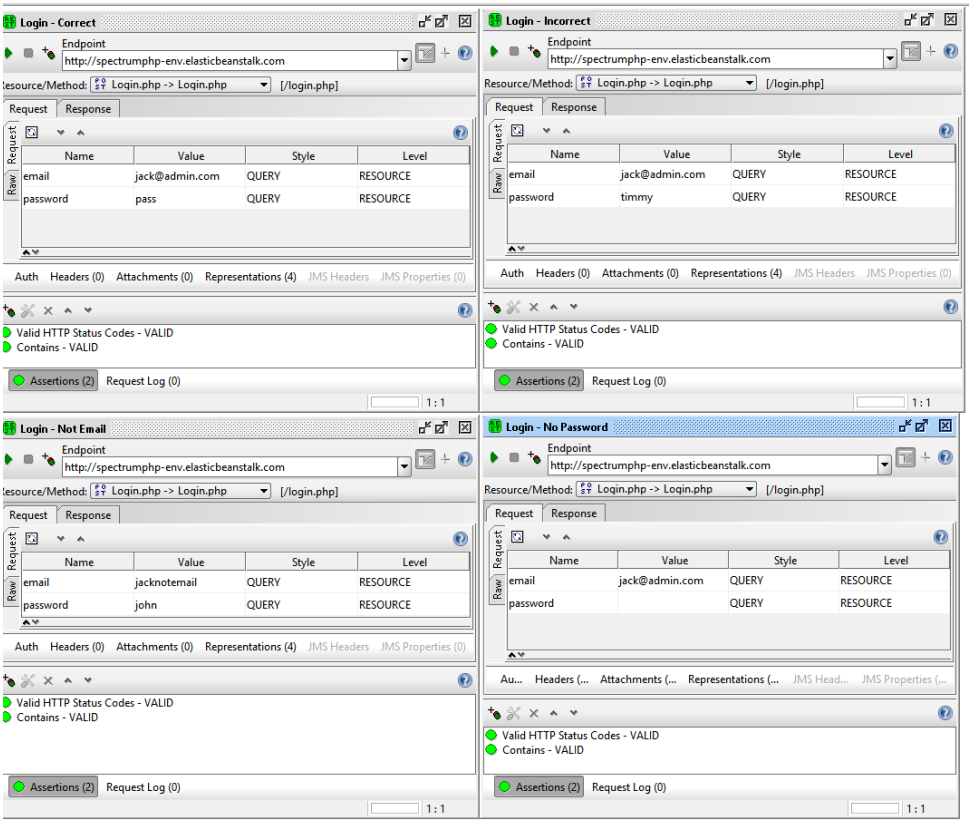


Figure 51 - The Login Coverage Testing for Load

APPENDIX 8 – PERFORMANCE TESTING THE PREDICTION ENGINE

```
        public void testAppend() {
            for(int i = 0; i < 1000; i++) { // CAN CHANGE THE AMOUNT OF APPENDS
                String message  = getRandomCSV();
                Intent append_intent = new Intent(getContext(), PredictionService.class);
                append_intent.setAction(PredictionService.ACTION_APPEND);
                append_intent.putExtra(PredictionService.MESSAGE, message);
                startService(append_intent);
                try {
                    Thread.sleep(100);
                } catch (InterruptedException e) {
                    e.printStackTrace();
                }
                String first = message.split(",")[0];
                Intent predict_intent = new Intent(getContext(), PredictionService.class);
                predict_intent.setAction(PredictionService.ACTION_PREDICT);
                predict_intent.putExtra(PredictionService.POSITION, 2);
                predict_intent.putExtra(PredictionService.INITIAL_SYMBOL, first);
                predict_intent.putExtra(PredictionService.RECEIVER, theReceiver);
                startService(predict_intent);
            }
        }

        public class PredictResultReceiver extends ResultReceiver {

            private Context context = null;
            private String TAG = "com.jgraves.spectrum.spectrum.PredictResultReceiver";

            void setParentContext(Context context) { this.context = context; }
            public PredictResultReceiver(Handler handler) { super(handler); }

            @Override
            protected void onReceiveResult(int resultCode, Bundle resultData) {
                getContext().notify();
                super.onReceiveResult(resultCode, resultData);
                if(resultCode == 1) {
                    int o = resultData.getInt("guess"); // THIS CHECKS THAT A GUESS IS MADE
                    assertNotSame("Guess shouldn't be empty as we just appended a message.",-1,o);
                }
            }
        }

        /**
         * Spits out a random message...
         * @return  A 5 digit CSV Message
         */
        public String getRandomCSV() {
            StringBuilder   builder = new StringBuilder();
            Random          random  = new Random();
            for(int i = 0; i < 5; i++) {
                builder.append(random.nextInt(78) + 1);
                if(i < 4) {
                    builder.append(",");
                }
            }
            System.out.println("Random CSV: " + builder.toString());
            return builder.toString();
        }
    }
```