An Investigation into the Usefulness of the Smart Watch Interface for University Students

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Abstract

The smart watch is not new to the area of wearable computing, however only recently it has become more widely available. Studies into the usefulness of the smart watch and the applications utilized, particularly by university students, have not been performed. The aim of this research was to investigate the usefulness of the smart watch, and to ascertain which applications or services university students would find most useful on a smart watch. Requirements were gathered from university students and used to develop two applications which were evaluated to achieve the research goals. The result of which, would determine whether the smart watch could be considered a useful interface to university students. The finished applications were evaluated in a field study, where students volunteered to use the smart watch with the developed applications installed. From the field study it was found that the majority of users found some use in the information they received on the smart watch, even if some would rather not use it on on a regular basis. Users found the interface to be convenient to use in situations where a smart phone was awkward to access. The results demonstrated that the smart watch can be a useful interface when used to retrieve small amounts of information as a complimentary device to a paired smart phone.

ACM Computing Classification System Classification

Thesis classification under the ACM Computing Classification System (1998 version, valid through 2014) [16]:

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background and Problem Statement

Smart watches as a form of wearable computing have been available for a number of decades, but have recently been found to be becoming more popular with the *Samsung Galaxy Gear* and the *Pebble* smart watch as some notable examples. The question has been posed as to whether these devices can be considered useful to university students, and what students would want to use a smart watch for. Smart watches which were previously available, such as IBM's Linux smart watch (Narayanaswami, Kamijoh, Raghunath, Inoue, & Cipolla, 2002), offered a limited number of applications at the discretion of manufacturers with no intention of taking advantage of any open source software solutions (Smith, 2013). With the standardization of an application programming interface (API) and the increasing availability of libraries through software development kits (SDK's) for smart watches, new applications can be created more quickly by developers in response to users' requirements (Sachse, 2010).

A number of applications are already available for smart watches, however investigations into the desire to use a smart watch for viewing information on, and the applications which are wanted by users are not commonplace. Another issue which needs to be addressed is that of using a smart watch as a feasible interface to view information on, especially in situations where mobile phones could be difficult or inconvenient to access (Chyla, 2013).

1.2 Research Goals and Objectives

This study aimed to investigate the applications which university students perceived to be useful on a smart watch. The desire to view information on the smart watch by university students was also analyzed. Once it was known what information was wanted by university students on a smart watch, two applications were developed as a proof of concept based on these requirements. These applications were then evaluated by a sample of university students in order to ascertain whether smart watches are a useful interface for university students. It was possible to determine the usefulness of the smart watch interface for university students, and what information these students wanted to view on a smart watch at the completion of this study.

Therefore the objectives of this research project as specified in the problem statement are to achieve the following goals:

1. Research the current developments in the field of wearable computing, in particular the area of smart watches.
2. Conduct research by means of a survey into whether the smart watch interface is perceived as a relevant and useful extension to the smart phone interface by university students.
3. Determine the applications which university students would want to use on a smart watch.
4. Develop as a proof of concept a few of the most popular applications selected by university students.
5. Allow a sample of university students to test those applications in a usability study, reporting on the usefulness of each application.
6. Analyze the findings of the usability study to determine whether the smart watch interface is useful to university students.

1.3 Approach

This project was conducted in four phases.

Phase one explored the area of wearable computing and the history of the smart watch. Any previous studies performed with regard to usability and application development on the smart watch as well as other mobile platforms such as the smart phone were documented.

Phase two consisted of a questionnaire which targeted university students at Rhodes University (Ethics clearance was awarded before commencing). The questionnaire focused primarily on asking whether or not a smart watch would be used if they had access to one, in addition the questions were geared towards the perceptions of using a smart watch to view information that university students would want. The responses from these questionnaires were analyzed and the general trends in the data noted in preparation for the next phase.

Phase three consisted of the development of applications for the *Pebble* smart watch based on the feedback provided by the respondents in the previous phase.

Phase four Incorporated an evaluation of the developed applications by a sample of university students from Rhodes University by means of a field study. During the field study aspects of usability such as ease of use, the learning curve of using such a device and the usefulness of each application on the *Pebble* smart watch were tested . Once the users had used the applications on the *Pebble* smart watch they completed another questionnaire and were interviewed about the aforementioned usability aspects of the smart watch; this evaluation was also approved by the ethics committee before commencement.

1.4 Structure of Thesis

This document is structured in the following way:

Chapter 2 consists of related work previously conducted in the field of wearable computing, specifically focusing on smart watches. A brief introduction is provided which explains why wearable devices are becoming more commonplace, along with a short history of wearable computing itself. The smart watch interface in the context of wearable computing is introduced, along with advantages and disadvantages highlighted in previous studies. The smart watch is analyzed in terms of its functionality to existing wearable and smart phone interfaces, and the application development process in conjunction with previous user studies performed with smart phones is addressed. Possible future smart watch advances are also highlighted as per current research being conducted.

Chapter 3 details the Spiral model describing the way in which requirements were gathered from the sample group in this study, the design and implementation of the application prototypes which fulfilled those requirements, and the expert user evaluation of those prototypes. The application design and development of the prototypes is briefly introduced before describing the usability study, which was performed by evaluating the applications developed from the requirements gathering process and input from the expert user evaluation. The methodology for the usability test conducted (a field study) is the DECIDE framework and is also discussed in this chapter.

Chapter 4 documents the design and implementation of the applications developed in this research. This includes the mock-ups, description of the prototypes and any general development considerations which need to be noted while developing for the Pebble using the CloudPebble IDE and PebbleKit SDK. The distinction between watch applications and watch faces is made, and the way in which Pebble executable files are sent from the IDE to the watch is detailed. The anatomy of a Pebble application is explained; including how the user interface is implemented and the way in which messages are handled between the phone and smart watch. Lastly, a high level overview of how each application was implemented is described.

Chapter 5 details the quantitative results obtained through the initial requirements gathering questionnaire, and documents any trends found between the demographic data collected and the results. A discussion of the requirements gathering process is also provided which offers possible reasons for the trends found. The qualitative results from the questionnaires and interviews conducted in the usability test upon completion of the field study are also documented. Any relationships discovered between the demographics of the participants and the results found, responses from the questionnaires, and the feedback from the user interviews are documented.

Chapter 6 provides an overall summary of this research and what it has achieved upon completion. How the findings connect with the initial problem statement are addressed and any final conclusions which can be drawn from the research findings are made. Future work which could be pursued from this research are also highlighted.

Chapter 2

Review of Literature

2.1 Introduction

The smart watch is part the family of wearable computing and has recently been emerging as an alternative interface for information access (Bieber, Haescher, & Vahl, 2013). This section provides a brief introduction into wearable computing and documents previous work done in using wearable devices to solve problems. The smart watch is introduced as a subset of wearable computing and recent smart watch developments are documented. Previous studies concerning alternative interfaces to the ubiquitous smart phone interface, and the information requirements of the users for these alternatives are also analyzed. The application development for both wearable computing and smart phones are looked at, and the information needs of users which have been found to be important in past studies are analyzed.

2.2 Wearable Computing

Modern day wearable computing began in the 1950's with work done by Edward Thorp who developed a small device which could be concealed in a shoe. This device analyzed the motion of a roulette wheel via micro-switch pulses and predicted which portion of the wheel the ball would land on (Thorp, 1998). Thorp's device was seen as tackling a single problem domain, where all resources on the wearable device were aimed at solving only one particular problem. As a result, many new wearable computing devices were developed in the 1970's which tackled single purpose problem domains only.

One such device in the area of computer vision was the *WearComp* device developed by Mann (1997a). This device categorized how scenes responded to different lighting situations and shot pictures accordingly (Mann, 1997a). A head mounted camera was also developed for the domain of computer vision, which viewed two dimensional objects as if they were in three dimensions by using two miniature CRT monitors in front of the user's eyes (Sutherland, 1968). Situational or contextual awareness was addressed in devices such as the *Olivetti Active Badge*, which provided the locations of users who wore them by receiving an infra-red signal from transceivers installed in specially wired buildings (Greaves, 2000; Want, Hopper, Falcao, & Gibbons, 1992). This approach to solving problems in a single domain was found to be too restrictive for a general purpose computing system, and so efforts were made to create devices which could solve problems in multiple domains (Starner, 2001).

According to Rhodes (1997), generalized wearable computing devices (devices which solve problems in multiple domains) should have the following characteristics:

a) Portable while remaining operational, thereby allowing a user to move and still operate the device.
b) Allow for hands free use and allow for non-obstructive access.
c) Integrate sensors such as wireless communications, cameras, GPS, microphones and accelerometers as input devices to provide information about the close environment.
d) Communicate information to the user in a proactive way, thus conveying information to the user even when not being actively used. An example would be alerting the user when a new email has arrived.
e) Always being on and continuously receiving information about its environment.

The points which Rhodes puts forward are evident to varying degrees in wearable computers taking a more generalized approach to problem solving.

The ability for a single programmable device to solve problems in multiple domains emerged in the early 1980's with a back-pack sized multimedia and text based system which was able to record video and positional information (Mann, 1997b). This inspired further research into augmented reality devices, in which three dimensional virtual objects are added into environments in real time (Azuma, 1997). Augmented reality approaches were used in military, entertainment and medical applications in conjunction with existing technologies to solve problems in more than one problem domain (Azuma, 1997; Mann, 1997b).

The multi-programmable approach to augmented reality in wearable computing resulted in the United States Military using an experimental wearable computing system with their troops, which incorporated a wireless communication link and a helmet-mounted display to aid in battlefield tasks (Zieniewicz, Johnson, Wong, & Flatt, 2002). This popular technique of generalizing the wearable computer to solve a broad range of problems through augmented reality spurred Carnegie Mellon University to develop *VuMan* in the early 1990's, which was a wearable computer that was far more general purpose than its predecessors (Bass, Kasabach, Siewiorek, & Smailagic, 1997). *VuMan* was one of the first devices to attempt to incorporate desktop functionality into a single wearable device (Bass et al., 1997). These early systems did not find any commercial success as they were cumbersome and not easily accessible, resulting in a lack of social acceptance (Starner, 2001).

Miniaturization of hardware components, the availability of low cost sensors and the existence of widespread Internet access over the last few years, have allowed wearable computing devices to become more commonplace, readily wearable and socially acceptable (Swan, 2012). This vigorous expansion of miniature computing devices has led to the concept of *The Internet of Things (IOT)* which can be described as a collection of interconnected and interactive devices which are able to communicate useful real-time information between one another (Swan, 2012). These devices are able to incorporate multiple sensors and vastly improved resources to provide users with convenient access to information relevant to a broad range of applications (Narayanaswami & Raghunath, 2000).

Some notable examples driving the idea of the *IOT* are: *Google Glass*, *Fitbit* and the *Nike FuelBand*. *Google Glass* (Google, 2014) has an optical head-mounted display providing users with a natural language and gesture controlled interface to allow for augmented reality. The *Fitbit* (Fitbit, 2014) and *Nike FuelBand* (Nike, 2014) extend the idea of interconnectedness, where the systems consist of a centralized base-station (smart phone) and a wristband interface which uses an integrated accelerometer to measure movement in a three dimensional space (Montgomery-Downs, Insana, & Bond, 2012). The smart watch also falls into the category of the *IOT*, in which it acts as a peripheral device to a connected smart phone (Bieber et al., 2013). The smart watch will be the primary focus of this literature review, and how it can be used in this interconnected way to solve some of these generalized problems which wearable computing devices have been developed for.

2.3 The Smart Watch

Using Rhodes (1997) definition of wearable device requirements, it can be seen that the smart watch meets these characteristics. The smart watch is: a) portable while still being accessible from the user's arm, b) allows for hands free operation, c) integrates sensors as input devices, d) communicates information to the user despite not being actively instructed to do so and e) continuously receives information on the surrounding environment. Starner (2013) has previously stated the smart watch should also allow for the integration of computer processing in everyday life, allowing users to retrieve information no matter where or when they wish to access it.

Smailagic (2002) has also said the smart watch needs to be aware of user context to be able to respond appropriately in particular situations. It is important that the hardware fits into a user's lifestyle without being an obstruction, and allow for human-computer interaction to occur with minimal cognitive overhead (Starner, 2013). Marks (2013) found that smart watches provided these attributes to their users by being an accessible and convenient method for accessing information; thus smart watches fit the requirements for wearable computing devices. In this section the advantages and disadvantages of the smart watch interface will be discussed, together with a description of one of the smart watches currently available on the market, the *Pebble*.

2.3.1 Advantages

Smart watches have the advantage of always being with the user due to their wrist-watch form factor, which allows for information access at the flick of the wrist, and also makes it less likely to be misplaced (Narayanaswami & Raghunath, 2000). Unlike the smart phone interface, smart watches allow a user to have both hands free thus enabling the user to be unhindered while accessing information (Pascoe & Thomson, 2007). Bieber et al. (2013) found that it aided users in tracking physical movements through the use of the watch's accelerometer, where the force exerted on the watch could be used in gesture controlled applications.

The wristwatch form factor is already socially accepted, where users are familiar with the commonly available wristwatch and feel comfortable wearing them (Kim, He, Lyons, & Starner, 2007). Like the common wristwatch, the interface provides a minimalistic approach to information access, and the user can choose what information they want without having to process unnecessary data (Angelini, Caon, Carrino, & Bergeron, 2013). Although the screen sizes on smart watches are small, their monochromatic nature such as seen on the *Pebble* provides users with a strong textual contrast to allow for strain-free viewing of information. Ye, Malu, Oh, and Findlater (2014) found that visually impaired users preferred to view information on these monochromatic displays rather than on the common smart phone interface.

Recent smart watch designs have resulted in more efficient power consumption (Bieber et al., 2013). This improved power efficiency has aided in the convergence of services into a single device which are based on sensory data and user context (Starner, 2001). These services differ from those incorporated into the smart phone interface as they are suited to particular user contexts to solve problems (Starner, 2001).

2.3.2 Disadvantages

Despite the advantages which smart watches present, there are still some noticeable drawbacks and limitations which need to be addressed. Hutterer, Smith, Thomas, Piekarski, and Ankcorn (2005) and Narayanaswami et al. (2002) have found that power consumption was a significant limitation in the smart watch architecture; this was due primarily to the Graphical User Interfaces (GUI's) and Operating Systems (OS's) used. Smart watches which are not architecturally designed to conserve power, still have to be charged regularly in order to be used (Narayanaswami et al., 2002).

Since the findings of Hutterer et al. (2005), there has been a steady increase in the complexity of GUI's and OS's used on smart watches, which has in turn spurred development in battery technology. However, the improvements in power conservation and extended battery life continue to lag behind computational requirements (Bieber et al., 2013). In some designs, this has resulted in a more centralised approach to data processing. Using such a design allows most data to be processed by a single base station and not on the smart watch itself (Bieber et al., 2013). This processed data can then be communicated back and forth to the smart watch as a peripheral device to the base station (Bieber et al., 2013).

The use of low powered monochromatic displays in newer, more minimal derivations of the smart watch also appear to mitigate the negative effects of increasing power consumption (Bieber et al., 2013). However GUI interaction remains limited to a small touch screen and a few external buttons on smart watches with monochromatic displays. Smart watches such as the *Samsung Galaxy Gear 2* incorporate power intensive features such a touch screen display, camera and heart rate monitor (Samsung, 2014). The use of these features continue the pattern of increasing battery capacity to scale with higher computational requirements (Ping, 2013).

The miniaturized screen on the smart watch can be seen as both an advantage and disadvantage. As stated earlier, Ye et al. (2014) found that the monochromatic screen and side button approach of the Pebble was described as being favorable to visually impaired individuals. However, on smart watches which allow for a touch screen interface, users have commented on the limitations imposed by their fingers obscuring the interface (Perrault & Lecolinet, 2014).

2.3.3 The Pebble Smart Watch

The *Pebble* uses an *ARM* Cortex-M3 processor as its CPU and runs its own *Pebble* OS, which is a customized version of *FreeRTOS* (Pebble, 2014d). It differs from its competitors, such as the *Samsung Galaxy Gear 2* and *Sony SmartWatch 2*, in that it is not a stand-alone device and requires pairing with a mobile phone within its Bluetooth range (Bieber, Kirste, & Urban, 2012; Samsung, 2014; Sony, 2014b). Data processing is not done on the *Pebble* smart watch itself but rather sent to the paired mobile phone

(Bieber et al., 2013).

This paired architecture between the watch and base station supports the *Pebble* being charged only once every few days (Bieber et al., 2013). Furthermore, the *Pebble* utilizes a monochromatic display which has an ambient light sensor that regulates the screen brightness depending on lighting conditions (Bieber et al., 2013). Despite the incorporation of a three-axis accelerometer and a magnetometer, which provides data input based on the surrounding environment, the Pebble still manages to maintain power efficiency (Chyla, 2013). The use of an OS which depends on few hardware resources, and an exterior design incorporating four buttons for human-computer interaction, means user interaction with the *Pebble* is kept simple and intuitive (Narayanaswami & Raghunath, 2000).

The *Pebble* presents a multi-programmable platform on which applications written for *Android* can be executed. This general purpose wearable computing solution incorporates many of the advantages of wearable computing such as convenience and always accessible data retrieval, while providing limited drawbacks when compared to other smart watches such as power consumption and complicated user interfaces.

2.4 Comparisons to other current mobile interfaces

Human-computer interaction techniques with wearable and mobile devices was found to be important when users selected to use one device over another (Starner, 2013). This included the physical ease with which the device could be used and interacted with, and the ease of access to desired information (Starner, 2013). According to Rukzio, Leichtenstern, Callaghan, and Holleis (2006), the context of the user is also important when assessing device preference, as some situations may make certain interfaces more accessible than others. Devices such as *Google Glass*, smart watches and other mobile platforms have their own unique attributes which separate them from one another in how users access information (Smailagic, 2002).

The smart watch takes the form of a standard wristwatch and thus allows for an unobtrusive and always viewable source of information without the necessity of reaching for any other external device (Marks, 2013). Some smart watches are currently viewed as complimentary devices to smart phones, where both devices synchronize their operations to complete tasks. Some smart watches fit this paradigm more closely than others, while some smart watches maintain an independent data processing model. For example, the *Samsung Galaxy Gear 2* is designed to operate as more of a standalone device, which is capable of synchronizing periodically to a smart phone, as opposed to the *Pebble* smart watch which communicates constantly to a paired smart phone (Bieber et al., 2013). These synchronization options have implications when assessing processing power on mobile devices.

In terms of processing power on mobile devices, the smart phone has been found to exhibit a greater ability to deal with computationally intensive tasks than its other wearable counterparts (Marcial, 2010). A more powerful processor is supported on the smart phone due to the smart phone having a more powerful battery than most wearable devices currently support (Bieber et al., 2013). Users have been found to derive benefits from familiar screen layouts when interacting with devices (Marcial, 2010). The smart phone provides a familiar interface to users through the use of icons and menus (Marcial, 2010). However, the smart phone is not specifically designed for problems which wearable devices aim to solve (Starner, 2001).

Wearable devices such as *Google Glass* are primarily concerned with augmented reality specific tasks, and are used in a hands-free way to retrieve data. The *Google Glass* interface allows for an always available head-mounted display above the eye, and can be interacted with via voice commands (Google, 2014). Applications for *Glass* have been used largely in the medical field, where data can be retrieved and synchronized to an external device. Levine (2014) described the ease of use for applications in the field of Obstetrics such as the streaming of vital signs during patient sedation and for streaming live ultrasound images. There was also a usage found for *Glass* in pediatric surgery by Muensterer and Lacher (2014), where relevant data required by surgeons was easy to access, and surgical procedures were able to be recorded while a simulated surgical procedure was performed. *Glass* has the advantage of convenience in allowing information retrieval without any arm movement, but has been seen to lack the necessary processing power to deal with any computationally intensive tasks and multitasking functionality (Muensterer & Lacher, 2014).

Smart phones, smart watches and *Google Glass* have the ability to synchronize their actions with a base-station for further processing or storage purposes (Bieber et al., 2013). These interfaces are designed to be used for specific tasks where the convenience of information access can be maximized depending on user context (Smailagic, 2002).

2.5 Application Development

The adoption of smart watches by users was addressed by Seppala and Broens (2013), where it was found that the experience of retrieving information was the key principle driving information access through any particular device. User experience was also affected by how users could control their personal flow of information. The way in which users retrieve and control their information is through the applications which have been developed for the relevant device. Application development for the smart watch has currently been pursued by *Android* and *Apple iOS* for the open source and proprietary markets respectively. These applications are initially installed on a smart phone where they are able to interact with a connected smart watch via Bluetooth.

2.5.1 Current mobile applications used by university students

According to Bowen and Pistilli (2012) mobile applications can be divided into the categories of:

- Device neutral, which are delivered to the device from a mobile browser; and
- Native applications, designed for a specific platform such as *Android* or *Apple iOS*.

The choice between which category of application is used, has been shown to be dependent upon the activity being performed and the nature of the information needed (Bowen & Pistilli, 2012). Application usage amongst university students has been found to be dependent upon students' lifestyles (Sandars, Homer, Pell, & Croker, 2008). The development of native applications appears to model the popularity of these lifestyle information requirements (Sandars et al., 2008).

Undergraduate university students have been found to use native applications more readily than device neutral applications accessed through a mobile web browser (Bowen & Pistilli, 2012). A study into the applications which were popular amongst undergraduate medical school students was conducted by Sandars et al. (2008), in which it was found that users were primarily involved with social networking, email and instant messaging based applications. The same users were found to use device neutral applications in circumstances where information was of a less personal nature. These device neutral applications are designed for widespread access among multiple users, such as online content sharing websites and wikis (Kreutzer, 2009).

Connectivity to the Internet has been found to be important when determining what applications are being used by university students (Sandars et al., 2008). Students have been found to use web based services primarily to download native applications for their devices and for communication services (Sandars et al., 2008). These native applications are subsequently used via the mobile web to perform social networking, shopping, news, education and location based services (Bowen & Pistilli, 2012). Native applications most commonly used without the use of the mobile web were found to be gaming, music and media based services (Bowen & Pistilli, 2012).

Software used on most smart watches is run on the paired smart phone, acting as a native application, with the exception of the *Samsung Galaxy Gear* variants (Chyla, 2013). The smart watch is then used as an external device for gaining access and generating any input data that can be processed further on the phone. Application usage on the smart watch has yet to be studied as in depth as its smart phone counterpart. However, sensor-based data on user context and information accessibility appear to be driving application usage on the smart watch (Chen, Grossman, Wigdor, & Fitzmaurice, 2014). Information can be easily accessed on the wrist while the user is engaged in an activity where it would be inconvenient to access information on a smart phone (Bieber et al., 2013). The wristwatch based design has also made time based applications such as the use of stopwatches, alarms and date information popular amongst users (Narayanaswami & Raghunath, 2000).

From studies done by Chen et al. (2014) it is evident that users want similar services from a smart watch as those they get from a smart phone. The method of information access is the primary aspect which has changed to facilitate convenience. Since users want similar applications from different devices, application development for both devices must adapt to meet a standardized output (Chen et al., 2014).

2.5.2 Application development comparison with the smart phone platform

Application development for increasingly powerful mobile phone hardware is currently supported by OS models such as *Windows Phone 8.1*, *Apple iOS* and *Android* (Meier, 2012). *Windows Phone 8.1* and *Apple iOS* are closed source and can prioritize applications depending on whether they are native or third-party, restrict inter-process communications and ultimately limit the control of data between user and system space in the OS (Meier, 2012). *Android* takes a different approach to partially eliminate such restrictions by employing an open source OS model and using a *Linux* kernel (Meier, 2012). The open source nature and common application structure of *Android* has also made it popular for smart phone application development (Joseph, 2013). The *Android* OS will be investigated for its development potential on both the smart watch and smart phone platforms.

Android development on smart phones has become increasingly popular. According to the smart phone market share in 2013, *Android* represented approximately 37% of the total mobile OS market (Liu, Li, Guo, Shen, & Chen, 2013). The study conducted by Bowen and Pistilli (2012) (n=1566) also found that 43% of the students who partook in their user study used *Android* devices, followed by *Apple iOS* (40%) and Other (17%). *Android* applications are developed via a *Java* based SDK and an *Android* Development Tools plug-in for the *Eclipse*[1] Integrated Development Environment (IDE) which can be installed from the developer website (Android, 2014a). These development tools include the necessary API's and libraries for the creation of *Android* smart phone applications. Applications developed using the *Android* SDK can be run on the integrated emulator or flashed to a connected *Android* device for testing and debugging (Sheusi, 2013).

The popularity of *Android* native smart phone applications is evident from Perez (2014) where it was found that *Android* applications were downloaded 45% more than their *Apple* counterparts in the first quarter of 2014. From the user study conducted by Bowen and

[1]http://www.eclipse.org/

Pistilli (2012), popular native applications used for social networking such as *Facebook*, *Twitter* and *Instagram* already have multiple variations for users to chose from. According to Bowen and Pistilli (2012) there are two approaches to developing native applications for a smart phone: standard native development and the use of online mobile development frameworks such as *PhoneGap*[2] and *Appcelerator*[3]. These online development tools allow for the creation of applications using a toolset of web development languages such as *CSS3*, *JavaScript* and *HTML5* (Bowen & Pistilli, 2012). Native device functions are still able to be accessed through a *JavaScript* API between the OS and the container running the application on the web (Charland & Leroux, 2011).

Device neutral applications or cloud-based services are less dependent upon device resources and run on a client-server architecture, allowing for access to information via a mobile Internet connection (Dinh, Lee, Niyato, & Wang, 2013). The development of device neutral applications is not specific to *Android*, the only prerequisite is the installation of a *HTML5*, *JavaScript* and *CSS3* capable browser on the smart phone (Dinh et al., 2013).

The application development for the smart watch follows a similar approach to that of the process used to create native smart phone applications. The main differences being the device used to install and debug the application on, and the use of a different SDK in *Eclipse*. The *Android Wear* SDK is a set of specific API's and libraries for wearable devices which use the *Android* platform (Wear, 2014). This SDK focuses on integrating unique wearable computing functionality, such as the use of wearable sensors, into the development of *Android* applications (Wear, 2014). Development for the *Pebble* smart watch requires *Pebble's* own SDK (*PebbleKit*), which is available for installation on *Linux* and *MacOS X*, as no *Android* OS runs natively on the *Pebble* smart watch itself (Bieber et al., 2012). *Pebble* also provide a web based development framework through *CloudPebble* for use on *Windows* machines (CloudPebble, 2014).

There are distinctions between smart watch and smart phone development (Chen et al., 2014). The *Android* OS on the smart phone is able to utilize more of the available on-system hardware resources than the OS on the smart watch. This is a limitation for application development on smart watches such as the *Samsung Galaxy Gear 2* and *Sony SmartWatch 2* which have native *Tizen* and *Android* OS kernels respectively (Samsung,

[2]http://phonegap.com/
[3]http://www.appcelerator.com/

2014; Tizen, 2014). Other smart watches implement a proprietary kernel, which is used to retrieve and send data to and from the smart phone (Bieber et al., 2013). This allows for a simpler approach to application development, where all development is performed on the smart phone, just as native smart phone applications are, and not on the smart watch (Bieber et al., 2013). Allowing the smart watch to become a peripheral device to the smart phone means the native kernel on the smart watch does not require access to a large number of on-device resources (Bieber et al., 2013).

2.5.3 Possible future smart watch advancements

The emergence of devices which solve new problems, and allow for data access in new user contexts will expand the family of wearable computing devices (Abowd, Dey, Orr, & Brotherton, 1998). According to Chen et al. (2014), this expansion involves smart devices, including smart watches, being interconnected to each other. Starner (2001) has previously stated that devices which satisfy user requirements most adequately will survive in the wearable computing market. According to Marks (2013), the smart watch interface has been predicted to replace the smart phone in accomplishing simple tasks such as the viewing of text and accessing sensory data. The growing popularity of the smart watch amongst users has already led to innovative solutions in problem areas involving gesture control and movement based analysis (Bieber et al., 2012; Morganti et al., 2012). With the continuing improvements of hardware and software being developed for the smart watch interface, it is expected to grow in popularity (Schlegelmilch, 2014).

The lack of rapid change in smart watch hardware growth is partly due to the interaction between the smart watch and smart phone, where the operation of the smart watch is largely dependent on the more powerful smart phone (Patterson, 2013). This observed slow change is also partly due to Bell's Law which states that a new platform emerges approximately once every decade, and is based on a new interface and form of usage which establishes a new industry (Bell, 2014). A new platform, such as that of the smart watch, will have an initially slow growth in performance characteristics in comparison to that of the smart phone (Bell, 2014). It is expected that the need for further changes in smart watch hardware will become more apparent as the platform becomes more popular (Patterson, 2013). Smart watches which are designed to perform more on-device computations in the future will likely have multiple processor cores incorporated into their designs (Horowitz, 2014). Such is the case with the *Samsung Galaxy Gear 2* (Samsung, 2014) and *Neptune Pine* (NeptunePine, 2014) which already incorporate multi-core CPU architectures. Besides the obvious hardware components of the smart watch interface, individual components such as the battery, display and radio transmitters / receivers have the potential to be improved upon in order to add to the overall functionality of the smart watch (Horowitz, 2014).

The ability to supply power to the smart watch device without negatively affecting user experience is an ongoing challenge (Hodges, 2013). Battery technology on smart watches continues to lag behind the improvements of hardware resources which follow Moore's law (Hodges, 2013). The majority of current mobile computing devices use rechargeable Lithium-ion (Li-ion) batteries which struggle to scale with ever increasing computational demands (Hodges, 2013). Currently the effects of this are mitigated by designing hardware as efficiently as possible (Weyland, 2013). Emerging technologies such as carbon-fiber wearable super-capacitors aim to store a combination of energy from environmental sources such as body heat, sunlight, body movement and ambient radio frequencies (Jost, Stenger, Perez, & McDonough, 2013). Until such technologies become commonplace, components which consume the most power like the display and radio transmitters will have to be designed with maximum power efficiency in mind (Horowitz, 2014; Weyland, 2013).

Alternatives are being found for current display technologies on smart watches which divert from the common liquid crystal (LCD) and monochromatic displays currently used (Mims, 2013). *Qualcomm* have developed a *Mirasol* display which operates by refracting light and requires no power unless being updated (Mims, 2013; Qualcomm, 2014). The monochromatic memory LCD display technology used on the *Pebble* is the same as that used by the *Agent* smart watch (Agent, 2014). This screen technology is being pushed as the future for minimal display technologies. Memory LCD's are being used primarily for peripheral screens which compliment a main LCD display being used on a device such as a smart phone (Mims, 2013). With the design of efficient display technologies and other components, new features are able to be incorporated into the smart watch, such as additional radio connectivity (Horowitz, 2014; Weyland, 2013).

Near Field Communication (NFC) is already being used for digital wallet applications on smart phones via the use of specialized chips which are based on existing Radio Frequency

Identification (RFID) standards (McHugh & Yarmey, 2014). According to Goss (2013) NFC applications on smart watches could be one of their most desirable features, creating a potential "killer app" which could take advantage of the convenience of an always available wrist based interface. NFC capability has yet to become a common feature on most current smart watches with only the *Sony Smartwatch 2* currently capable (Sony, 2014a), as well as a lack of widespread use on smart phones. The convenience of the smart watch paired with NFC highlights the need for some degree of interconnectedness between smart watches and the *IOT* (Goss, 2013).

With the growing nature of the *IOT*, smart watches are set to join smart environments which consist of multiple interconnected devices performing micro-interactions via radio technologies such as RFID and Bluetooth (De Russis, 2014; Weyland, 2013). An example of such an environment would be that of household automation systems, which are able to be controlled from a device such as a smart phone to interact with physical objects in an environment. Automation systems being developed by *iControl*[4] plan on incorporating the paired connection architecture of the *Pebble* and smart phone (De Russis, 2014). In such an architecture, the smart phone acts as a gateway to access the web and consequently is able to control actuators in a physical domain (such as a building) via a web service (De Russis, 2014).

Smart watches which present the right balance between hardware performance, extended battery life, interaction with their environments, and the use of applications which improve user experience will ultimately lead the smart watch interface into the future (Patterson, 2013). Hardware advancements provide a solid foundation for the OS's being run on them, including any Input/Output (I/O) software which is developed. I/O has been found to be a challenge on small devices, both as a hardware and software issue, and often requires unique implementation techniques (Funk, Sahami, Henze, & Schmidt, 2014).

When harnessing the power of recent hardware advances, possibilities begin to arise as to what information can be accessed through that hardware (Narayanaswami, Raghunath, & Kamijoh, 2001). I/O software being developed for smart watches attempt to take advantage of, and compliment, the hardware available (Bieber et al., 2013). Since the smart watch has limitations associated with its small screen size such as text input and data output techniques, there have been attempts to alleviate these issues (Funk et al.,

[4] http://www.icontrol.com/

2014). Research has been conducted in building onto existing hardware and software available for the smart watch to improve I/O techniques. (Funk et al., 2014).

For small screen devices such as the smart watch, Dunlop, Komninos, and Durga (2014) found an easier way to input text in email, messaging and social networking applications. The new method uses an optimized on-screen alphabetic layout, similar to those currently used on smart phones, and can be used on smart watches with a touch screen interface (Dunlop et al., 2014). Funk et al. (2014) developed a wristband based text input system which has replaced the wrist-strap of the watch. This solution uses multiple sensors in the watch strap which are mapped to visual elements on the surface of the strap, such as function keys and letters for text entry (Funk et al., 2014). Wrist-strap input aims to remove the problem of screen occlusion caused by text input via the user's finger on touch screen displays (Funk et al., 2014).

Amma and Schultz (2013) have developed a hand gesture method for text input, which uses the hand of the user as a stylus and a character recognition algorithm. User interaction with smart watches involving flexible input and rapid text entry are vital components of the smart watch interface (Wobbrock, 2006). The way the user interacts with the smart watch in terms of both input and output has much to do with the overall user experience (Wobbrock, 2006). Other means to allow for the input of information have been researched such as gesture based interaction and voice commands.

Gesture controlled input for smart watches has been studied by Bieber et al. (2012), in which it was found that situational awareness and the use of sensors could be used as input to the smart watch device. A study performed by Xiao, Laput, and Harrison (2014) studied user input using wrist gestures where an application was developed that used pan and tilt movements to navigate different menus and select various icons. Voice commands are now being used as the primary input method in some smart watches such as the *Martian* (Martian, 2014), which allows for communication with *Google Now*[5] and *Apple Siri*[6] on the connected smart phone. The use of voice as an input has limitations in terms of clarity for the smart watch to recognize in noisy situations, however attempts at implementing noise cancellation into the device's microphone have proven to be successful (Shanklin, 2013). Both voice and gesture control software have been implemented as a

[5]http://www.google.com/landing/now/
[6]http://www.apple.com/ios/siri/

standard feature on the *Kreyos Meteor* (Kreyos, 2014) smart watch. The *Kreyos Meteor* has the functionality to answer calls at the wave of a hand, and can be programmed to perform any number of actions when interacted with by a specific wrist gesture (Garber, 2013).

Data output techniques on smart watch displays have to be developed with physical size constraints in mind (Chen et al., 2014). Attempting to display too much information on devices with small screens can raise the problem of text overflow onto multiple screens or information clipping (Sanchez & Goolsbee, 2010). *Spritz* text reading software is now available, which allows the user to maintain the viewing of a fixed position on the screen, while text enters the view area from right to left for the user to read (Spritz, 2014). This method of reading text has the advantage of only allowing a few characters to be displayed at any time on the screen, thus saving screen space (Spritz, 2014). However, the *Spritz* technique used for reading has the disadvantage of a possible loss of context while reading, this is due to there being no past reference kept of the text being read (Paul, 2014). The *Samsung Galaxy Gear 2* has this software already installed, however the SDK is freely available from the *Spritz* website for developers to implement on other devices (Petrovan, 2014). Output on the smart watch is not only limited to visual data representations, but also haptic and aural via the use of vibration motors and internal speakers respectively.

2.6 Summary

This literature review has discussed the smart watch interface within the domain of wearable computing with specific focus on the *Pebble*. The *Pebble* has been compared to other smart watches currently available such as the *Samsung Galaxy Gear 2*, *Sony SmartWatch 2*, *Kreyos Meteor*, *Neptune Pine*, *Martian* and the *Agent*. The advantages on the *Pebble* were also discussed, such as the minimal display, efficient power management and simple user interaction techniques used. The smart watch has been analyzed as an alternative interface to the conventional smart phone, and the differences between these interfaces have been addressed. Convenience and always accessible information access have been found to be the driving factors for the popularity of the smart watch interface amongst users.

Previous studies found that university students prefer to use native applications over web based services on smart phones. Issues relating to how university students interacted with these devices for information access, and issues affecting information needs on such devices have been highlighted. This literature review has reviewed relevant issues relating to smart watch usage, such as how information accessibility and user context contribute to its growing popularity. It has also been shown that users want similar information from smart watches as they do from smart phones.

The next chapter uses this review as a basis to introduce the methodology used in the design and development stages of the prototypes and applications on the smart watch. User requirements from previous studies provided some guidance as to what findings were to be expected in the findings from the requirements gathering process. Previous applications which were developed as a result of user requirements found, allowed for design and implementation decisions to be made on the development of future applications on the smart watch.

Chapter 3

Methodology

3.1 Introduction

This chapter describes the methodology used in undertaking this research. The goals of this research were to determine whether university students would want to use a smart watch and what applications they would consider to be useful on one. This methodology includes the method by which information was gathered from participants, and how the applications, which were created as a result of this information gathering process were developed. The Spiral model was used as a framework to describe the way in which the requirements were gathered, design and implementation was performed and how evaluation was conducted. This framework was used for both the prototype applications developed from the requirements gathering part of the study, and the final applications used in the field study performed. The way in which the usability evaluation was conducted and guided by the DECIDE evaluation framework is also discussed. The DECIDE framework is described in terms of its component parts and how each part relates to the usability study that was performed.

3.2 The Spiral Model

The Spiral model is an iterative framework used in system development, developed by Boehm (1988), where an iteration consists of the four phases of requirements gathering, designing a solution, implementing a solution and evaluation (Krogstie, 2012). Upon completion of the evaluation phase of the spiral model, the achievements of that iteration should be reviewed and the next iteration should be planned (Krogstie, 2012). Boehm (1988) found that using such a framework allowed for necessary changes to be made at an early stage of application development, and for further refinement until system completion. This section will document two iterations of the Spiral model that were applied to the initial prototype applications developed from the requirements gathering process, and subsequently the final applications developed for the user study. The Spiral model depicted the iterations towards the final applications developed, and is shown in Figure 3.1.

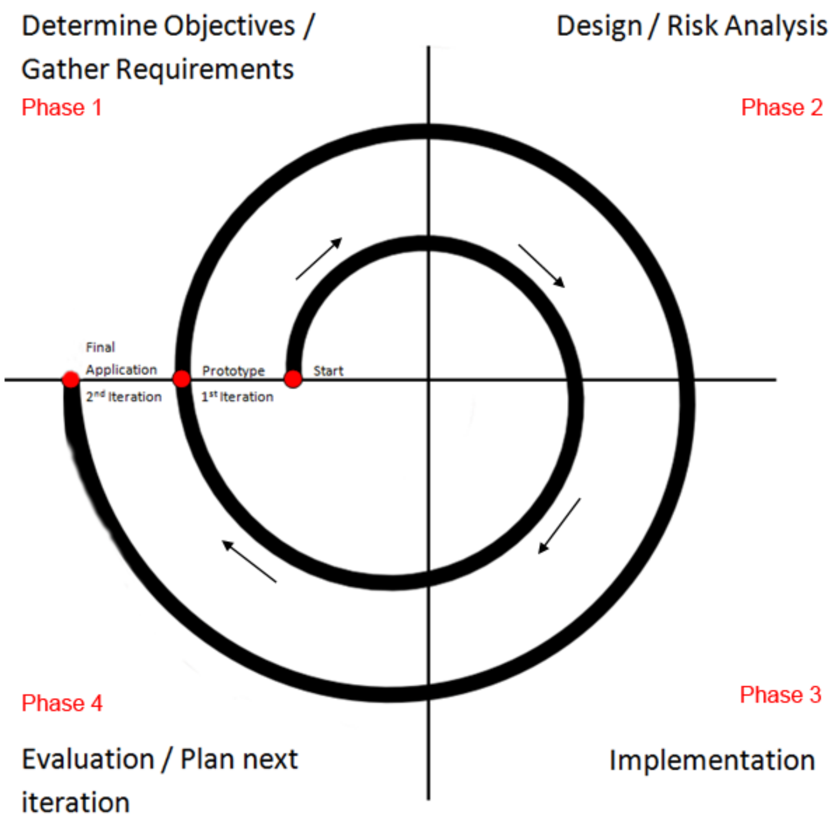

Figure 3.1: Spiral model showing the iterations towards final application development

3.3 Requirements Gathering

3.3.1 Approach

The requirements gathering part of the study had the aim of collecting data on potential smart watch users among university students. As part of the first phase of the Spiral model, a questionnaire (described in greater detail in Section 3.3.2) was developed to solicit opinion pertaining to smart watches. The questionnaire (see Appendix A.1) was created and deployed online through the use of Google Forms. Google Forms was used due to its simplicity and ease of accessibility for participants (Guay, 2014). Consent was sought and then granted by Rhodes University (control no. CS-14-01) and the relevant course coordinator. The participants were from the Computer Science Literacy (CS1L1) class at Rhodes University, and the questionnaires were answered in the afternoon practical sessions (31 March - 3 April 2014) which were held in one of the computer laboratories on the Rhodes University campus.

On each afternoon the class were informed of the goals of the research study being performed, and that a questionnaire had been made available to them by the researcher. They were also informed that their participation was voluntary but would be appreciated. Electronic consent (see Appendix B.1) was completed by interested participants which informed them of the goals of the study, ensured their anonymity and informed them that they would be free to withdraw from the study at any time. The requirements gathering part of the study was considered quantitative in nature and so as many participants as possible were preferable in order to gain a broad understanding of the types of applications wanted, and the perceptions surrounding the use of the smart watch (Rogers, 2014; Rudd, Stern, & Isensee, 1996). From the CS1L1 class (n=211), 89 gave consent to participate in the study.

3.3.2 Questionnaire

The requirements gathering questionnaire asked for demographic information such as age, gender, ethnicity, year of study and subject majors. The question of whether or not participants would use a smart watch was then asked. Assessing the desire for the use of a smart watch was a prerequisite for further analysis of application development. A list of possible applications was presented in the questionnaire from which participants were asked to select the ones which they would consider to be most useful, as well as providing ideas for other useful applications. This gave participants the opportunity to give their input on their general perceptions of the smart watch and on a broad variety of applications which were available. From that information there would be further investigation into the applications which seemed to be most valuable to them.

The participants were then asked about any other application ideas they might have that they would like to see incorporated into the smart watch. Lastly, participants were asked if they thought using the applications they selected would be easier to use on the smart watch as compared to a smart phone, and the reasoning behind their answers. The results were collected with Google Forms and the results were noted for further analysis. The raw data collected on Google Forms was imported into a Microsoft Excel spreadsheet where further analysis was performed and any particular trends in the data were sought. Google Analytics has been found to be an effective tool in assessing the results of linked Google Forms and provides a visual representation of the results produced by the completed questionnaires (McGuckin, Conor and Crowley, Niall, 2012).

3.3.3 Application Design and Implementation

After analyzing the results from the questionnaires (see Section 5.1), the applications which were described as the most useful by participants were selected for development. As per the results obtained in Section 5.1, it was noted that weather, email and calendar applications were most popular. These findings prompted the development of a single application (notifier application) which incorporated these functionalities and attempted to satisfy user requirements.

Out of the applications proposed by the users (see Table 5.5), any interesting or unique applications suggested were taken into consideration for further development. Phone finding functionality was found to be the most popular suggestion, and was subsequently decided upon to be developed into an application. After the requirements gathering process, two applications were designed using mock-ups (see Section 4.1.1) and developed as Prototypes in Microsoft Powerpoint (see Section 4.1.2) to fulfill the user requirements identified. The design and development of the prototypes represents phases two and three in the Spiral model (see Figure 3.1).

3.3.4 Expert User Evaluation

An evaluation of these application prototypes took place upon their development as per the fourth phase of the Spiral model in the first iteration (see Figure 3.1). Input was gathered from two expert users who provided constructive feedback on the operation of these prototypes. Prototypes were used to simulate the content and user interaction with the applications without engaging in the development of the final application (Treder, 2012). This meant that user input could be used in the planning stages for further application development, and to guide development of the applications towards achieving their goal of satisfying user requirements (Treder, 2012).

The notifier application was found by the expert users to be best suited to having a watch face as the main screen, from which a main menu could be accessed and the other functionalities used. The incorporation of larger weather icons and fonts were also requested by the users for the weather functionality. It was also requested that the calendar functionality should incorporate an alarm which alerts the user of an appointment before the appointment time.

3.4 Final Applications

The feedback gathered from the expert user evaluation was taken into consideration for the requirements gathering phase (phase one) for the second iteration of the Spiral model (see Figure 3.1). The design and implementation (phases two and three) of the second iteration for these two applications (see Figure 3.1), is addressed in Chapter 4. The finished applications were then evaluated by users in the usability study, which represented the fourth phase of the spiral model of the second iteration.

3.5 Usability Study

A usability study was performed to determine the usability of the notifier and phone finder applications by a target group of university students after the prototypes of these applications had been developed. This was conducted through the a field study in which participants were evaluated through questionnaires and interviewed. By performing the usability study it could be determined if the smart watch was a device which could be useful to view information on. The DECIDE framework was used to guide the evaluation of both applications and kept the study directed towards achieving its goals (Rogers, 2014). In this section the evaluation phase (fourth phase) of the second iteration of the Spiral model (see Figure 3.1) is described, and the DECIDE framework is explained where each of its component parts are addressed in terms of the usability study performed.

3.5.1 DECIDE Framework

Identifying the goals which need to be achieved and the right questions to be asked are fundamental in planning and evaluation (Basili, 1992). The DECIDE framework defines six items which should be followed in a usability study that are used to create an overall scope of the evaluation and achieve its established goals (Rogers, 2014). These items are listed as:

1. Determining the goals which need to be achieved
2. Exploration of the questions
3. Choosing the evaluation methods
4. Identifying the practical issues
5. Deciding how to handle the ethical issues
6. Evaluation, interpretation and presentation of the resulting data

The way in which the usability study was performed is described in terms of each component of the DECIDE framework (see Section 3.4.2 - 3.4.6)

3.5.2 Determining Goals

The goal of this study as whole was to determine whether the smart watch would be considered useful by university students. This was to be achieved through the development of two applications for the smart watch satisfying user requirements gathered in the requirements gathering process (see Section 3.3), and evaluating those applications by means of a field study. The development of the final applications took the requirements gathered in Section 3.3 and the expert user feedback from the evaluation of the prototypes into consideration. The final result of the evaluation of the applications in the field study will allow for a conclusion to be drawn as to the usefulness of these applications on the smart watch, and for the usefulness of the watch itself as a form of wearable computing.

3.5.3 Questions and Evaluation Paradigm

The questions which were asked in this research were whether the smart watch could be a useful interface to university students, and what applications students would want to use on such an interface. The answer to the latter was answered through the results obtained in the requirements gathering process in Section 5.1. Whether or not the smart watch could be useful through the installed applications was answered through the field study described in this section, which consisted of a questionnaire and interview process.

The questionnaire (see Appendix A.2.1) used in the usability study was comprised of two sections; one relating to the notifier application and the other to the phone finder application. The questions in the questionnaire concentrated on the usability aspects of the smart watch with the developed applications installed, and were based on the System Usability Scale (SUS) developed by Brooke (1996) as a guideline to determine overall application usability. A series of interview questions were also asked (see Appendix A.2.2) which also focused on the usability aspects of the smart watch and the applications developed.

The evaluation was conducted in the form of a field study in which participants used the smart watch outside of a laboratory and in a more natural setting (Alston, 2014; Rogers, 2014). The advantage of using a field study was that users were able to use the smart watch in a more natural environment, thus allowing the evaluation to be centered around actual events and life experiences (Blackstone, 2014). The field study also had the potential to highlight real-world usability factors which may have not been apparent at first by the participants (Blackstone, 2014). While allowing for detailed data to be retrieved through the evaluation, field studies also have the disadvantage of not being able to collect data from many participants (Blackstone, 2014).

The questionnaire was made up of multiple statements which each required a response on a scale from one to five; where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree. The SUS evaluation scale is composed of ten alternating positively and negatively worded statements which are numbered from one to ten (Bangor, Kortum, & Miller, 2009). Users are required to rank each statement on a scale between one and five. A user response for an odd numbered question is subtracted by one, and a response on an even numbered question is subtracted from five; thus creating a new set of scores between a range of zero and four (Smichaels, 2012).

The complete SUS method was not implemented in this questionnaire as an explicitly followed procedure as it uses ten questions to calculate a specific score; this questionnaire used six. The decision to use six questions instead of the ten used in the SUS method was due to the irrelevant nature of the last four questions in relation to the applications being evaluated. The SUS method was thus just used as a basis, and the scoring method in this questionnaire was done by using the average scores of all participants per answer to a question. By using multiple evaluation techniques as described by Rogers (2014), with both a questionnaire and an interview, the researcher was able to gather user perspectives on using the watch in finer detail. The themes behind the questions asked in the questionnaire were used as a basis for further evaluation. Notably the themes of ease of use, the usefulness of information received through the smart watch, and the perceived learning curve of using such a device.

3.5.4 Practical Considerations

The usability study was conducted over a period of a week, and participants consisted of second year Computer Science students from the Computer Science 202 (CS202) class at Rhodes University. Prior to the study taking place, the researcher advertised the study to students in one of their lectures, informed them on the goals of the study and explained that potential participants with an Android 4.0 (Ice-Cream Sandwich) phone were invited to participate. Participants were invited to contact the researcher via email if they were interested in participating, and the participants could select a day at their convenience within the specified week of the study in which to take part (15 - 19 September 2014). The usability study was a qualitative evaluation and thus did not require as many participants as the requirements gathering process (Rogers, 2014). A total of eight participants expressed an interest in taking part. Six of the eight participants finally participated in the study to provide information on the usability of the applications on the watch.

The interested participant would meet the researcher in the morning within the Honours laboratory in the Computer Science department at Rhodes University. For easier device preparation, each participant was asked to install the native Pebble control application on their phones before meeting the researcher. The Pebble smart watch was paired with the participant's phone, and the notifier and phone finder applications were installed in conjunction with the native Pebble control application (if it was not installed on the participants phone already). The phone finder application on the watch was also installed in conjunction with the companion application on the user's phone, the installation process is documented further in Chapter 4.2. The researcher did not give any instruction to the participants on how to use the applications once they were installed on the watch. Once the process of pairing the watch with the participant's phone (which took approximately five to ten minutes) was completed, the participant was then allowed to use the Pebble smart watch throughout the day in a real-world environment.

After seven hours, the participant met the researcher to answer a questionnaire and to be interviewed, thus completing the evaluation of the field study. A demonstration of how the phone finder application worked was then provided. The researcher asked the participant to leave the room for a short time period while the participant's phone was hidden. The participant was then asked to enter back into the room and use the phone finder application on the smart watch to find their phone. Upon completion of using the phone finder application, the participant was asked to complete a questionnaire relating to the usability of both the notifier and phone finder applications which they had used during the day. The questionnaire was hosted on Google forms and all results were captured electronically for further analysis. Upon completion of the questionnaire, the participant was interviewed on the use of the smart watch throughout the day. The interview was recorded with a Dictaphone and was later transcribed (see Appendix A.3). The afternoon evaluation session lasted approximately fifteen minutes.

3.5.5 Ethical Issues

Before the usability study was performed it was cleared by the ethics committee in the Computer Science department at Rhodes University (Control No. CS-14-07) and permission was granted by the CS202 course coordinator. In addition to the ethical clearance given by the committee, the participants signed a consent form (see Appendix B.2) before they participated. The consent form, which was part of the questionnaire hosted on Google forms, informed the participants of the goals of the study, ensured their anonymity and also that they would be free to leave the study at any time.

3.5.6 Evaluation, Interpretation and Presentation

The results of the usability study are presented in Chapter 5.2 of this document. The results from the questionnaire consisted of the descriptive statistics of the means and standard deviations of the scores obtained for each question asked (see Table 5.7 and Table 5.8). These scores were downloaded from the Google Forms analytics tool and captured in a Microsoft Excel spreadsheet where this statistical data was calculated. The distribution of participant answers are also shown in Figure 5.5 and Figure 5.6, and were also extracted from the Google analytics tool into Microsoft Excel to be analyzed and presented in a stacked bar graph. The interview results were analyzed using a top-down approach, where questions were used to derive themes and all analysis from users' answers centered around these themes. The responses from the participants were not dealt with statistically, besides the inclusion of means and standard deviations, due to the qualitative nature of the usability study (Rogers, 2014)

3.6 Summary

This chapter introduced the Spiral model as a framework to explain how requirements were gathered from users, leading to the design and development of application prototypes which attempted to satisfy users' information requirements. The same framework was used to explain how information was elicited from expert users through use of prototypes, and how that user feedback was used as an input into the design and development phases of the applications. The usability study of the notifier and phone finder applications was documented using the DECIDE evaluation framework, in which the goals of the evaluation were set and achieved. The design and development phases in the Spiral model were closely linked to Chapter 4 where these phases are explained in further detail.

Chapter 4

Design and Implementation

This chapter documents the design and implementation of the notifier and phone finder applications used in this research, the development decisions made and the way in which both applications achieved their design objectives. The mock-ups and prototyping methods used to gather information for the development of the actual applications are discussed, and the way in which the development of the prototypes closely followed these mock-ups are shown. The general way in which Pebble applications are developed in the CloudPebble IDE and the concept of message passing which is used in these applications are also highlighted.

4.1 Prototype Design

The notifier and phone finder applications were designed using mock-ups and prototyping techniques to first assess their logical screen transitions and user interactions. This section documents the mock-ups and prototypes used in this research. These techniques followed the low and high-fidelity prototyping models used by Rudd et al. (1996), and were used for the second and third phases of the Spiral model for its first iteration (see Figure 3.1). The design and implementation of the prototype only commenced after requirements were first gathered from participants. The applications selected through the requirements gathering process and the evaluation from expert users in Section 3.3.4 were developed for the Pebble smart watch using the web based CloudPebble IDE. CloudPebble utilizes the C language for its primary code base, as well as JavaScript to import web based data for updatable content. Both applications demonstrated message passing between devices connected via Bluetooth 4.0 Low Energy (BLE) for short range communication (Gomez, Oller, & Paradells, 2012).

The fidelity, which refers to how similar the method of interaction is to the finished product, is multi-dimensional and covers the breadth and depth of design processes (Nielsen, 1994). The breadth of a design refers to how many of the actual features are implemented in the design process, and the depth of a design refers to how much detail each feature incorporates. A horizontal prototype is concerned with a large breadth of multiple features and functionalities with little to no depth, whereas a vertical prototype represents a single feature and its full implementation. Any general considerations for further application development are also presented, such as the development environments used, and how compiled applications are sent from the coding environment to the smart watch for code execution.

4.1.1 Mock-ups

A mock-up is a visual representation of the whole design of an application (Hughes, Long, Maddock, & Bearman, 2013). The mock-ups used in this section displayed a limited feature set (limited breadth) of the applications used, and there was no depth into how each feature operated. Due to the shallow breadth and depth which the mock-ups exhibited, they were determined to be low-fidelity (Snyder, 2003). Low-fidelity techniques allow for the illustration of high level design concepts of the applications to be transformed into testable models without any actual development occurring (Egger, 2000). Mock-ups are normally used in the early stages of the design process of an application as an effective mechanism for gaining user input (Hughes et al., 2013). Low-fidelity methods used such as mock-ups represent more of a hypothetical situation which describe the actions as a result of an event, and omit much of the finer details in using the application features (Havighurst, Fields, & Fields, 2003; Snyder, 2003), such as the events which occur after a button click on an application. The mock-ups for the notifier and phone finder applications were used to clarify any design issues for the benefit of the developer, and therefore helped in the development of the application prototypes. The mock-ups for the notifier and phone finder applications can be seen in Figure 4.1 and Figure 4.2 respectively.

The mock-up for the notifier application is shown in Figure 4.1 and consists of a main watch face displaying weather information, as well as the screen transitions to the main menu, email and calendar functionalities. The mock-up of the notifier application also displays the main menu where all functionalities are able to be accessed, as well as the agenda functionality associated with a particular day of the week selected in the calendar functionality. Figure 4.2 displays the mock-up for the phone finder application, and the screen transitions upon the appropriate button presses which reflect the application states; which are Ready, Ringing, Silencing and BT Ping. The companion Android application is also displayed in the mock-up and any messages which can be sent or received from it are displayed.

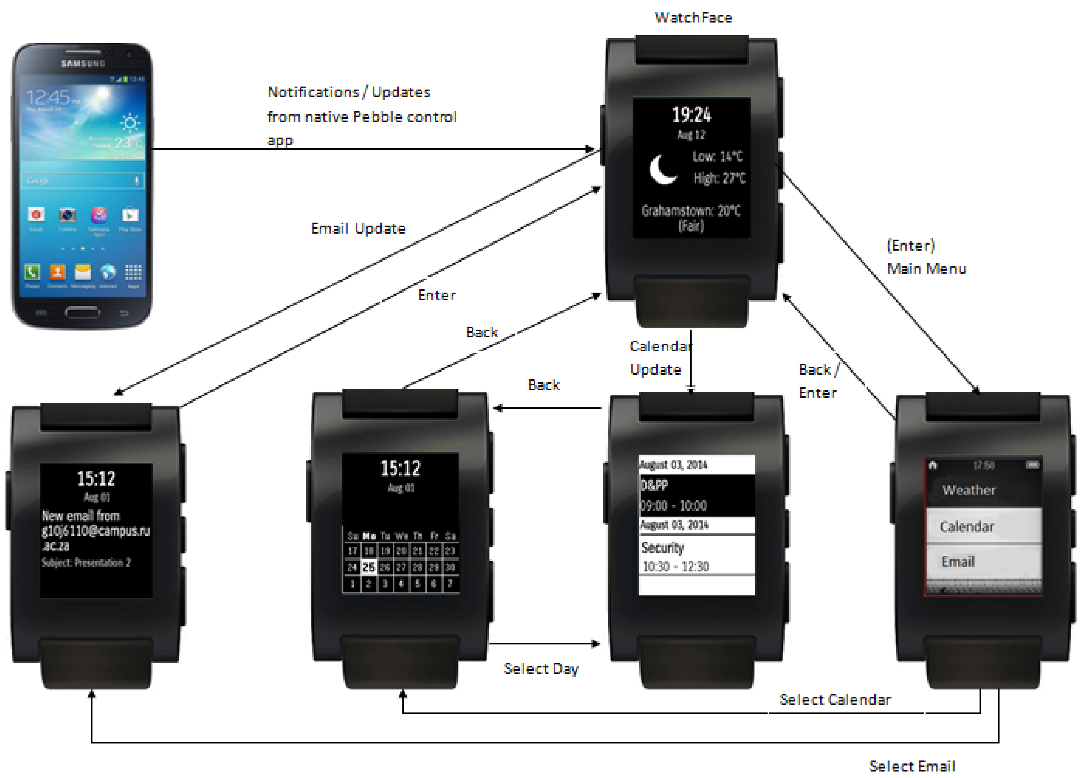

Figure 4.1: Mock-up of the notifier application

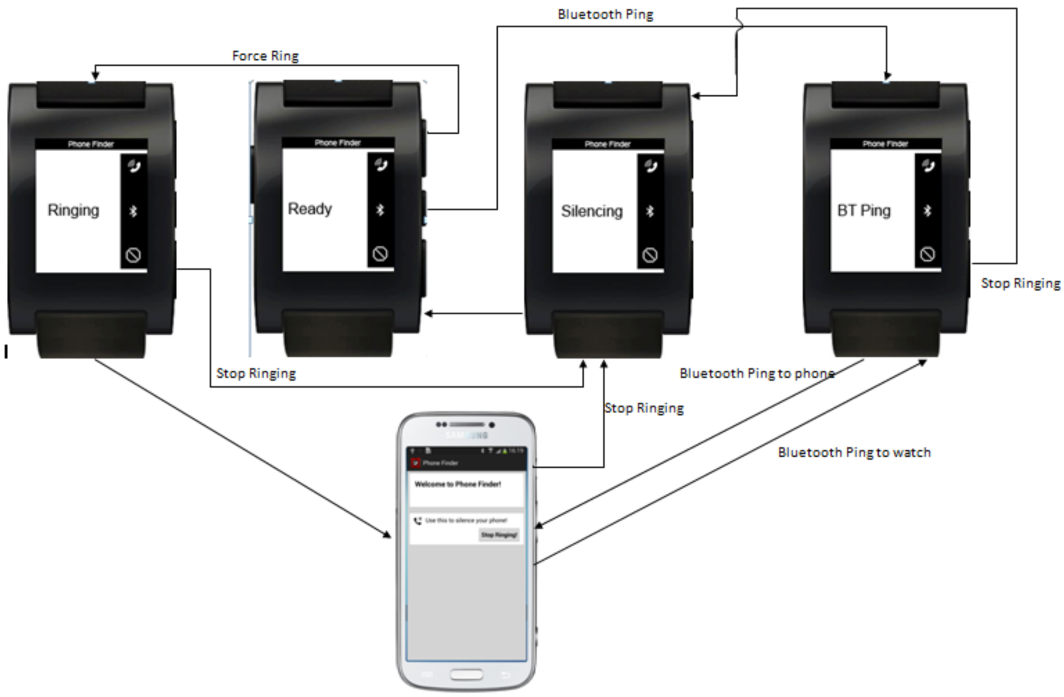

Figure 4.2: Mock-up of the phone finder application

4.1.2 Prototyping

Prototyping is a medium to high-fidelity representation and tangible artifact of the final application to study its feasibility, and is considered to be the best way to evaluate the user interaction with an application through a simulation (Treder, 2012; Virkus, Gülle, Rouffineau & Brady, 2010). Prototyping methods allow for a more realistic way of human-device interaction, modeling similar functionality to that of the final application (Havighurst et al., 2003) such as the simulation of physical button presses, unlike the low-fidelity mock-ups described in Section 4.1.1. The prototypes used in this section were a combination of both horizontal and vertical methods. All the features available on the applications were shown, and the events which occurred via button presses were also implemented. Since button interaction was incorporated but full system functionality was not, it was determined to be a medium-fidelity model (Treder, 2012).

The prototyping for each application was performed using Microsoft Powerpoint. Each presentation consisted of multiple slides which had an image of the Pebble smart watch displaying a different screen of the application being prototyped. A transparent textbox was positioned over each of the buttons on the smart watch image, and an activity was associated with that textbox upon the user clicking it. The purpose of having these textboxes was to simulate user interaction with the watch; a mouse click on a watch button would allow the relevant textbox to trigger its event and transition to the relevant screen of the application.

These prototypes were used to simulate the actual button presses which a user would perform upon using the smart watch, and displayed the screen transitions which would accompany these button presses. The prototypes developed were used for evaluation by the expert users (see Section 3.3.4), where they commented on the screen transitions, screen content and any usability issues found. The results from the expert user evaluation was then subsequently used in conjunction with the requirements gathered from the questionnaire in Section 3.3.2, for the requirements gathering phase for actual application development (see Figure 3.1).

4.2 Development Considerations

According to Pebble (2014f) the available options for developing Pebble applications currently consist of:

1. Installing the Pebble SDK directly onto a Linux or Mac OS machine.
2. Using the web based CloudPebble IDE.

The Pebble SDK, which enables applications to be written for the Pebble smart watch, is currently not available for direct installation on the Windows environment. So for the purposes of this study, the CloudPebble IDE was selected for the application development environment. The reasons for this were the ease of use from a compilation and debugging perspective (Pebble, 2014f), and the use of Windows as the operating system on the machine being used to develop these applications.

Pebble applications are divided into two categories of watch faces and watch applications (Pebble, 2014e). Watch faces are developed with the intention of running for an extended period of time, where information is updated in regular time intervals of either a minute or second and displayed to the user (Pebble, 2014e). Watch faces cannot respond to the user through button presses other than through the back button, or through the watch sensors. Watch faces are therefore developed to work with the least amount of system resources possible (Pebble, 2014e). Watch applications provide users with more functionality than watch faces, and are able to respond to user interactions through button presses. The information that watch applications display are also able to be updated more frequently, and are able to respond far quicker to user interactions than watch faces (Pebble, 2014e). Watch applications allow the programmer to use as much of the system resources as necessary. In the CloudPebble IDE the programmer is able to specify whether they are developing a Pebble watch face or watch application.

For watch applications that need to interact with a paired smart phone, applications need to be developed and implemented on the phone to intercept Pebble communications. This is achieved though the use of the open source PebbleKit library available from the Pebble website (Pebble, 2014e). The PebbleKit library is available for both Apple iOS and Android mobile operating systems, and is implemented in an Objective-C and Java environment respectively. The native Pebble application is installed on the smart phone, and is available from the Google Play store (PlayStore, 2014). It executes any PebbleKit code generated by an application attempting to communicate with the Pebble smart watch (Pebble, 2014e).

Android companion applications can be written to communicate with a Pebble watch application in the same way that the native Pebble application does. For the purposes of this research, the Android applications developed for the smart phone were written using Java SE 8u25 and Android Development Tools v22.6.2 in the Eclipse v3.9.1 IDE. The smart phone which was used to test the companion application was a Samsung Galaxy S4 Mini (GT-I9190) with Android v4.2.2 (Jellybean) installed.

Pebble watch faces and watch applications which are developed on the CloudPebble IDE are sent to the smart phone via the use of WiFi. The CloudPebble user interface allows for the input of the phones IP address on the current WiFi network. The C code which is compiled in the CloudPebble IDE is sent to the specified IP address over the WiFi network, where the native Pebble application intercepts and packages it into a .pbw file to send to the smart watch. The .pbw file is sent to the smart watch over Bluetooth where it is subsequently executed (see Figure 4.3).

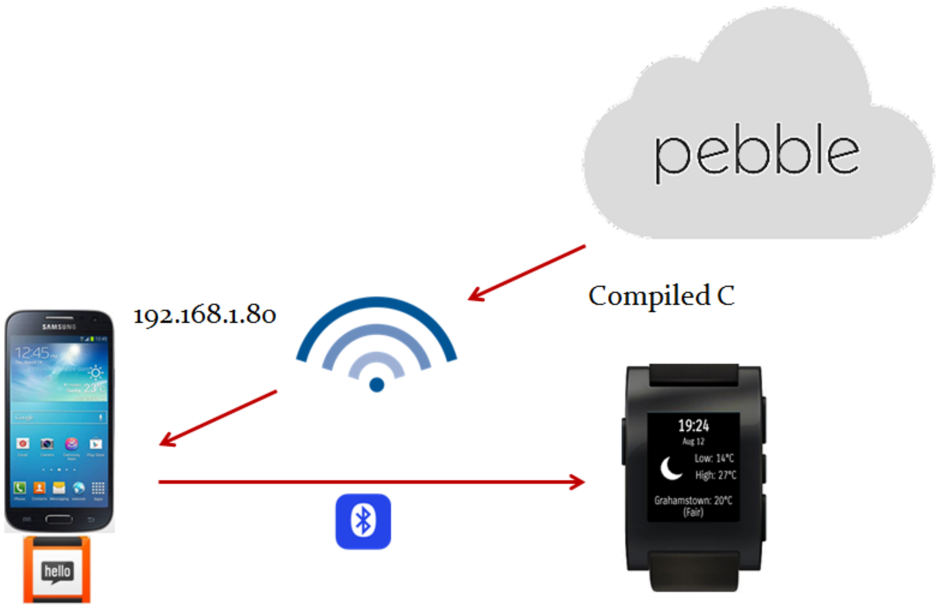

Figure 4.3: Visual representation of how a watch face / application is sent from CloudPebble environment to the Pebble smart watch

4.3 Pebble Application Anatomy

Any Pebble interfaces and functions are imported from the Pebble SDK through the `pebble.h` header file. The `pebble.h` header allows the programmer to access the functions and data structures necessary to develop a Pebble application. Pebble applications developed in the CloudPebble IDE are written in C and therefore follow the C coding conventions. As in any C program a `main()` method is declared in the C file, which is the primary entry point for the application. With the `main()` method, it is recommended that there are methods created for initializing the application through `init()`, beginning the application event loop with `app_event_loop()` and finally deinitializing the application with `deinit()`.

Application initialization is used to initialize any resources to be used in runtime and allocate memory to any data structures used. The event loop of a Pebble application is executed during the application runtime and is not explicitly defined in the application. The event loop within a Pebble application is designed to route events to the appropriate handlers, and executes until the application is ready to exit (Pebble, 2014a). The event loop initiates the communication service on the Pebble smart watch and allows for message passing between the phone and watch. Application deinitialization involves the release of any system resources which were allocated in the calling of the initialization process.

Developing a Pebble application requires the creation of user interface (UI) elements which are to be displayed on the watch screen. Pointers to these UI elements are stored as global variables. An application UI primarily consists of a window and any number of graphics layers. The window serves as a container (root layer) for any graphics layers (children layers) which are to be displayed. Layers are drawn on the screen when the Pebble OS registers that the screen needs to be updated. These layers contain the geometric information used to draw them on the screen and any meta-data such as font and text alignment information. A code representation of the pebble application structure with a simple UI can be seen in Appendix C.1.

4.4 Message Passing

The notifier and phone finder applications represent a proof of concept of the passing of messages between devices. The bi-directional message passing between the smart watch and smart phone is handled by the `AppMessage` library in the PebbleKit SDK where there are four functions which manage the sending and receiving of messages (see Appendix C.2). The `out_sent_handler` function is responsible for sending a message to the application installed on the phone, whether this be the native Pebble control application or an application written in Java hosted on the phone that can intercept this message (Pebble, 2014c). The `out_failed_handler` function is called after an outbound message is unsuccessful in being sent to the phone, and provides a way in which to handle errors in the message sending process (Pebble, 2014c).

When messages are passed from the phone to the smart watch, the `in_received_handler` function allows for these messages to be stored in a buffer and for further processing to be performed (Pebble, 2014c). The `in_dropped_handler` function allows for any message errors to be handled. Errors can occur when receiving a message from already pending messages which need to be processed first before any new messages can be received, as well as in situations where buffer overflow occurs (the received message is larger than the buffer used to receive it) (Pebble, 2014c).

Messages which are sent and received by the watch are identified through key-value pairs and are sent / received as JavaScript dictionary objects (Pebble, 2014g). The keys are defined as an enumerated type, and allow for the Pebble to identify the appropriate JavaScript function to execute in order for the relevant data to be updated (Pebble, 2014g). The value associated with the key is the payload which the JavaScript function will use as an argument for further processing (Pebble, 2014g).

4.5 Notifier Application

The prototype for the notifier application which was evaluated (see Section 3.3.4) in conjunction with the findings in the requirements gathering process (see Section 5.1.3) provided input into the development of the notifier application. Participants expressed their desire to have weather, calendar and email functionality available on the smart watch, and these requirements were incorporated into the notifier application. The notifier application consisted of a watch face and a watch application following the same development structure as seen in Figure 4.5, however there were some methods introduced to allow for more logical code representation. These methods in conjunction with the message passing methods (see Section 4.4) are discussed further in relation to how the notifier application provided weather, calendar and email functionality.

This section provides the Unified Modeling Language (UML) representations and screen shots for each functionality of the notifier application and descriptions of their operation, thus describing phases two and three of the second iteration in the Spiral model introduced in Section 3.2. The full source code for the notifier application is available on the electronic appendix accompanying this document (see Appendix D).

4.5.1 Weather

The weather section of the notifier application was developed as a watch face and thus was unable to respond to button presses from the user as explained in Section 4.2. The application consisted of three primary C files with a header file for each housing any function declarations (see Figure 4.4). The `Main.c` file hosted the main components of the weather functionality such as the window layers for the UI, the `main` method for the program entry point and the message passing functions. The `Weather.c` file defined the functions used to load previously saved weather information in persistent storage as well as request an update through the accompanying JavaScript file. Lastly the `Preferences.c` file incorporated utility functions which the `Weather.c` and `Main.c` files used.

A header file `config.h` was also included in the weather implementation which defined the appropriate `AppMessage` keys which were used for message passing in the JavaScript update process (a description of this process is given in Section 4.4). The JavaScript file, which included the functions used to update weather information through requests to the appropriate web API, was included in conjunction with the C files to complete the implementation of the weather functionality.

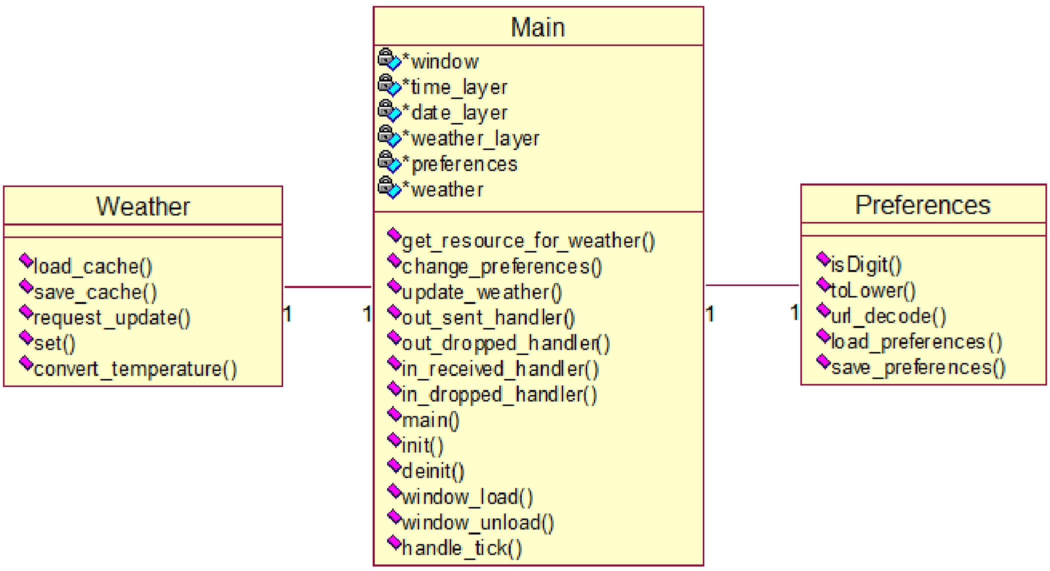

Figure 4.4: UML diagram for the weather functionality in the notifier application

The UI elements consisted of the current time, date, an image of the weather condition and the current temperature. The weather functionality was updated once every hour, upon which the temperature and condition icon changed according to the information received through the JavaScript web interface and the receipt of the appropriate OpenWeatherMap API [1] information. The final weather UI can be seen in Figure 4.5.

Figure 4.5: Weather UI and main watch face for the notifier application

4.5.2 Calendar

The calendar functionality consisted of two screens; one where the days in the current month were displayed and the other displaying the agenda for a particular day. The user was able to navigate through the days of the month by using the up and down buttons of the watch, and then use the select button to display the agenda for the selected day. This operation followed the mock-up shown in Figure 4.1. The `CalendarApp.c` file was the program entry point housing the `main` method, the button handlers and the message passing methods. The `CalendarApp.c` file also initiated the drawing of the main screen defined in the `CalendarWindow.c` file. The main screen in the UI can be seen in Figure 4.10. The `CalendarUtils.c` file was included which housed any utility functions required when performing calendar calculations for the drawing of the calendar on the screen.

[1] http://openweathermap.org/api

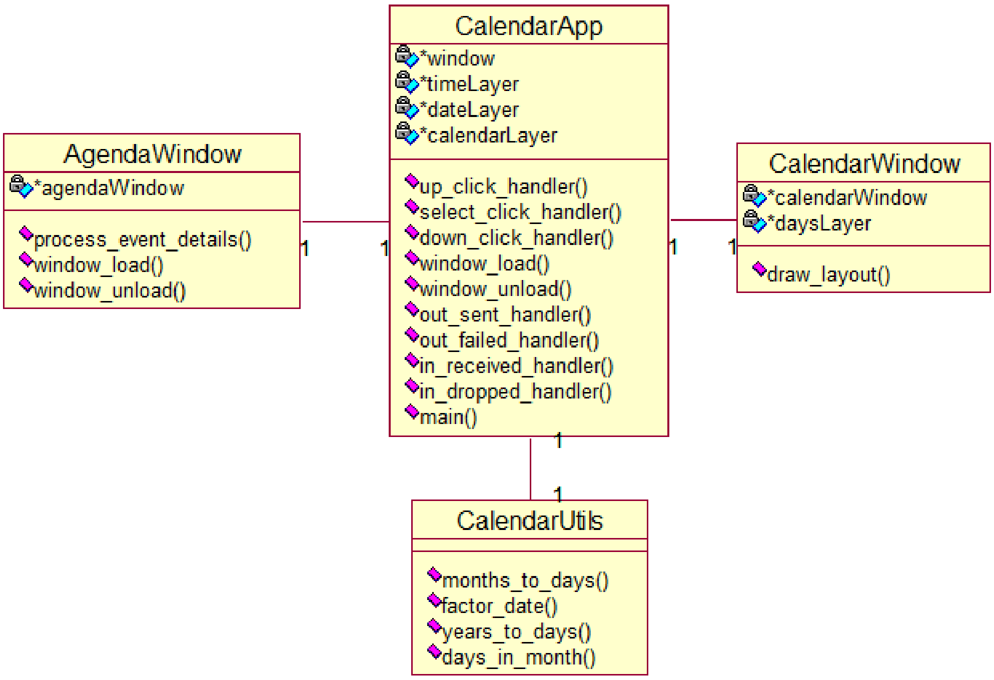

Figure 4.6: UML diagram for the calendar functionality in the notifier application

A `select_click_handler` method invocation on a day of the month initiated a screen transition to the agenda window for that particular day. The agenda screen layer (see Figure 4.8) is implemented in `AgendaWindow.c` and displays the calendar appointments on a selected day in the month. The `up_click_handler` and `down_click_handler` methods call the appropriate layers on the current screen of interest for navigation purposes. Any other relevant functions used to further data processing are shown in the UML diagram in Figure 4.6.

The calendar implementation acquired its data for each day through the use of the same key-value pair JavaScript messaging framework used in the weather implementation. The `AppMessage` keys of enumerated type which identify the information to be updated were defined in the `Config.h` header file. Upon receipt of any messages from the phone, which were stored in the buffer created in the `in_received_message` method, the appropriate calendar information was updated by identifying the key and updating the associated value. The value to replace any stale data was the payload of the JavaScript dictionary object sent to the watch, which contained the appropriate value retrieved from the Google

Calendar API[2].

Figure 4.7: Main calendar UI in the notifier application

Figure 4.8: Screen showing agenda for a particular day in the calendar

4.5.3 Email

Email functionality was incorporated into the notifier application through the use of one screen (see Figure 4.10) which was drawn upon on the display window on receipt

[2]https://developers.google.com/google-apps/calendar/

of a particular AppMessage object from the connected phone. If the AppMessage object contained a key specifying it was an email, the email functionality was able to be executed on the watch. The value of the object was extracted into the email component parts of the subject and message which formed part of the email layer updated on the watch screen. In order to bypass the default email functionality already present on the Pebble native application, the K-9Mail (K9Mail, 2014) email client was installed as a native email client on the connected phone. Since the email functionality only allowed for the retrieval of email messages the in_received_handler and in_dropped_handler functions were used for message passing (see Figure 4.9).

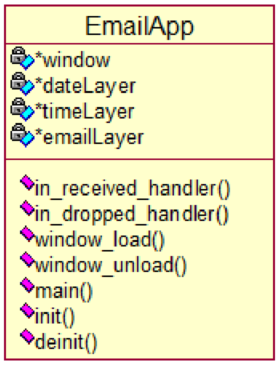

Figure 4.9: UML diagram for the email functionality in the notifier application

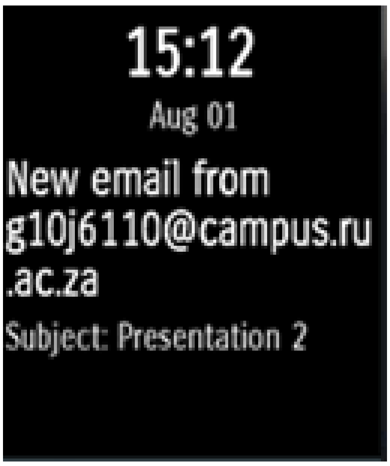

Figure 4.10: Main email UI in the notifier application

4.6 Phone Finder Application

The phone finder application was developed as a result of the information provided by expert users in the prototype evaluation (see Section 3.3.4), and participants in the requirements gathering process (see Section 5.1.5). The phone finder application consisted of a single watch application which was able to respond to button presses. The application provided two functionalities; namely the initiation of the ringing service on a connected Android smart phone, and the vibration of the watch as a function of distance between the watch and phone through Bluetooth. In conjunction with the Pebble application, an Android companion application was developed to intercept any messages passed from the watch to the phone and to send any relevant messages back to the watch. This section documents the development of the phone finder application and the way in which the mentioned functionalities were implemented, thus documenting phases two and three of the second iteration in the Spiral model introduced in Section 3.2. The full source code for both the watch and phone applications are available on the electronic appendix accompanying this document (see Appendix D).

4.6.1 Bypassing Android Modality

A market analysis was conducted before the implementation of the phone finder application documented in this section. Some notable examples found were the Phone Pebble finder (Playstore, 2014b) and Pebble Rocker (Playstore, 2014a). However, these applications were found to not have the ability to bypass the Android modality settings and provide ringing functionality even when the phone is in silent mode. The way in which this was achieved in this implementation of the phone finding application was to override phone modality through the allocation of appropriate access rights in the Android manifest XML file in the Android companion application. The Android manifest is able to grant permissions to the running application if it requests any access to phone resources (Android, 2014b). In the case of the phone finder application developed, the watch requests the phone to receive incoming Bluetooth messages using PebbleMessageReceiver and engage the RingerService in order for a ringtone to sound (see Appendix C.3).

4.6.2 Watch Vibration as a Function of Distance

A more thorough investigation into current phone finding applications for the Pebble smart watch revealed that there was no functionality in place to determine phone proximity as a function of Bluetooth signal strength. The Pebble Bluetooth API for Pebble firmware version 2.7 currently provides methods for determining whether a connection exists, but does not provide a method for determining signal strength (Pebble, 2014b). This raised a challenge as to how to measure the approximate strength of the Bluetooth signal between the phone and connected Pebble watch. Messages sent from the watch are received through the mobile application installed on the phone through the use of a Receiver class and subsequently sent back. The time in which the message sent from the watch to the phone, and back to the watch again is measured, resulting in a value relative to the distance between the phone and watch.

Bluetooth signal strength between connected devices was ascertained through the use of timing the interval from when a message request was sent from the watch to the phone, and when the response was received from the phone to the watch. The watch vibrates at a frequency which is relative to the time period elapsed. An increase in the frequency of watch vibrations indicated a closer proximity between both devices due to the stronger Bluetooth signal. The Bluetooth radio on the watch was made as sensitive as possible at the time of message passing to allow for a more accurate timing to be measured. This was achieved through changing the application communication state from normal to a reduced mode via a method call to `app_comm_set_sniff_interval(SNIFF_INTERVAL_REDUCED)`. More details on how this was achieved is explained in Section 4.6.3.

4.6.3 Pebble Watch Application

The application developed for the Pebble smart watch was able to transition between four different states; Ready, Ringing, Silencing and BT Ping (see Figure 4.12). The transitions between these states can be seen in the mock-up for the application (see Figure 4.2). While the Pebble application is in its ready state, the phone's ringing service can be activated through the pressing of the up button on the smart watch. While the watch sends a message to the connected phone the watch application is set in a Ringing state, and the phone can be silenced through the bottom button press on the watch or through the companion application on the phone.

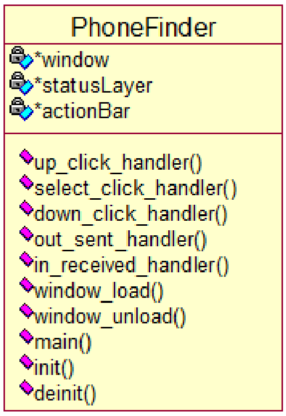

Figure 4.11: UML diagram for the phone finder application

(a) Ready State

(b) Ringing State

(c) BT Ping State

(d) Silencing State

Figure 4.12: Multiple states of the phone finder Pebble application

The BT Ping state was engaged on the watch application if the middle (select) button was pressed. While in this state the watch sent a message via Bluetooth to the connected smart phone and initiated a message to be sent back from the smart phone. As seen from the UML diagram for the phone finder watch application in Figure 4.11, button handlers were implemented to initiate the state transitions which were mentioned. The elements used to create the UI consisted of the `window` layer discussed in Section 4.3 as well as layers to display the current watch application state (`statusLayer`) and sidebar (`actionLayer`) displaying the available actions.

The messages passed between the smart watch and phone work on the concept of key-value pairs as used in the notifier application. Each watch button press sent a dictionary structure to the phone companion application, with a key indicating it was a command and an associated value determining the command's actions (initiate ring, stop ring or Bluetooth ping). This dictionary structure was sent via the `out_sent_handler` function to the connected smart phone for further processing (see Section 4.6.4), while the handler function for receiving messages (`in_received_handler`) listened for responses from the companion application on the phone. Messages received from the companion application consisted of JavaScript dictionary structures for Bluetooth message responses as well as acknowledgments that the ringing service on the phone had stopped, thus allowing the watch application to return to its Ready state.

Upon the initiation of a Bluetooth ping being sent to the companion application on the phone, the current system time on the watch was stored. A second instance of the system time was captured upon the receipt of a Bluetooth message back from the companion application. The initial system time was subtracted from the time captured upon receipt of the message from the companion application to arrive at a Round Trip Time (RTT) taken for a message to be sent from the watch to the phone and back to the watch. Since Bluetooth is highly susceptible to attenuation and interference (Haartsen & Mattisson, 2000), the Bluetooth radio in the smart watch was placed in a reduced sniffing mode in order to achieve a more accurate timing. Since enabling reduced sniffing significantly increases power consumption on the smart watch (Pebble, 2014c), it was returned to normal once the relevant response message was returned from the companion application.

The RTT was used to determine the approximate distance the phone was to the watch. A watch vibration strength and frequency was then calculated using this time. This resulted in a series of three vibrations on the watch of appropriate strength and successions between one another to indicate how far the watch was to the connected smart phone. By initiating this Bluetooth ping functionality over multiple iterations, the user would be able to home in on the phone based on the strength and frequency of the watch vibrations.

A function was used on the watch application (see Appendix C.4) to determine watch vibration strength and frequency. The vibration strength was set between one and seven depending on the distance between the phone and watch; the further the watch was from the phone resulted in a weaker vibration strength. The function to vibrate the watch was called from the `in_received_handler` function (see Appendix C.5). The strength of the vibration was programmed to increase by a factor of one for every 200 millisecond (ms) reduction in proximity as the phone came closer to the connected watch. This was based on the RTT taken between a message passed between the watch and phone. A test was performed to determine the strength and frequency of watch vibrations as a function of distance (see Table 4.1)

Distance (m)	**Strength (1 - 6)**	**Time between vibrations (ms)**
15	1	978
12	2	883
9	3	642
6	4	398
3	5	125
0	6	44

Table 4.1: Strength and Frequency of watch vibrations dependent on distance between phone and watch

The values found in Table 4.1 were found to vary slightly with each successive test, and so average values were calculated over three iterations of using the phone finder application. The variance in timings can be attributed to interference of other signals and objects which is known to hinder Bluetooth signals (Gomez et al., 2012), and any Bluetooth message scheduling factors in the Android and Pebble OS's which were not studied further.

4.6.4 Companion Android Application

The phone finder Android application, which operated in conjunction with the Pebble phone finder watch application, was developed using Java's Android Development Tools (ADT) which was integrated into the Eclipse IDE. The main function of the companion application was to intercept any messages from the phone finder application on the smart watch, and send any messages back if necessary. In order to do this it used the `PebbleMessageReceiver` class (see Figure 4.13) which used the PebbleKit SDK and was imported into the Eclipse environment, listening for any incoming messages from the phone finder application. Any messages from the watch were intercepted and unpackaged, and a dictionary object was sent back to the the watch in the case of the message being part of the Bluetooth ping functionality. This object consisted of one byte and acted as an acknowledgment of message receipt from the watch. The payload of this object was kept deliberately small in order to keep transmission delay to a minimum when sending the object to the watch over the Bluetooth link (Kurose & Ross, 2002).

Any message received from the watch which was concerned with the initiation or cessation of the phone's ringing service launched a new Intent in the `RingerService` class. The appropriate permissions were granted in the AndroidManifest.xml file (see Appendix C.3) to allow for the ringer service to be accessed on the phone. In the case of a stop request for the ringer service, a new Intent would be started in the the `StopRingingReceiver` class. A stop request to the ringing service could also be sent using the "stop ringing" button on the UI (see Figure 4.14).

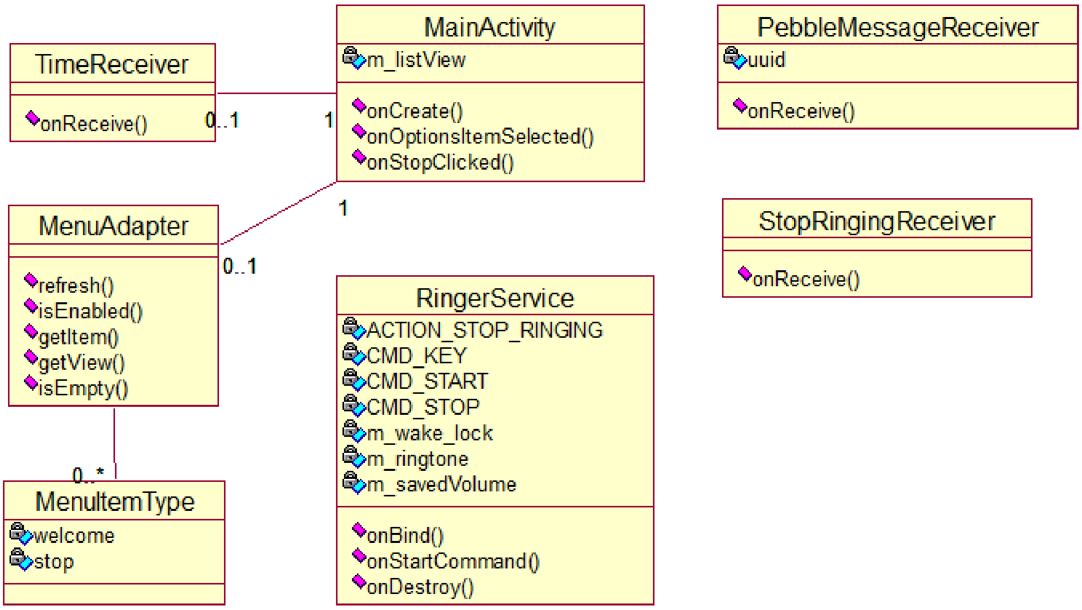

Figure 4.13: UML diagram for the Android companion application used with the phone finder

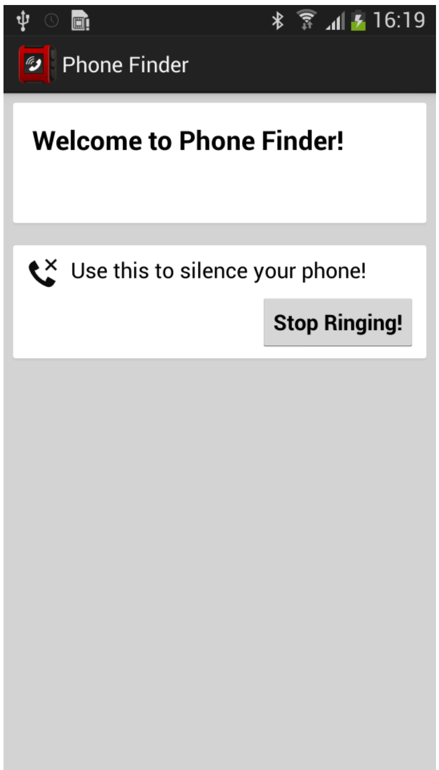

Figure 4.14: Screen capture of the companion application for the phone finder

4.7 Summary

This chapter documented the approach taken in developing the final products (notifier and phone finder applications) for this research project, and corresponds to the second and third phases in both iterations of the the Spiral model (see Figure 3.1). The mock-ups used for the design of the prototypes were explained, and how they proved to be an effective design tool for the development of the prototypes is shown. This chapter also shows how user perceptions collected in the requirements gathering phase, and information gathered from the expert user evaluation of the prototypes, provided input for the development of the actual applications to be evaluated in the field study. Any development considerations for both applications were addressed, such as the development environments and SDK's used. The way in which Pebble applications are structured and operate were presented, and the concept of message passing in the context of the smart watch to smart phone communication architecture were addressed.

The design and implementation of the notifier and phone finder applications were discussed. The design of these applications was provided through the use of relevant UML diagrams for each of the functionalities implemented. The UML diagrams took the information gathered from the earlier requirements gathering phases and expert user evaluation of the prototypes into consideration before any coding commenced. Once the UML diagrams had been completed, the applications were developed in the relevant IDE and the resulting screens were shown as screen shots. For the development of the phone finder application, additional sections were included which explained how Android modality was bypassed and how the Bluetooth ping functionality was implemented through the measurement of the distance between the watch and connected phone. The notifier and phone finder applications developed were used for evaluation in the usability study (see Section 3.4) and the results of this study are documented and discussed in Section 5.2.

Chapter 5

Results and Discussion

This chapter documents the results of the requirements gathering questionnaire answered by participants, as well as the results from the usability study. Any trends which emerged as a result were then discussed, and the salient points raised by the participants in the usability of the applications which were developed are analyzed further. The results were presented in a top-down approach such that any questions asked were presented and the participants answers to those questions were discussed.

5.1 Requirements Gathering

The quantitative analysis achieved through the use of the questionnaire distributed to the Computer Science Literacy (CS1L1) class is documented in this section. The requirements gathering process satisfies phase one of the first iteration in the Spiral model (see Section 3.2) for the development of the application prototypes. Out of a class size of 211, 89 students consented to participate. The questionnaire was available electronically using Google forms and was designed to collect information about potential smart watch users, and their application preferences. Ethical clearance for this study was organized before any of the participants were addressed about this study and all participants who volunteered to participate were asked to complete a consent form before answering any questions. Demographic results were obtained from the participants involved, as well as the answer to whether they felt the smart watch could be a useful interface for them to use. The participants were also asked to select from a list of applications, the ones which they perceived to be most useful to them, and to give some ideas of other applications they would want to use on a smart watch.

5.1.1 Demographic Results

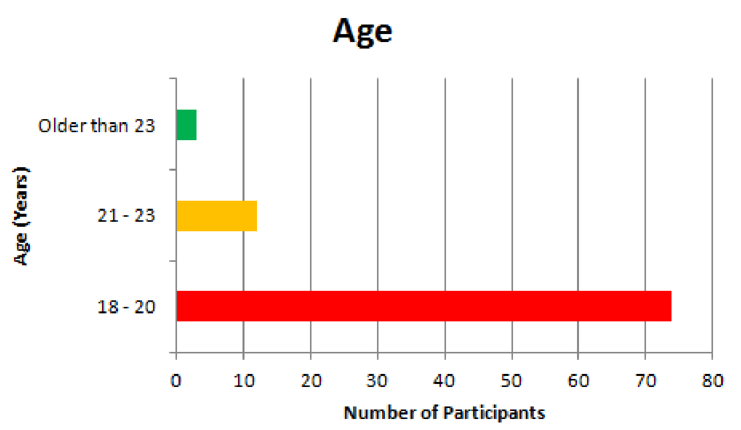

Figure 5.1: Age of participants

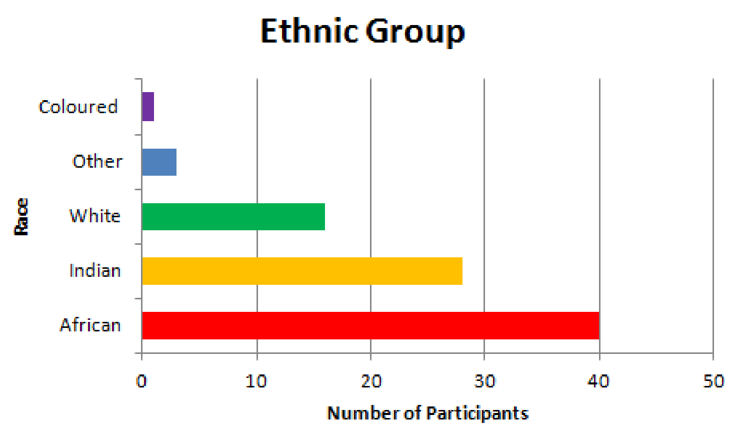

Figure 5.2: Ethnic Group of Participants

The participants were asked to provide their age, gender and race. This was required for statistical purposes, and to possibly infer results from a particular demographic group. From the questionnaires it was found that 74% of participants were female and 26% were male. It was also found that 83% of the participants were between the ages of 18 and 20, 14% between 21 and 23 and 3% were older than 23 (see Figure 5.1). The ethnicities of participants were found to be 45% African, 32% Indian, 18% White, 3% Other and 2% Coloured (see Figure 5.2). The female to male ratios for each ethnic group were (3.3:1), (2.5:1), (3.25:1) for African, Indian and White ethnicities respectively.

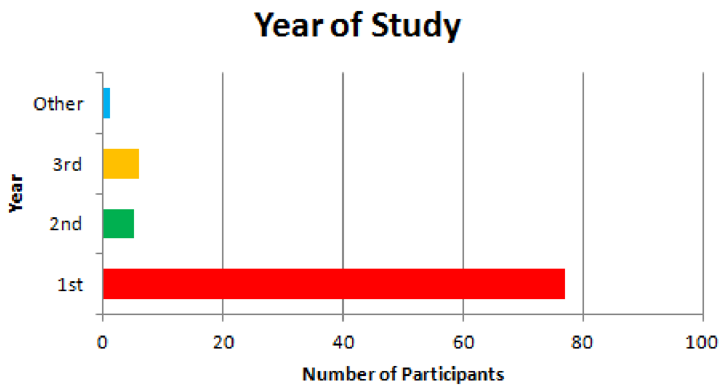

Figure 5.3: Participants' Academic Year of Study

The majority of participants (86%) were in their first year of study, 6% and 7% were in their 2nd and 3rd years of study respectively (see Figure 5.3). Of the first year participants; 49% were African, 35% Indian, 12% White and 4% Other.

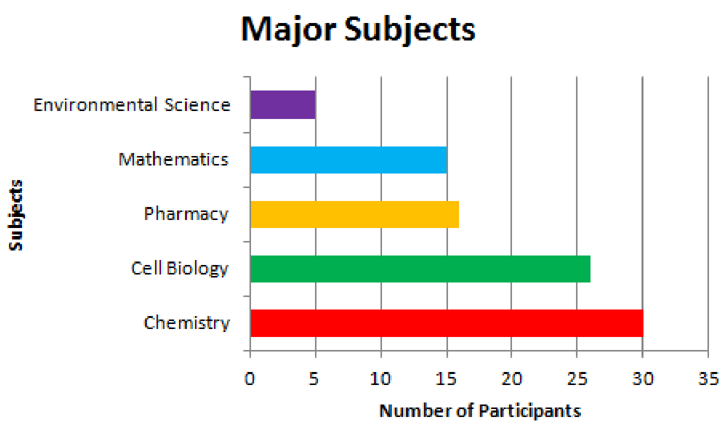

Figure 5.4: Major Subjects taken by Participants

It can be seen from Figure 5.4 that most participants were taking Chemistry (34%), Cell Biology (29%), Pharmacy (18%) as their major subjects. Any subject which was taken by less than 5 people was considered to be insignificant in this study and not included in Figure 5.4. These subjects included Sociology, Economics, Law, Anthropology, Politics, Psychology, Journalism, Geography and English.

5.1.2 Smart Watch Perceptions

Participants were asked a series of questions to determine their perceptions on the use of the smart watch, and whether or not they would choose to use the smart watch if they had access to one. The majority of participants (86%) answered that they would use a smart watch if they had access to one. Their reasons for wanting to do so were varied, but a common answer was the ease of use and convenience of an always viewable display on the wrist. Participants made comments such as "*It seems very convenient and the fact that it stays in your wrist make it easy for anyone not to forget and cannot be easily stolen*", "*A smart watch would be more convenient to use and more portable to carry around on my wrist with all my favorite apps*" and "*It is much easier to access information this way, and you would not have to carry your mobile device all the time*".

The opponents of using the smart watch provided reasons such as the difficulty related to viewing a small display, its limited functionality when compared to a smart phone and the discomfort of wearing a wrist based device. Some participants made statements such as "I would assume that the screen would be small, this is something that I am not comfortable with", "*I already have access to different technologies through different devices. A smart watch on top of that would be too onerous*" and "*I do not like things around my wrist. I do not own a watch or wear bangles/bracelets*".

It was found that 88% of females and 83% of males would use a smart watch. In the largest age group which was between 18 to 20 (see Figure 5.1); 92% of the participants answered they would use a smart watch and within that group 44% were African, 33 % Indian, 17% White and 6% Other ethnicities. A breakdown of participants who were male and female and would use a smart watch can be seen in Table 5.1. It was also found that the percentage of participants who were in their first year of study and would use a smart watch was 92%. This was broken up further into first year females and males who said they would use a smart watch at 90% and 94% respectively. The different ethnic groups of first year participants who would use a smart watch are shown in Table 5.2 and appears to be uniform over the most prevalent ethnic groups participating in this study.

Ethnicity	**Males**	**Female**	**% of first year participants who would use**
African	100%	83%	89%
Indian	87%	95%	92%
White	50%	100%	88%

Table 5.1: Percentage of male and female participants, and first year participants who would use a smart watch

5.1.3 Application Requirements

A list of possible applications was presented in the questionnaire from which participants were asked to select the ones which they would consider to be most useful. Table 5.2 shows the results of which applications the participants thought would be of most use to them.

Application	**No. of suggestions**	**% of participants**
Event Reminders	71	77%
Weather Information	70	76%
Social Networking Updates (Facebook, Twitter, WhatsApp)	61	66%
Sending and receiving emails	61	66%
Gesture control applications	49	53%
GPS services (View latitude and longitude information / current speed)	49	53%
Finding restaurants / coffee shops (Location based services)	48	52%
Number of steps taken while running / playing sport	43	47%
Voice activated commands	40	43%
Logging sleep patterns	37	40%
Results of your favorite sporting fixture	25	27%
Playing Games	19	21%

Table 5.2: Participants' Application Preferences

Of the applications presented to the participants in the questionnaire, the most popular ones were found to be those which generated weather information, event reminders, email services and social networking updates.

5.1.4 Comparison to the Smart Phone

The participants were also asked if they thought the applications they selected in Table 5.2 could be used more easily on the smart watch as opposed to the smart phone. This question was designed to provide some insight into user perceptions on ease of use related to the smart watch interface. From this question it was found that 59% of the participants thought it would be easier to use the selected applications on the smart watch. Of the participants who thought it would be easier to use these applications on a smart watch, 62% were female and 56% were male. From the largest age group in the study of between 18 and 20 years old (see Figure 5.1); 65% of those participants thought using the applications would be easier on the smart watch. Within that group 52% were African, 23% Indian, 16% White and 5% from other ethnicities.

A gender and ethnicity breakdown of participants who felt it would be easier to use a smart watch is shown in Table 5.3. It was also found that the percentage of participants who were in their first year of study and thought a smart watch would be easier to use was 65%. This was broken up into first year females and males at 73% and 57% respectively. Of first year participants; the sub-groups of African, Indian and White participants felt a smart watch would be easier to use than a phone for their selected applications at 76%, 55% and 55% respectively.

Ethnicity	**Males**	**Females**
African	77%	71%
Indian	63%	53%
White	25%	69%

Table 5.3: Percentage of participants who felt it would be easier to use a smart watch as opposed to a smart phone with regard to the applications selected

Participants who would use a smart watch and also thought it would be easier to use for the applications they selected in Table 5.2 was found to be 56%. It was found that 59% of female and 52% of male participants thought this to be the case. The complete breakdown as per ethnic group and gender is shown in Table 5.5 below.

Ethnicity	**Males**	**Females**
African	78%	61%
Indian	50%	55%
White	50%	62%

Table 5.4: Participants who wanted to use a smart watch and also thought it would be easier to use for the applications selected

5.1.5 Participant Application Ideas

Participants were asked to suggest any other applications that might be useful to them. Not all participants made suggestions, but from those who did, the most common suggestion was a phone finding system (see Table 5.5). This was selected for design and development in conjunction with the notification system for use in the usability study. Further analysis of their suggestions is presented in Section 5.1.6.

Application	No. of Participants Requesting Application
TV Guide	1
Playing Music	2
Body Temperature	2
Phone Finder	5
Web Browser	2
Calendar App	1
Birthday Reminders	2
Camera App	2
Thermometer	3
Flashlight	2
World Clock	1
WhatsApp	1
News Updates	1
FM Radio	1
Quick Dial Function	3
Video Calling	2

Table 5.5: Participants' Application Ideas

5.1.6 Discussion

The demographic information of the participants in the requirements gathering part of the study were not surprising in terms of their ages as most of the participants (86%) were in their first year of academic study (See Figure 5.3). It was also expected that the number of people who belonged to the older age groups in the study would reduce as the age ranges increased. Almost three quarters (74%) of the participants were female, this is not surprising as the CS1L1 class primarily consisted of female students. The sample of users who volunteered in the requirements gathering process was representative of the demographics of the CS1L1 class.

Participants were asked if they would use a smart watch if they had access to one. The majority of participants (86%) answered that they would use one. The willingness of the participants to use the smart watch might be attributable to the phenomenon seen by Arnone, Small, Chauncey, and McKenna (2011), where user curiosity for new technology was found to be an important motivator in using it. Participants made statements such as; "*It is one of the latest digital devices and I like new things*", "*It is easy to carry around and a seemingly interesting gadget*" and "*It is a new piece of technology and I would try it if it were compatible with my cellphone*". These statements highlight the curiosity aspect in the use of devices such as the smart watch. Some other reasons were given by participants for wanting to use the smart watch, such as convenience of having an easily accessible interface on the wrist, and being able to view information on their phones without having them on their person. Participants also noted that it would be more difficult to lose a watch as opposed to losing a phone, and having one device to view information from would save time.

Opponents of using the smart watch commented that wearing a watch annoyed them, and this was why they would prefer not to use the watch. The female participants in particular noted that the smart watch was large and did not look appealing. Some participants said the small screen size would provide limited display capabilities and others believed operating the smart watch would be too complicated. There were also many participants who were deterred from using the smart watch because of the financial cost of purchasing one. The duplication of functionality on both the smart watch and smart phone also appeared to be a deterrent for participants wanting to use the watch.

When comparing the percentages of female and male participants for the different ethnic groups who would use a smart watch, it was found that African males were more willing to use a smart watch (100%) than females of African ethnicity (83%). In the cases of Indian and White ethnicities it was found that less males, (87%) and (50%) respectively, wanted to use the smart watch than females of the same ethnicity. However it was noted that there were more females who partook in the requirements gathering process (see Section 5.1.1) and so this result is not surprising. The reason fewer African females wanted to use the smart watch could be due to the same reasons participants did not want to use the watch as mentioned earlier. Reasons such as the large form factor of the watch, and the thought that there would be no reason to use a watch if a smart phone achieved the same functionality, were expressed by some African females in the questionnaires.

Participants were presented with a list of possible applications and were asked which ones would be of most use to them. There was no limit imposed on them as to the number of applications they could choose. The application list as well as the percentage of users who would find them useful is shown in Table 5.2. Of the applications which were presented to the participants, the four most popular ones were found to be ones providing event reminders (77%), weather information (76%), sending and receiving emails (66%) and social networking updates (66%). Similar results were seen by Bowen and Pistilli (2012) where a user study on application preferences on smart phones found that text and social media based applications were most popular. Chen et al. (2014) found that participants tended to want similar services from the different devices they use. Since their smart phones already provided these functionalities they would thus want them from a smart watch. Even though the way in which the smart phone and smart watch interface are interacted with by users is different, the information requirements from both interfaces would need to be similar to satisfy user requirements.

The participants were asked if they thought the smart watch would be easier to use than the smart phone for the purposes of retrieving information provided by the applications they selected. 59% of the participants thought that accessing a smart watch would be easier than accessing a smart phone. Proponents for easier accessibility on the smart watch commented that it would be easier and faster to access due to its convenient position on the user's wrist. Some participants who were already familiar with wearing watches noted that using such an interface would feel commonplace to them, and ease of use would not be a problem. Although it was assumed the participants had not seen the smart watch before, some participants who did not believe the smart watch would be easier to access commented on the potential difficulty in reading information displayed on a small screen which the watch might provide. It was found that female participants perceived the watch to be too large on the wrist and they felt it would become an obstruction in accessing information. Some participants also noted that accessing the watch would only be able to be accomplished with the use of one hand, which according to them could be "*awkward and slow*".

It was found that 59% of participants wanted to use a smart watch and believed it would also be easier to use than a smart phone for the applications they selected in Table 5.2. This is a large difference from just wanting to use the smart watch, in which 86% of participants said they wanted to do so. This could again be attributed to the curiosity of new technology as seen by Arnone et al. (2011). This result could also be due to participants wanting to maintain familiarity with the device they are used to using in everyday circumstances and retaining that functionality (Li, 2014). Li (2014) also found that participants will want to adopt an interface if they are certain they can also adopt the functionality of the interfaces they are currently familiar with.

The participants were asked to make suggestions on what applications they thought could be beneficial to them on the smart watch. Not all participants provided feedback on their ideas for an application. Also, as the participants had not been aware of the functionality which the Pebble smart watch already provided, there were some suggestions which had already been implemented natively on the Pebble. Suggestions which were already available were music control, calendars, reading emails, event reminders and news updates. Additionally, some of the suggestions made were not supported by the Pebble hardware, such as the ability to capture pictures from the watch, measure body temperature and make phone calls by speaking into the watch as a transmitter / receiver.

Of the applications suggested by the participants, most already existed on the Pebble or other variants of the smart watch which had supporting hardware. A phone finding application was suggested by five participants (see Table 5.5), which has been implemented before on the Pebble. After investigating the phone finder applications currently available, it was discovered that the application could be improved upon. It was therefore selected as the second application to be developed for later evaluation in the usability study.

5.2 Usability Study

Once the notifier and phone finder applications were developed, a usability study was conducted. The usability study represented the evaluation (phase four) of the second iteration in the Spiral model (see Figure 3.1) and its aim was to determine if these applications were useful to participants. The usability study was a qualitative assessment of the notifier and phone finder applications which were developed, and required direct observation of each participant for evaluation (Mayoux, 2014). Fewer participants were required in the usability study due to the nature of the assessment, where each participant was evaluated through the use of a more in-depth questionnaire and interview process than that which occurred in the requirements gathering process (Mayoux, 2014).

Apart from the assessment of the applications themselves, it also allowed for possible inference to be made on how users felt about using the smart watch as a physical device for viewing information. Ethical clearance for this study was organized before any of the participants were addressed and all participants who volunteered to participate were asked to complete a consent form before answering any questions. The results of the usability study are documented in this section along with a discussion of the findings.

5.2.1 Demographic Results

A total of six participants from the Computer Science 202 (CS202) class at Rhodes University were involved in the usability study, which involved them using the smart watch with the notifier and phone finder applications installed. The detailed methodology on how the usability study was performed is documented in Section 3.3. This was a field study and so the participants used the watch with the developed applications outside of a laboratory setting and in a natural environment to them (Alston, 2014). At the end of the time period allocated for using the watch (approximately seven hours of the day), they were asked to use the phone finder application and complete a questionnaire, as well as answer several interview questions as per the methodology used for a field study (Alston, 2014). The participants were labeled from A to F and their demographic information is shown in Table 5.6 below.

Participant	**Gender**	**Age**	**Ethnicity**	**Major Subjects**	**Year of Study**
A	Male	21- 23	White	Mathematics, Computer Science	2nd
B	Female	21- 23	White	Computer Science, Linguistics, Chinese, Classics	2nd
C	Male	>23	White	Computer Science, Information Systems	2nd
D	Male	>23	White	Linguistics, Computer Science	2nd
E	Female	18 - 20	White	Physics, Applied Mathematics	2nd
F	Female	21- 23	Indian	Microbiology, Biochemistry, Computer Science	3rd

Table 5.6: Participant Demographics for the Usability Study

The participants were asked for their age, gender and ethnicity as part of the demographic information obtained for the usability study. As can be seen from Table 5.6, three of the participants fell within the ages of 21 - 23 years old, two were older than 23 and one was between 18 and 21. There appeared to be an even split between male and female participants and the ethnicities of the participants, were comprised of five White and one Indian participant. As can also be seen from Table 5.6; five out of six participants were taking Computer Science as one of their major academic subjects. Applied Mathematics was the next most common major subject, and all other major subjects mentioned were only taken by one person each. It is also shown that five of the six participants were in their second year of academic study at Rhodes University.

5.2.2 Questionnaire

The results for the evaluation of the notifier and phone finder applications are documented in this section. Participants were asked to complete a questionnaire hosted on Google forms which was designed to provide insight into how useful the notifier and phone finder applications installed on the smart watch were. The questionnaire design was based on the System Usability Scale (SUS) developed by Brooke (1996) as a guideline to measure overall application usability. The SUS evaluation method as well as the reason for not using the complete SUS method is explained in in Section 3.4.3. Each question in the questionnaire required an answer on a scale of one to five; where 1 = Strongly Disagree, 2 = Disagree , 3 = Neutral, 4 = Agree and 5 = Strongly Agree. The mean and standard deviations for the answers to the questions relating to the notifier and phone finder applications are shown in Table 5.7 and Table 5.8 respectively. The distribution of the answers for the participants answering the questionnaire on the notifier application are shown in Figure 5.5, and for the phone finder application in Figure 5.6.

Notifier Application	**Mean**	**Std. Dev**
1. I would like to use this application frequently	3.33	1.5
2. I found the application complicated to use	2.16	0.98
3. I would need the support of a technical person to be able to use this application	1.67	0.81
4. I think most people would learn to use this application very quickly	3.5	0.83
5. I felt confident using the application	4.16	0.98
6. The information I received was useful to me	3.83	0.75

Table 5.7: Mean and Standard Deviations for the answers to the questions relating to the notifier application

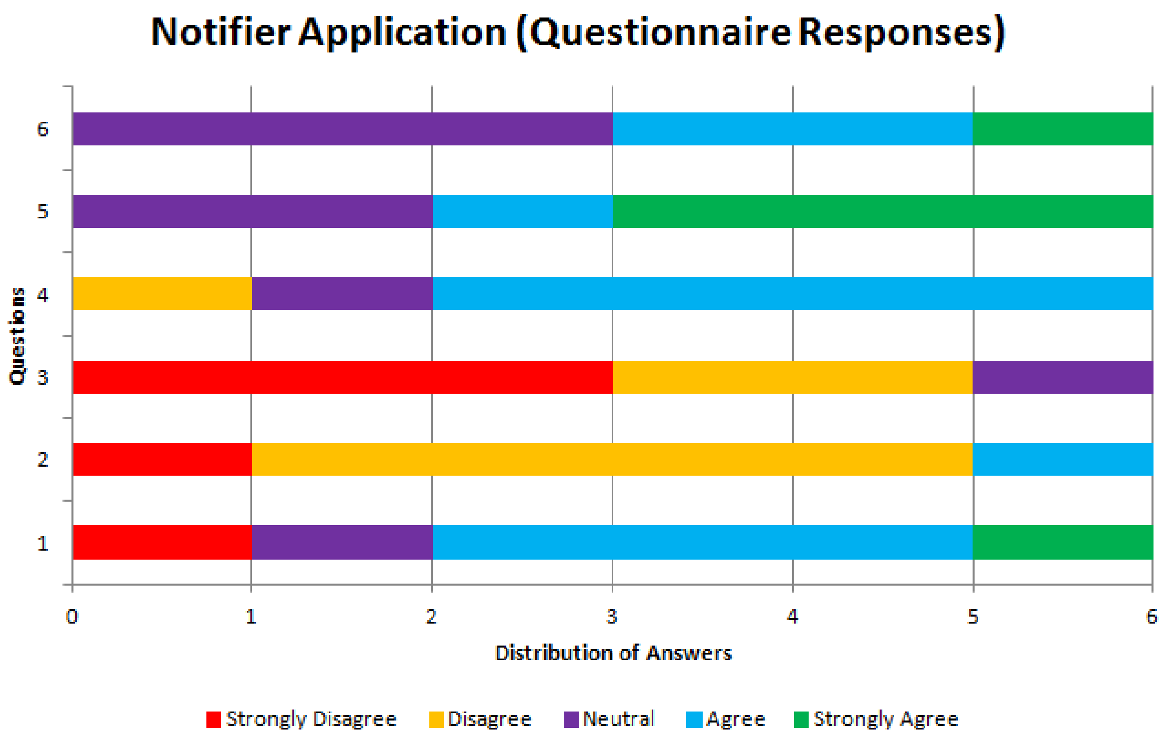

Figure 5.5: Distribution of participant answers relating to questions asked for the notifier application

The question numbers in Figure 5.5 relate to the same question numbers in Table 5.7. It can be seen from Figure 5.5 that four out of the six participants agreed or strongly agreed they would use this application frequently, and that people would learn to use this application quickly. Four of the six participants also did not find the application complicated to use, and three of the six participants strongly agreed that they felt confident using it. The majority of participants (five out of six) did not feel they needed the support from a technical person to be able to use this application. Half of the participants felt they received useful information from using the application and the other half remained neutral on the matter.

Phone Finder Application	**Mean**	**Std. Dev**
1. If I lost my phone I would use this application	4.83	0.41
2. I found the application complicated to use	1.5	0.84
3. I would need the support of a technical person to be able to use this application	1.33	0.52
4. I think most people would learn to use this application very quickly	4.33	0.82
5. I felt confident using the application	4.67	0.52
6. The information I received was useful to me	4.5	0.55

Table 5.8: Mean and Standard Deviations for the answers to the questions relating to the phone finder application

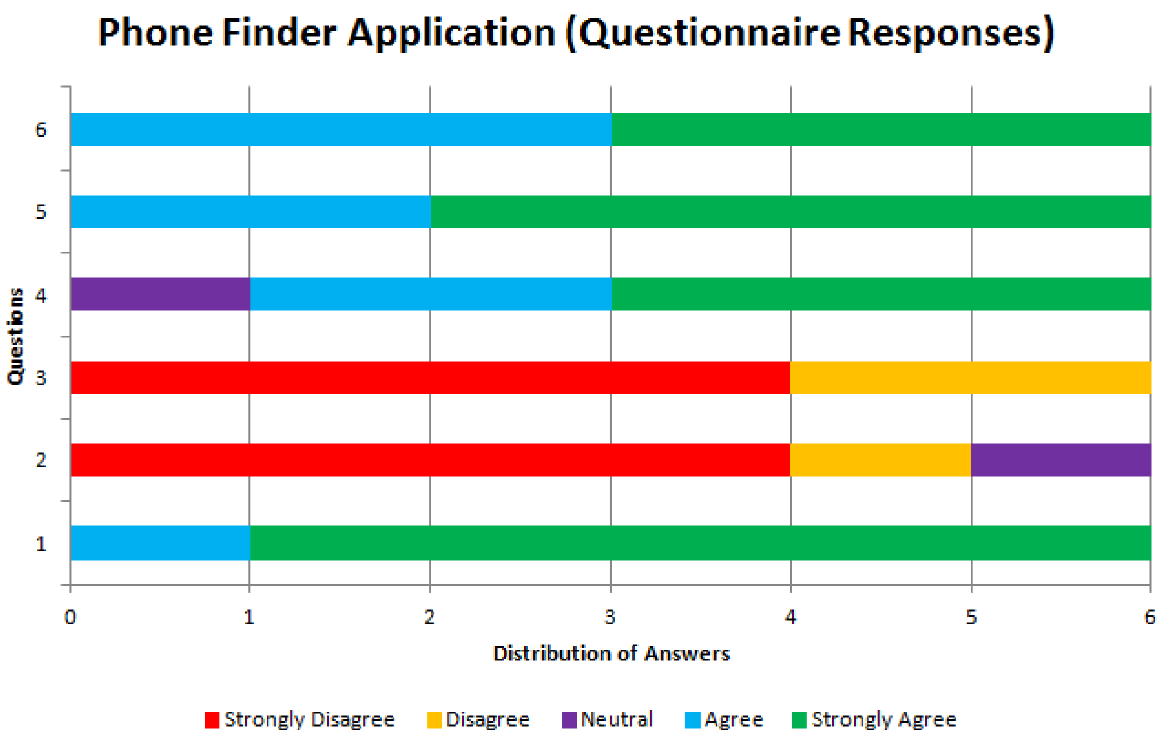

Figure 5.6: Distribution of participant answers relating to questions asked for the phone finder application

The question numbers in Figure 5.6 relate to the same question numbers in Table 5.8. All the participants either agreed or strongly agreed that they would use this application if they lost their phone, they also felt confident using this application and they felt the information they received was useful. All participants disagreed that they would need a technical person to be able to use the application, and five participants found the application easy to use. The majority of participants (five out of six) also felt that most people could learn to use the application quickly.

5.2.3 Interview Results

The interviews in the usability study were conducted after the participants had used the watch for a few hours of the day, and after they had answered the online questionnaire forming part of the field study. The interview questions asked to the participants were designed to assess usability of the smart watch by asking users how they interacted with the watch throughout the day, and if there were any challenges they faced while doing so. These questions were aimed at assessing the usability of not only the applications being used by the participants, but also of the smart watch as an interface to view information on. The six participants were labeled from A to F for easier analysis and to ensure anonymity. The results which were found from each of these questions are given below the relevant question. The details on how the interview process was conducted can be seen in section 3.4.3.

1. After using the notifier and phone finder applications on the smart watch, would you say the smart watch interface is useful?

   The general consensus was that the applications on the smart watch were useful to participants, with five out of six answering they found some benefit in using the applications on the watch. Participant C answered that it would only be useful in certain circumstances where small amounts of information could be viewed at a time, and would be useful for a "*Managing my day kind of thing*". Participant D found that being in contact with their phone was convenient as they would not have to check the phone for incoming notifications, and rather be notified by the watch vibration on the wrist. A similar answer was obtained from participant E where they said they would not have to take their phone out in circumstances such as walking around campus. It was found that some participants did not find use in the applications on the smart watch. Participant A did not feel the watch provided any new benefits as the smart phone provided the functionality they already required.

2. How would you describe the physical user interaction with the smart watch? (In terms of button presses and what actions you thought the buttons would perform)

Participants were asked about how they physically interacted with the smart watch throughout the day and if the the buttons were intuitive in terms of the functions they performed. Participant A commented that the buttons were too difficult to push, it was difficult to place their fingers on the watch to apply pressure to the buttons and what the buttons initially did was confusing. Three out of six participants did not have a problem in determining what each button did on the watch. Participant B, C and D, felt the interaction with the smart watch was simple and there was not any confusion in what the buttons did. However the female participants (B, E and F) found the smart watch awkward to use at first, and commented on the large size of the buttons and of the watch itself. From observational (anecdotal) evidence this could have been attributed to the large size of the watch relative to the size of the wrists of the female participants.

3. Did the applications on the Smart Watch help you in consuming useful data? Can you give examples?

   Five of the six participants replied that the smart watch provided them with useful information. Participants A and B mentioned the weather functionality of the notifier application to be especially useful to them saying that it provided a convenient service for weather updates. Participant C noted it was useful to be able to read emails and be notified of an incoming phone call without having to reach for a phone. Being able to accept or decline a phone call from the wrist was found to be useful for participant E. Participant F did not feel as if any useful information was obtained through the use of the smart watch other than the receipt of WhatsApp messages.

4. Have you have used some sort of device finding application before? If yes, how would you compare the one you used on the watch to find your phone? Would you use the phone finding application used in this study to find your phone?

   It was found that none of the participants had used a phone finding application before, and so they had nothing to compare to the one they were using in the usability study. The participants informed the observer that they had never been exposed to any phone finding application before the day of the user study. However, all of the participants said they would use the phone finding application used in the usability study to find their phones. Some participants commented that it had some "*Novelty value*" attached to it, and it would seem useful in the situation where a phone was lost.

5. Was there a particular circumstance you came across today where accessing information on the watch was easier than accessing information on your phone? Can you tell me what happened (describe the events)?

   All participants came up with at least one circumstance where viewing information on the smart watch was easier than viewing the same information on a phone. Participant A said that switching between analogue and digital watch modes throughout the day was useful and circumvented the necessity to view the time on the phone. Participant B and C commented on the usefulness of being able to retrieve emails and messages while in a lecture without looking at a phone. Participant C added that viewing information on the watch was much easier than on the phone while driving and in circumstances where both the user's hands are busy. Participant D said that looking at a watch while walking was far easier than holding a phone in one hand. Participant E found it useful to decline calls on the watch instead of on the connected phone. Participant F said that using the watch to view small amounts of information reduced the frequency of using the phone for the day.

6. Have you used other smart watches before? If yes: In terms of usability which one do you prefer? If no: Is there any reason you have never used a smart watch before?

   The participants involved in the study had never used other smart watches before. Most participants noted that they had not really been exposed to what smart watches can be used for that their smart phones cannot do. Another important factor for not having used a smart watch before according to participant A, C and D, was that smart watches were too expensive to purchase. Participant E said that they saw no reason to get one as their phones gave them all the functionality they already required, and that wearing a watch annoyed them. Participant F also commented on the annoyance of wearing a watch around the wrist.

7. Did you feel the smart watch you were wearing today impeded you in performing any tasks or activities? If yes, can you provide an example where this occurred?

Two of the three female participants who were interviewed commented on the size of the watch on their wrists, and how that impeded them in tasks. Participant A said "*It would catch on things and I was not expecting it to catch*". Participant E said the watch was a bit wide and the buttons were hard to push, which resulted in some discomfort. Participant C did not feel as if the watch was in the way, but felt uncomfortable due to the unfamiliarity of wearing one. Similarly, participant D found the vibration of the watch in the wrist to be uncomfortable and commented that it would take some getting used to. Participants B and E did not feel the watch impeded them from doing any tasks.

8. Did you feel it was more convenient to check notifications on the smart watch or on the phone? Can you explain further?

   Participant A said that using the smart watch was convenient when viewing small amounts of information without other unnecessary information on the phone. Participant C said that having the watch at a convenient position such as driving with hands on the steering wheel was more convenient than viewing information on a smart phone. Participants D, E and F said it would be more convenient to view notifications, or small amounts of useful information on a smart watch as opposed to a smart phone.

9. What further functionality or features would you like to see incorporated into the smart watch you were using today?

   Some participants acknowledged the limited functionality of the smart watch and provided some features they would like to see included. Participant A wanted a more intuitive way of turning off the Bluetooth pairing to the phone. Participant B wanted to see a GPS incorporated into the watch for navigational use while driving. A way to have more interaction with the phone was suggested by participant D, such as browsing through a music library or contact list. Participant F wanted to see a more refined version of the calendar functionality on the notifier application, where further details of events on particular days are shown.

10. Are there any criticisms you may have in general about using the smart watch?

Of the general criticisms made, three of the six participants made comments around ergonomic issues. Participant A, D and E commented on the buttons being difficult to press, and the awkward way in which their fingers needed to be positioned in order to apply pressure. Participants A and E also said the physical size of the watch on their wrists felt large and uncomfortable. There was some initial difficulty in determining what the buttons did when they were pressed. This was evident with participants B and E, however after some time becoming acquainted with the buttons actions, the participants noted they were pleased with the actions they performed. Participant C commented on the native Pebble application being overly complicated to use and participant F said the screen on the watch was too small.

5.2.4 Discussion

This section discusses the results which were obtained in the usability study, including the answers obtained in the online questionnaire as well as the results from the interviews (see Section 5.2.3). There were some notable findings from the mean scores relating to the notifier application questions in the questionnaire of the usability study (see Table 5.7). It was found that users were confident in using the application and the information they received from doing so was useful. This can be seen from the mean scores of 4.16 and 3.83 in Table 5.7 respectively. The mean score of 1.67 relating to the question on whether a technical person would be required to help using the application further indicated that users felt confident in using the application by themselves.

Four out of the six participants believed that most people could learn to use the notifier application quickly. The mean score of 3.5 in Table 5.7 represents a score of slightly above neutral, this could be due to the participants selecting the “agree” and not “strongly agree” response thus lowering the average for that question. The participants also felt that the application was not complicated to use as a mean score of 2.16 was the result for that question. However, the physical user interaction with the smart watch was found to be problematic for some participants. Some of the participants commented on the difficulty in pressing the buttons, particularly the three buttons on the right side of the watch. Kerber, Krüger, and Löchtefeld (2014) also saw this “fat-finger” problem occurring when users interacted with a smart watch, and Knibbe, Martinez, and Bainbridge (2014) found that the small size of the watch is a limiting factor in the comfortable operation of using one. Participant A, D and E said it was difficult to place the correct fingers on the watch to apply pressure to the buttons. Participant C and F commented that they were not familiar with wearing a watch and found that wearing one was uncomfortable and felt unusual.

Participants were found to be hesitant in using the notifier application frequently with a mean score of 3.33 seen in Table 5.7. This could be attributed to the attitudes towards using the smart watch discovered with the female participants in the interview. It was noted that the female participants found the watch to be useful but they would rather not use it to retrieve information. The female participants felt that their phones already provided the information which the notifier application generated and they did not see a reason for using another device to provide the same functionality. It was therefore interesting to note that male participants were more willing to use the notifier application and the smart watch more frequently. Some reasons they gave for wanting to use the watch were the convenience of having a watch on their wrist which could access useful information, and were curious in using new technology.

This finding also reinforces the initial perception of using the smart watch found in the requirements gathering process, where 86% of participants wanted to use a smart watch if they had access to one (see Section 5.1.2). Participant C commented on the ease of viewing information while driving and said "*I did find it convenient while I was driving, you can essentially just look at the watch while your hands are on the wheel to see what's coming in, and you don't have to check your phone for messages*". Participants C, D and E found the smart watch especially useful during lectures as they did not have to use their phones but were still able to view messages and emails. Participant C said "*During lectures it was useful, because I didn't have to take the phone out so often to see what message was coming in*". Participants B and C commented on the convenience of being able to decline calls from the wrist and controlling a music playlist instead of directly accessing the phone.

The convenience of having a device on the wrist to quickly view useful information, such as viewing messages while having both hands free, was found to be an important factor in using the watch. Participant C commented on this when speaking on how the watch was useful when driving. The results showing the smart watch to be a more convenient way to access information over the smart phone confirms the initial perceptions which participants had in the requirements gathering process. Most participants found they could use the information in a useful way when using the notifier application on the smart watch. The weather and calendar functionalities were particularly useful according to participants A, B and C. Participants also noted that they felt comfortable being aware of the notifications they received on their phones even though they were not physically using them.

Participants said that the phone finder application would be used by participants if they lost their phones. This was evident with the mean score of 4.83 for that question from Table 5.8. Participants felt confident when using the application and felt its operation could be learned quickly from the mean scores of 4.67 and 4.5 from Table 5.8 respectively. Mean scores of 1.5 were calculated for how complicated participants found it to use, and 1.33 calculated for participants who believed they required a technical person to be able to use the application. From these mean scores it can be seen that participants found the application simple enough to use themselves without direction from a third party.

Ease of use for using the phone finder application was seen to be higher than that of the notifier application, where the scores were 4.67 and 4.16 were calculated respectively. The reason for this could have been due to the phone finder being a less complicated application as there was only one main screen to use. Another possible reason could have been due to the limited functionality associated with the phone finder application, as the only functions available were to initiate the phone ringer and vibrate the watch according to the phones proximity. A mean score of 4.33 was obtained from the question on whether participants thought people could learn to use the phone finder application quickly. This result further highlights the less complex nature of using the phone finder application in relation to the notifier application, and thus the ease of use and perceived learnability in using the phone finder application.

None of the participants had used a phone finding application before. They were asked if they would use the phone finder application if they were in a situation where they lost their phone. Unanimously the answer was yes. Reasons included the "novelty value" of using such an application, and they thought the functionality was useful in that situation. Participant B added "*I really enjoyed that, I thought that was cool*", after using the phone finder application. This curiosity factor for using the phone finder application has been seen before in a study conducted by Arnone et al. (2011), where it was found that user perceptions of new technologies might be impaired due to the initial curiosity of using that technology.

The participants were also asked what further functionality they would like to see included in the smart watch. Participant A stated there should be an easier way from the watch to turn off the Bluetooth pairing to the phone. Integrated GPS functionality for on-wrist navigation was proposed by Participant B. Participants A, C, D and E stated there was only so much a watch could be used for, however participant C stated there should be more interaction between the phone and watch, such as "*Being able to adjust the volume on the phone via the watch*". Participant D wanted to see a history of messages received and a way of grouping these messages together.

All participants had never had access to other smart watches before the user study took place. The general consensus was that they had not been aware of the smart watch and what they could use it for. Criticisms of the smart watch were found to be the initial learning curve of what the buttons did, and the "*awkward*" way in which the buttons had to be pressed. The calendar application also required further refinement according to participant C and F. Participant C also commented on the "*buggy*" nature of the native Pebble control application on the paired smart phone. This could have been due to the participant's version of Android installed on the phone and not necessarily a problem with the application itself.

It was also noted that all but one participant thought the watch was expensive and did not believe the benefits outweighed its cost. All female participants commented on the large size of the watch on the wrist and that deterred them from wanting to use one, which reflected the perceptions found by females in the requirements gathering survey (see Section 5.1.2). The male participants did not feel that the watch was too large in physical size or that it became an obstruction in a real-world environment. The male participants could have been more comfortable with wearing the watch due to their larger wrist sizes. Some participants did not feel the necessity for owning a smart watch and said their phones already provided the functionality they required. The findings on how female participants perceived the usability of the watch reflected those seen in the requirements gathering process (see Section 5.1.2).

5.3 Challenges

During the usability study the participants were asked to meet the researcher as discussed in Section 3.3.5, where the notifier application was installed on the Pebble smart watch and paired to the participants phone. Since participants all had different phone models this posed some challenges. Upon pairing the smart watch to the participant's phone it was discovered in some cases that the phone enabled the *TalkBack* Android function. This resulted in all screen transitions on the phone being read out to the participant. This issue was seen with phones that had Android 4.0 (Ice-Cream Sandwich) installed as an OS. It was also interesting to note that while testing the phone finder application in the afternoon of the study some of the users' phones exhibited different reaction times to Bluetooth pings. This could also have been due to the different Android versions installed on the participant's phone and the way in which it handled message passing between the watch and connected smart phone.

5.4 Summary

This chapter set out to document the findings of the requirements gathering survey and the usability study of the research. The requirements gathering survey represented the first phase and usability study represented the fourth phase of the first and second iterations of the Spiral model respectively (see Figure 3.1). The requirements gathering process was aimed at eliciting information from participants on their perceptions on smart watches and the applications they would want to use on them. The information obtained through the use of questionnaires was presented in terms of the demographical data of the participants found, their perceptions on the smart watch and the applications they would like to use on them. In addition to these findings, any relationships or trends which were found from the information gathered was discussed.

Results from the usability evaluation which gathered information on the usability on the installed smart watch applications are also documented, including the demographics of participants as well as the results from the questionnaires and interviews. The results from the questionnaires included the distribution, means and standard deviations of participants' answers. The feedback from the participants gained in the interview process were also presented in a top-down approach, and any trends noticed from the questionnaire and interview evaluations were discussed. Any challenges or unexpected events which were incurred while gathering results were also mentioned.

Chapter 6

Conclusion

6.1 Summary

This project set out to determine if the smart watch would be useful to university students. A review of literature was first conducted where wearable computing was discussed further, specifically in the area of smart watches where their known advantages and disadvantages were acknowledged. Previous work done on application development for smart watches and other mobile devices such as smart phones was also investigated. The application requirements of users found in previous usability studies were documented, where it was found that users want similar functionalities from different devices. Possible future smart watch advancements based on current research were also discussed.

The Spiral methodology was used for the development of two applications for use on the Pebble smart watch. Requirements were initially gathered through the use of a questionnaire in a quantitative study, where user perceptions about the smart watch were analyzed; such as whether they thought the smart watch would be useful to them in terms of the information they want. Application preferences were also gathered from these participants where they were asked from a list of existing applications which ones they would consider to be most useful. Participants were also asked to give their own additional ideas for the applications they would like to use on a smart watch.

From these questions in the initial requirements gathering questionnaire, the most cited information which participants wanted was weather, calendar and email applications. It was therefore decided to create an application which incorporated these functionalities together, called the notifier application. The most requested application from their own ideas was a phone finding application, and so one was developed. Apart from attempting to satisfy user information desires on the smart watch, these applications represented a proof of concept as to what the smart watch can achieve through message passing between itself and a connected smart phone.

From the participant information collected in the requirements gathering process, a low-fidelity design process took place through mock-ups to allow for the development of high-fidelity application prototypes for the notifier and phone finder applications. These prototypes were evaluated by expert users who provided feedback on interaction with the watch and any improvements which could be made. This expert user input which was provided together with the initial findings from the requirements gathering process, allowed for the design of the final watch applications. The design and implementation of the watch applications were accomplished through the creation of UML diagrams which guided the development of the watch applications in the C language. The same was true for the companion application created for the phone finder which was coded using the Android Development Tools in Java.

Upon development of the notifier and phone finder applications, a usability test was performed as a field study. This was a qualitative evaluation in which a small number of participants used the smart watch in a more natural environment. Upon completion of the field study, the participants were asked questions through the use of a questionnaire and an interview. This allowed for detailed data to be gathered on the usability aspects of the smart watch and the applications which were used. The DECIDE framework was used as an evaluation technique and defined what needed to be achieved in the usability study.

6.2 Review of the Problem Statement

This study aimed at investigating the usefulness of the smart watch for university students. The information which smart watch users wanted was ascertained through the use of the initial requirements gathering survey, and two applications were subsequently developed to satisfy these information requirements. The applications selected were those which hosted weather information, calendar appointments and email functionality, and were integrated into the single notifier application. A system for finding a phone via Bluetooth was also developed in response to additional suggestions made by the participants in the requirements gathering part of the study (see Section 5.1.5).

The notifier and phone finder applications were then evaluated by a sample of different users in order to ascertain whether the smart watch was a useful interface among university students (see Section 5.2). From the results obtained in the usability study, it was found that the majority of users found some use from the smart watch and the applications which were installed on it. As discussed in Section 5.2.4, the smart watch was found to be a convenient interface to view information upon in situations where the connected phone was awkward to use, such as in a lecture or while driving a motor vehicle.

It was also found that while most participants acknowledged the usefulness of the smart watch, female participants would not use it on a daily basis due to its physical size. Male participants were found to want to continue using the watch for daily activities and were curious as to what else the watch could accomplish. It can be concluded from the research done that the smart watch provides small amounts of information usefully, albeit as a complimentary device to an attached smart phone. University students found the smart watch to be useful to view information generated by the applications which were developed for it, even if some of them would not use it on a frequent basis to do so.

6.3 Future Work

The information which was collected through the usability test could be used for the requirements gathering phase in a third iteration of the Spiral model (see Figure 3.1). A third iteration of the Spiral model would see the notifier and phone finder applications being further refined in their design and implementations. The calendar functionality could be updated to highlight days of the week on which there are appointments, and more interaction between the watch and the phone can be implemented such as viewing a history of the emails sent and received. A more intuitive way of turning off the Bluetooth connection between the smart watch and the phone was also suggested by users, and the incorporation of social media functionality into the notifier application could be developed. The button used for the silencing of the RingerService on the Android companion to the phone finder application was labeled “Stop Ringing!” this should be changed to “Found Phone!”.

Different users’ phones exhibited a variance in Bluetooth message passing times with regard to the ping functionality in the phone finder application. Due to this variance in timing, a learning mode could be introduced which takes a sample of Bluetooth messages sent between the watch and phone to establish a baseline average time, and attempt to compensate for the variance exhibited. This would also allow for all users who run the phone finder application to have an optimized version of the application regardless of the OS or phone model they run it on. A few more of the applications suggested by participants in the requirements gathering phase could also be implemented such as gesture control applications and GPS services, upon which another usability test could be performed and more data recorded. Participants commented on the convenience of using the watch in a lecture environment, this could possibly be investigated further, namely how the smart watch could be used as a learning device in a lecture environment as a form of e-learning.

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Appendix A

Evaluations

A.1 Requirements Gathering Questionnaire

Smart Watch Questionnaire

Smart Watch Questionnaire

Thank you for participating in this study. The smart watch operates as an interface with a paired Android or iOS smart phone, where it uses applications to access data from that smart phone.

Please select the relevant buttons below:

Age

- ○ 18 - 20
- ○ 21 - 23
- ○ Older than 23

Gender

- ○ Male
- ○ Female

Race

- ○ African
- ○ Coloured
- ○ Indian
- ○ White
- ○ Other:

Major Subjects

Year of study

- ○ 1st
- ○ 2nd
- ○ 3rd
- ○ Other:

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66% completed

Smart Watch Questionnaire

Would you use a smart watch if you had access to one?

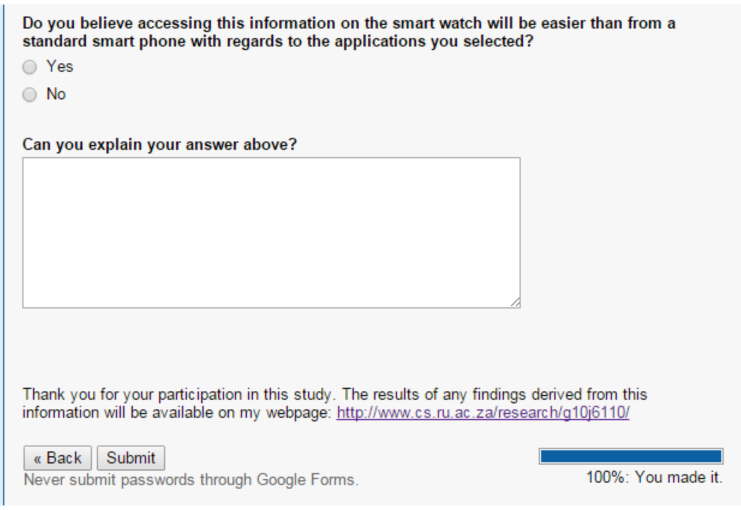
- ○ Yes
- ○ No

Can you explain your answer above?

From the list of possible applications below, select those which you would consider the most useful to use on a smart watch?

- ☐ Weather information
- ☐ Number of steps taken while running / playing sport
- ☐ Logging sleep patterns
- ☐ Results of your favourite sporting fixture
- ☐ Gesture control of applications (eg. Music control)
- ☐ Finding restaurants /coffee shops (Location based services)
- ☐ Social networking updates (Facebook, Twitter, Whatsapp)
- ☐ Sending and receiving emails
- ☐ Playing games
- ☐ GPS services (View lattitude and longitude information / current speed)
- ☐ Voice activated commands
- ☐ Event Reminders

Can you think of any other useful applications?



Do you believe accessing this information on the smart watch will be easier than from a standard smart phone with regards to the applications you selected?

- Yes
- No

Can you explain your answer above?

Thank you for your participation in this study. The results of any findings derived from this information will be available on my webpage: http://www.cs.ru.ac.za/research/g10j6110/

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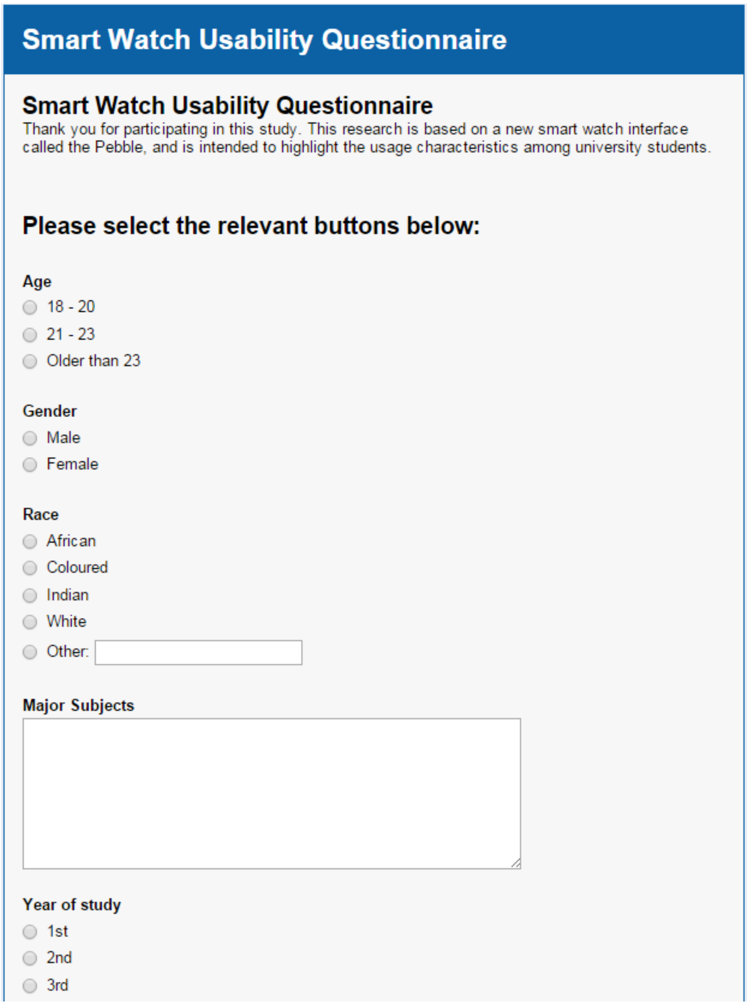
100%: You made it.

A.2 Usability Study

A.2.1 Questionnaire



Smart Watch Usability Questionnaire

Smart Watch Usability Questionnaire

Thank you for participating in this study. This research is based on a new smart watch interface called the Pebble, and is intended to highlight the usage characteristics among university students.

Please select the relevant buttons below:

Age
- 18 - 20
- 21 - 23
- Older than 23

Gender
- Male
- Female

Race
- African
- Coloured
- Indian
- White
- Other:

Major Subjects

Year of study
- 1st
- 2nd
- 3rd

Smart Watch Usability Questionnaire

You have used the Pebble for the day. Please answer the following questions based on the applications used.

Notifier Application

I would like to use this application frequently

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

I found the application complicated to use

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree
- ○ Option 6

I would need the support of a technical person to be able to use this application

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

I think most people would learn to use this application very quickly

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

I felt confident using the application

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

The information I received was useful to me

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

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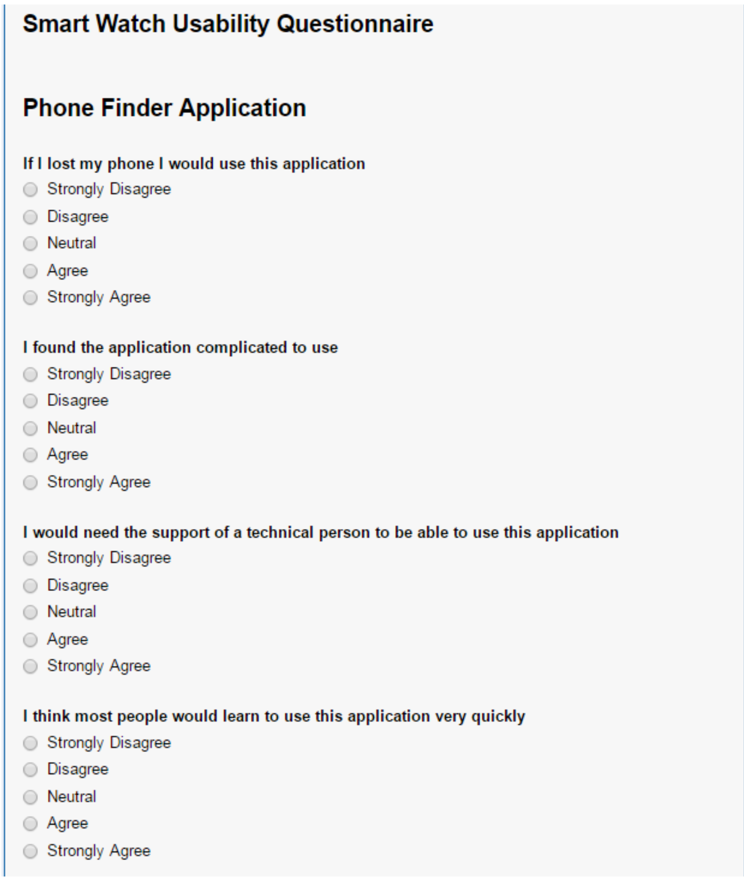


Smart Watch Usability Questionnaire

Phone Finder Application

If I lost my phone I would use this application

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I found the application complicated to use

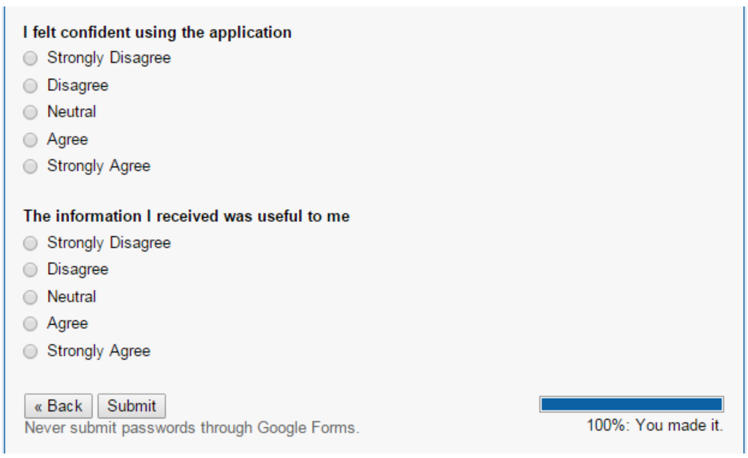
- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I would need the support of a technical person to be able to use this application

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I think most people would learn to use this application very quickly

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree



I felt confident using the application

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

The information I received was useful to me

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

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Never submit passwords through Google Forms.

100%: You made it.

A.2.2 Interview Questions

The questions asked in the interview were as follows:

1. After using the notifier and phone finder applications on the smart watch, would you say the smart watch interface is useful? <wait for response>Why do you say that?

2. How would you describe the physical user interaction with the smart watch? (In terms of button presses and what actions you thought the buttons would perform)

3. Did the applications on the Smart Watch help you in receiving useful data? <Wait for response>Can you give me examples of how that went?

4. Have you have used some sort of device finding application before? <Wait for response>How would you compare the one you used on the watch to find your phone?

5. Was there a particular circumstance you came across today where accessing information on the watch was easier than accessing information on your phone? <Wait for response>Can you tell me what happened (describe the events)?

6. Have you used other smart watches before? <Wait for response>If yes: In terms of usability which one do you prefer? If no: Is there any reason you have never used a smart watch before?

7. Did you feel the smart watch you were wearing today restricted you in performing any tasks or activities? <Wait for response>Can you provide an example where this occurred?

8. Did you feel it was more convenient to check notifications on the smart watch or on the phone? <Wait for answer>Can you explain further?

9. What further functionality or features would you like to see incorporated into the smart watch you were using today?

10. Are there any criticisms you may have in general about using the smart watch? <Wait for answer>Can you explain?

A.3 Participant Transcriptions

A.3.1 Participant A

Participant A [A]
Observer [O]

[O]: So when you first looked at the phone finder app <uhm >what did you initially think the buttons did? Did it ring any, like, bells as to what they would do?
[A]: You mean the buttons down the side?
[O] Yeah
[A] Those were fairly obvious, one was to phone, one was to do with the Bluetooth and something was either to cancel, I assumed it was to cancel.
[O] Okay, so you found it sort of self-explanatory?
[A] Yes
[O] Okay, um, so after using both applications for the whole day would you say that it's a useful device to have?
[A] Not for me personally, I think it's a, my phone dies all of this anyway, so why do I need a watch to tell me when I have a phone?
[O] Okay, How would you describe the, um, physical user interaction? Like with the buttons.
[A] They're, they're too <pause >hard to push sometimes and I couldn't get my fingers into the right place to not push the one on the left when I was trying to push some of the ones on the right.
[O] Okay
[A] So it was a bit tricky there.
[O] So um, and also, just, generally did the buttons do what you thought they would do?
[A] Um <pause >trying to work out how to go back took quite a while and then sometimes going forward took me back again and then it got a bit confusing at times.
[O] Okay
[A] Ja
[O] Alright, um, did the applications that you were using, um, provide any value to you? Were they, were they valuable in consuming like important data?
[A] I liked the weather, I thought that was quite cool, and I liked the fact you can get games on there.
[O] Okay, alright, any other examples?

[A] I think the phone finder would be useful, but I didn't know about it until afterwards <laugh >but I was trying to work out what it was, so
[O] Okay ja <pause >uhm, so have you ever used any sort of phone finding application before? Obviously not hey?
[A] uh uh no
[O] Alright, um, if you did have a phone finder application would you, would you initially use that to actually find your phone?
[A] Yes
[O] Okay
[A] Especially for the novelty value and then when I did actually lose my phone I think it would be quite useful.
[O] Of course, um <cough><cough >so was there any circumstance that you came across today where looking at the watch was easier than accessing the phone?
[A] Yes, um, I was tutoring today and I changed the display from a digital to an analogue.
[O] Okay
[A] And then back to a digital, because digital is more useful in certain times and analogue was more useful in the tutorial, it was quite interesting, it was very weird. <Pause >I used the watch the whole day though not the phone.
[O] Okay, that's interesting, have you used other smart watches, um, before?
[A] No, never
[O] Is it, okay. <Pause >is there any reason?
[A] Too expensive, never had much exposure to them, that's why I thought this one would be cool.
[O] Did you feel that, um, at any time today the watch, um, impeded you in doing any tasks?
[A] It's too big on my wrist, so sometimes it would catch on things and I wasn't expecting it to catch.
[O] So did you feel it was more convenient, perhaps in certain circumstances, to use, the watch, than using your phone?
[A] No definitely, it's <pause >limited functionality but you know what's there so you can use that one more than the phone. Like I used it for an alarm to remind myself to come here.
[O] <laugh >okay cool <pause >um, okay so what further functionality would you suggest on a watch like this?
[A] A way to turn off the pairing, a more obvious way to turn the pairing off between the phone and the watch so if you wanted to turn off the Bluetooth, to be able to just turn it off by the watch and also to be able to check the battery life, because you don't know

what the battery is doing on the watch.
[O] Okay so in general are there any <pause >criticisms that you can, that you can give?
[A] The buttons are very hard to work out what they do initially, once you get it it's okay but especially the back, you need some sort of, even like just the images that you used in the phone finding, something like an arrow or something just to show that this is the way to.
[O] So they aren't really intuitive?
[A] uh uh <pause >the images are, the buttons themselves are not.
[O] Alright, I think that's about it then

A.3.2 Participant B

Participant B [B]
Observer [O]

[O]: Okay cool, so like um, when you were looking at the watch what did you initially think the middle button did?
[B]: Uh, this button here? The first time I ever looked at this watch?
[O]: Yeah
[B]: Um, I assumed it to be a selecting button.
[O]: Okay, and what did the image, did the image mean anything to you?
[B]: Uhm <pause >the image, no I didn't like really mess around with the image, I found this button the left to be the one that denoted everything for me, I realized like if you click on this one you enter in and then obviously these ones were selecting but I mean that is what I initially thought, so like click in and then as soon as I realized that this button was back, like that was a good noticing like thing <laugh >that determined a lot for me and um I don't know I found the interface like very straight forward to be honest.
[O]: Okay so in general would you think that it's useful to use?
[B]: Ja, I think so, definitely, I think there's some things that could be fixed up like the calendar app for instance for instance I tried to go here and look at my actual like events it didn't have them signalled there but I mean other than that it was pretty good, um the only thing that I found quite irritating was they didn't have notifications for whatsapp and for other messaging services which might be interesting, uh to like consider. Then <pause >other than that I don't know I found the other applications all very cool to be

honest, I downloaded a few.
[O]: Okay
[B]: I got skateboard+ <laugh >
[O]: <laugh >I've never heard of that one before.
[B]: Ja, which shows how many times you push on your skateboard, so it's like a motion thing.
[O]: Oh hectic okay.
[B]: Two kicks and then it like goes to three <laugh >and then um this chordinator also which is this guitar uh like guitar chords and stuff like that and piano chords.
[O]: Oh chilled
[B]: So um, that's pretty cool, from a music perspective, um <pause >ja I found it quite cool, I found it useful um it makes me think of my little brother's like Samsung he's got a watch as well that like does the same kind of thing, from a hardware perspective.
[O]: So you'd say, how would you describe the physical user interaction with the watch?
[B]: I found it very easy to use, enjoyable actually, and I found that the menu interface was very cool as well, um it was simple, it wasn't too much to like be confused about to be honest.
[O]: Okay, did it help you.
[B]: There was everything that I really needed to get to though. I enjoyed that when someone called you, you could just decline them straight from the watch.
[O]: <laugh >true.
[B]: which was cool.
[O]: Okay, okay so it sort of helped you in consuming important data or useful information?
[B]: Ja, useful information and like ja <pause >I don't know it's kind of like some of the stuff you are going to get those apps that just are a bit gimmicky and stuff like that but I mean that's inevitable, but I thought it was cool. I mean if it wasn't too much I'd probably purchase it.
[O]: Alright
[B]: I also liked the function of the weather, it shows the weather on your watch and I thought that was very cool although it disappeared like after a while I don't know why.
[O]: Is it, it's probably a Bluetooth issue again, Bluetooth 4.0 has that issue, it has like an LE sniffing mode, so it goes into a low powered mode very very quickly.
[B]: Okay hectic
[O]: Um, so have you ever used like a phone finding application before?
[B]: No never, I really enjoyed that, I thought that was cool.
[O]: Okay
[B]: I think if you could put that to like car keys or like something else like that would be

sweet <laugh >that is generally the easier thing to find.
[O]: Alright, so was there any like particular situation you were in today where <pause >where looking at information on the watch was easier than say taking your phone out?
[B]: Um <pause >ja I'd say for messages, especially um <pause >for instance like because we're university students and in class it was quite useful, to not have to take out your phone or anything you could just be like hey my wrist just vibrated <laugh >let me look at who that was from. Especially getting calls from all these telemarketers and stuff, not telemarketers but from standard bank , like keep on calling me and you can stop them.
[O]: <laugh >decline, decline
[B]: Ja so it was always decline decline so it was useful, um ja and then the music thing was cool as well , once that started going, especially for me because I wear headphones and stuff so I can just walk and change songs. Would be cool if you could implement like a shuffle thing so you actually get your full library, like that could be quite cool.
[O]: Okay, so um, you've used other smart watches before?
[B]: I haven't, I've just seen my little brother's one before, and that one was very cool, you could make calls from his watch.
[O]: So how would you like compare them? Like this one and the <pause >
[B]: Well the little bit that I did see of that one, um, that one kind of had a bit more usability in terms of like calling people from your watch and um I think he even had a GPS on his watch, so that was quite cool. But um, ja I think they much of a muchness to be honest, like it was a bit bigger the screen, the interface was a little bit different it was more sleek. I'd say it looked a little bit more sleek. But I didn't get to press, I didn't get to play around with the buttons or anything like that.
[O]: Okay, so that was the Galaxy Gear hey?
[B]: Ja ja I think so.
[O]: Alright, okay, so <clears throat >did you fell that it might have impeded you in like any tasks that you were doing today? Did it get in the way of anything?
[B]: Not really hey, I mean the only thing really was just playing around with all the apps and finding stuff on the actual Pebble service on the phone. I found that very very well done as well I'd say, the actual app on your phone was very straight forward and easy to use.
[O]: So in terms of the convenience factor, would you say that the, the watch is more convenient than checking the phone ?
[B]: Hmm ja I would say so.
[O]: Alright <pause >um, so like further functionality or like functions, I think you mentioned earlier, um, ah a few applications that you'd like to see, um would you mind just going through why you'd like to actually see those?

[B]: Well I'd like to see the music one to, to be able to see all that thing, well I suppose it's not really an application but to able to see like all your artists and stuff.
[O]: Like a library?
[B] mmm <nods head >, I'd enjoy that, um <pause >what else would I enjoy? I suppose, like a GPS on this thing would be crazy, like something that just sends you like your directions from your phone and that would take away a lot of looking at your phone and stuff like that.
[O]: Yeah because your hands are on the steering wheel yeah.
[B]: Yeah exactly so that could be quite cool, um <pause >I don't know I was thinking of other apps that could actually like you know be implemented with this, because in my head when I first looked at this I was like Ja no the only thing could be really like a calendar app like calendar or something and then like I saw music and I was like cool. But when I saw all these other like chord ones and skateboard ones I was quite amazed, like I'm very impressed with the motion sensor inside here, that's very cool, something that can be used a lot, and like fitness wise and like monitoring your health it's like very good. I think all those apps are really cool. I can't of any particular apps that I'd use other than the GPS one that aren't on there already.
[O]: So in general do you have any criticisms about it?
[B]: Um <pause >, I found, okay ja, the one issue I had with the actual app was that when I went into it there was a bit of confusing I ended up resetting up the whole thing, so it deleted some stuff, I didn't know if it deleted or if it just reset some stuff which was a bit interesting. Like I didn't expect it to do that. Um, no I can't think of anything that really is bad about it to be honest. I found it smooth and usable <laugh >How long is the battery life I guess?
[O]: <laugh >A few days actually, better than the gear that's for sure.
[B]: Ja, okay cool
[O]: It's very minimal
[B]: Ja it seems like that, I mean maybe a calculator could be cool <pause ><laugh >
[O]: <laugh >
[B]: There is a calculator on here if I'm not mistaken

A.3.3 Participant C

Participant C [C]
Observer [O]

[O] So after using the watch for the day would you describe it as being a useful device?
[C] I think it's useful in the kind of diary way, um time and weather, appointments and stuff like that I thought it was quite useful.
[O] So for certain types of applications you'd say?
[C] Ja, I, I, I was, when I was using it I found that it was that it could be really cool to use for, for like keeping track of things. Um not like, not really useful for I think there was extra applications like for running and steps, um navigation and stuff like that, I didn't really um use that much, I used it more with managing my day kind of thing.
[O] Okay, how would you describe the ah, the user interaction like the physical button presses, and um did the buttons do what you thought they would do when you pressed them?
[C] um, the button presses were easy, um I mean there's only like four of them so it was pretty easy to, to figure out which one does which eventually. Um, they work quite, you did have to press them really hard, uh well you had to put effort into pressing them. Um, especially with that game flappy bird, it was <laugh >I was worried that I was going to break the watch off my hand eventually.
[O] Alright, um, so did it help you in consuming useful data?
[C] In consuming useful data? What do you mean?
[O] Like, was it, was it useful in um, in terms of finding out certain things. Like if you wanted to I don't know, look at your emails or news updates.
[C] Oh okay, ja, ja no definitely it was, it was actually quite useful because you don't have to take the phone out of your pocket, I could like, if a message comes in, um or emails and stuff I can access them and I could view them. And I could also like um, phone calls and stuff like that I didn't have to take my, the phone out of my pocket to see who's calling I could just cancel it if it wasn't important, ja.
[O] Um, in terms of like the phone finding application, have you ever used an application like that before?
[C] Um, the closest I've used to it, was a, I think it was a, a whistle and the phone would answer, a phone would pick up on the sound of your whistle, and it would make a noise. But no I haven't used anything , uh, like that where you can actually press a button and your phone will start ringing.
[O] Okay, um, how would you compare that whistling application to the one that you used today?
[C] Um, there is no comparison, because the whistling one was, it was very like, um, very basic and you had to get the right whistle and you had to be in the range of the phone

for it to hear you kind of thing. This is much better, because you just have to be in the range of Bluetooth don't you?
[O] Ja, um so was there a particular circumstance today where accessing information on the watch was easier than accessing on the phone?
[C] During lectures it was, because um, especially with whatsapp and messages, they were um, I was getting quite a lot of messages coming in so, so the phone like, I mean lecturers don't really like it if you sitting on your phone in lectures. But definitely I didn't have to take the phone out so often to see what message was coming in if it was important and stuff like that. And also with, I set um, I set alarms and stuff like that, or kind of reminder alarm as well that I needed to be back here at three, I set an alarm so it was easy just go to the alarm thing and set it and then it goes off yeah.
[O] Alright, have you used other smart watches before?
[C] No I haven't.
[O] Is there any particular reason for that?
[C] Um <pause >probably, well, probably the main reason for me is that they are expensive. Um and I haven't, uh I don't know they are pretty new well from what I'm aware of they are pretty new on the market so, I haven't really, the only one I've really been made aware of is the Samsung watch I don't know what It's called. But I believe iPhone, Apple's bringing out one but those are the only two I know of and they are quite expensive.
[O] Um, was there any instance today where it impeded you in doing any activities? Or was it a hassle? Or did it get in the way of one sort of activity?
[C] Um no it didn't get in the way I'm just not used to wearing a watch, so it was a bit uncomfortable at first, but anything, anything like watch wise for the first day or so it's uncomfortable but then you get used to it so. As far as getting in the way of things, I wouldn't say so it was just like ja.
[O] Okay, so how would you rate the convenience aspect of the, of viewing information on the watch in comparison to the phone?
[C] On a scale? Or just
[O] No just in general like
[C] Well, It is convenient, it definitely is and also um, why I did find it convenient as well is while I was driving, um, you can essentially just look at the watch to see what's coming in you don't have to have your phone, or check your phone for messages or something like that, you shouldn't be using your phone whilst you're driving but if a message comes in you're going to want to see what it is so you can just check the watch. Even with navigation I tried navigating on the way here, so it was quite convenient because you can just look at it.

[O] Was it because of the position?
[C] Because of the position and also it's, you have both hands free when you doing stuff so um ja both hands, both of your hands are free so you can do stuff with your hands and still have, be able to check the time or messages and stuff that come in.
[O] Um, what further functionality would you like to see incorporated into the smart watch?
[C] What further functionality?
[O] mmm
[C] Um <pause >, I'm trying to think now um <pause >, I'm not too sure I think um there's probably only so much you can do with a watch but I think maybe um, sorry I'm trying to think now <long pause >
[O] Take your time
[C] Uh, probably I couldn't find volume controls on it so I know with the music player, I couldn't I didn't figure out how to adjust the volume, um ah that's just minor, apart from that I think just the, all the applications are there um they just could be refined I guess in a way or um, I'm not sure <laugh >
[O] Okay, that's fine. Um so are there any criticisms in general about the smart watch you were using?
[C] About the watch, uh, the watch was cool but I think the application on the phone to use it was a bit, was quite, call it buggy or um it was, ja it was difficult to use that application should I say. It's easy enough to get the applications on and off the phone, that was pretty straight forward um, I don't know its just a watch so you are limited to the space but I think I was only able to put like four or five applications on there and then it said that the watch was full. So the watch itself was fine its just I think getting applications on and off there was the issue, um I know I struggled with the navigation I had to download a companion app.
[O] Ja, that's about it.
[C] Okay cool

A.3.4 Participant D

Participant D [D]
Observer [O]

[O]: So um, so after using the notifier and phone finder applications, uh would you say

that the smart watch is useful?
[D]: Very Useful, yes.
[O]: Okay, could you explain further maybe?
[D]: Um <pause>, well I only typically look at my phone a couple of times a day, um but like with the smart watch, I was basically contacted all the time so, there have been instances where people have been trying to contact me in a lecture and I haven't been aware of it. Whereas today I felt in contact all the time, and even though it wasn't necessarily a practical gain for me today, the feeling was cool. And I could see how it would be useful.
[O]: How would you describe the physical user interaction with the button presses, and did the buttons do what you thought they would do?
[D]: Um, well I liked the fact that the buttons were big, um and the, the, the up and down buttons were very intuitive obviously but the select, the enter button and the back button for me, took me a couple more seconds to get the hang of it. And I started thinking of them like the four buttons as up and down and forward, back, even though that wasn't quite what they do, that was sort of the mindset I was getting into, um but it was relatively simple yes. I didn't suffer unduly.
[O]: Okay um so, did it help you in consuming useful data?
[D]: Yes, um <pause>the, obviously the functionality is limited, it's essentially just sending messages to the watch, there's not much else interaction but it was enough to make me feel like I was, like I said earlier, connected to my phone even though I couldn't look at it, so it was enough, it was, the right information was there.
[O]: Have you used any other device finding application before? Or phone finding application before? Is that just because you haven't sort of had access to one?
[D]: Ja, I haven't been in contact with them, never had access to them. As I was saying earlier if I had I would have wanted to have used them.
[O]: Alright, was there a particular circumstance today where um, where accessing the watch was easier than accessing your phone?
[D]: Um, well it was always easier, but you know the fact that there's limited functionality you can't really interact it's just a message that something has happened, a notification. Um I still had to go and dig around in my bag for my phone. So it wasn't necessarily, give me easier access it was just more convenient if that distinction makes sense?
[O]: uh ha, so have you used any other smart watches before?
[D]: No
[O]: Any particular reason?
[D]: Uh, I've never had the chance, just the expense, if I'd wanted to use one I'd have to buy it. Uh I suppose I could have gone to the shop and asked to look at one <laugh>

[O]: Demo it.
[D]: Demo
[O]: Did you feel that the smart watch that you used today impeded you in any way in any activity, did it get in the way of anything?
[D]: No, not at all. Well, just as, sort of like a side note, tangentially related to that, having a vibration mode on the wrist took a while getting used to. It was a bit startling at first.
[O]: Um, so I think you noted earlier that the convenience aspect did feature quite heavily in the notifications um, what further functionality would you like to see on the smart watch?
[D]: Um, more ways of interacting with the phone, I played a little bit with the music functionality being able to control what music the phone was playing. Um, again that was just a little bit of convenience because you can get remote controls on your earphones and stuff but you know other apps which do similar things, which interact more with the phone. Um, maybe let you scroll through your contacts list, things like that that would be useful.
[O]: Alright, any more examples that you can give me?
[D]: <pause>Oh, um, one thing, I did notice was, it's linked to the fact that your phone is just sending notifications from the watch, so you get this, like a whole long list of messages which you received but you have no way of grouping them together or organising them, so if you want to go look through your history you have to scroll through your whole history, and that I thought could get a bit inconvenient. But that's if you're wanting to get, sort of more functionality out of it, if you're just using the watch as a, as a notification, hey something's happened, then that wouldn't be such an issue.
[O]: Okay, so would you say that's sort of a criticism?
[D]: Yes, I'd say a minor criticism. It's an area which it could be better in.
[O]: Do you have any other sort of general criticisms about the watch?
[D]: Oh just one thing, um, the button placement um like when pushing the buttons I liked to brace the watch on the other side with my finger so I could push it along my wrist and it was easier for the buttons in the right hand side because there's a space on the left hand side to put my thumb, but the reverse isn't true, the buttons take up all the space on the right hand side. So I had to like brace it on the top and it was a bit awkward?
[O]: So it was a bit of an ergonomic challenge?
[D]: Yes that's exactly what it was, an ergonomic challenge.
[O]: Alright yeah, I think that's about it then.

A.3.5 Participant E

Participant E [E]
Observer [O]

[O]: Okay ja, so after using the watch for today would you say that it's a useful device?
[E]: Ja, definitely
[O]: Okay, can you elaborate on that?
[E]: Um, I like the fact that it tells me when my phone is ringing even though my phone's on silent at the bottom of my bag and the fact that it tells me what messages I'm getting on my phone as well. So it means I don't have to take my cellphone out, like in the middle of high street where I have to worry about it being taken.
[O]: Okay, how would you describe the physical interaction with the device? Like the button presses, and did the buttons do what you'd thought they would do?
[E]: Um, it took a while to figure out, especially on the right hand side what was going on, um cos first I thought that the one bottom button was like the button that was like that. Um the buttons are quite hard to press, um have to press them a few times. Um the watch itself is a little bit too big for my wrist.
[O]: So did it help you in sort of consuming useful data?
[E]: Well it helped me when my phone was ringing, it was really really useful.
[O]: Have you ever used um, some kind of device finding application before? Like the phone finder app?
[E]: No, other than phoning a cellphone with another phone.
[O]: Okay, just you haven't come across one or?
[E]: No.
[O]: Is it. Okay.
[E]: Ah actually, there was, someone had, a friend of my mom's she had a thing on her key ring and if you whistled it whistled back. That was quite cool, but this is cool.
[O]: Okay, you also get these things called iBeacons which is like a sticker, a Bluetooth sticker, you can put on random things you can put on keys or a laptop or whatever, and you can ping it with Bluetooth. Um ja, but I digress. Was there a particular circumstance today where accessing information was easier on the watch than on the phone? Besides the obvious example.
[E]: Yes well I didn't have to take it out my bag <laugh>
[O]: Alright, um so that's about it hey?
[E]: Um so have you ever used any other smart watches?

[O]: No
[E]: Any reason?
[O]: I didn't know they existed.
[E]: And I'm not such a big technology user really, I don't install many apps on my phone.
[O]: Okay, did you feel that wearing the smart watch today impeded you in any activities or tasks?
[E]: No I forgot it was there.
[O]: So I think you mentioned the convenience factor earlier, yeah um, so you'd definitely say it's more convenient in certain circumstances to use or to access information on the watch as opposed to the phone?
[E]: Yes definitely.
[O]: What further functionality would you like to see on the watch?
[E]: Uh I'd love it to see how far I was running or something as well, because then I could have one watch that did everything.
[O]: Alright, is that it?
[E]: Yeah I think so.
[O]: Just like in general are there any criticisms that you'd express?
[E]: Well apart from it being a bit wide and the buttons being a bit hard to push.
[O]: So you would say it's more of an ergonomic issue?
[E]: Ja it's definitely more of an ergonomic issue, not what it has on it. It's slightly think as well.
[O]: What did you think of the control app on the phone, to install applications and such?
[E]: I didn't really
[O]: Ypu didn't really look around at it?
[E]: No
[O]: Okay no worries, that's about it then.
[E]: Cool

A.3.6 Participant F

Participant F: [F]
Observer: [O]:

[O]: Ja okay, so after, after using um the watch for today would you describe it as being a useful device?

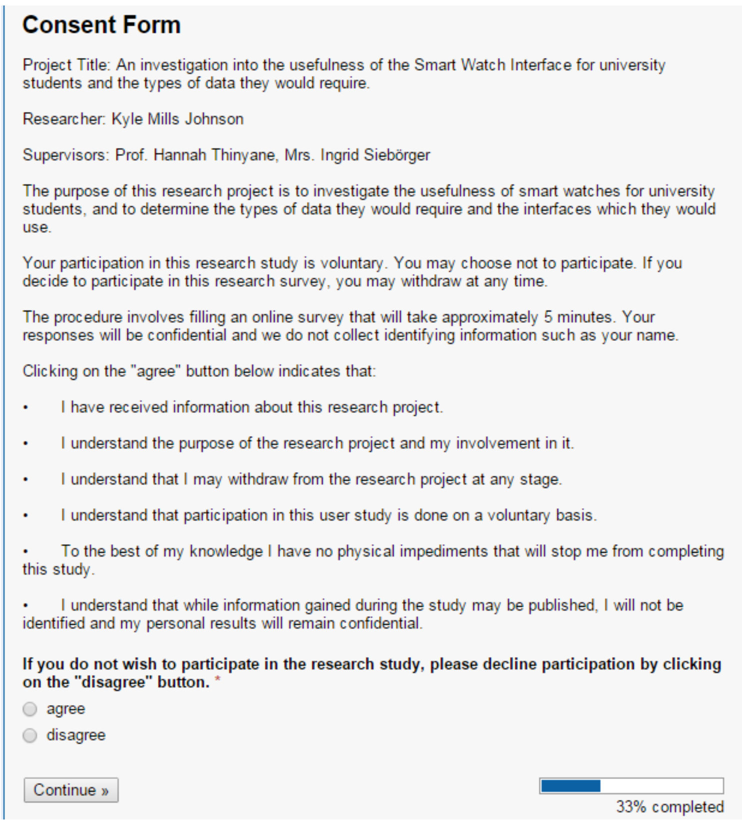
[F]: Um, to a point, yes. But, okay things like for instance the notifications, it would be great if I could get WhatsApp notifications as opposed to text, because nobody really texts these days. So, um, yeah. Um <pause>, other than that, like I didn't really use the watch much other than looking at the time.
[O]: Oh is it, okay.
[F]: ya.
[O]: So you didn't like play around with the settings?
[F]: I did, I actually ended up playing my music on my phone <laugh>, in class but hey.
[O]: Oh alright.
[F]: Cos yeah, that was cool, and even the calendar app was pretty cool, but it would be great if you could actually highlight the days that you actually have something on, cos then I went through trying to find, like, the, without having to go through each date. Cos it doesn't do that, I don't know, I have stuff on my phone that is highlighted but not on the watch.
[O]: Not on the watch, that's good feedback. Um how would you describe the user interaction of the actual watch like the button presses and did the buttons do what you thought they would actually do?
[F]: Yeah it took me a few, like the first few tries to figure out what they did. But then it's easy to get the hang of it, like you know up and down and then back, it's just the up button.
[O]: Oh okay, so it's quite intuitive?
[F]: Yeah
[O]: Um, did it help you in consuming useful data throughout the day?
[F]: mmm, other than time, not really.
[O]: Nothing else? Ok, alright. Um, is there any particular reason for that? That you didn't use it for anything else?
[F]: Well, like I said notifications, I didn't get notifications of whatsapp messages or you know, or if it let me know like <pause>, that would be great, but text messaging, yeah.
[O]: Have you ever used um, a device finding application before? Like earlier
[F]: No
[O]: Okay, um was there any circumstance that you came across today where accessing information on the watch was easier than accessing it on the phone? But considering you only used it for time, was it easier to look at the time on the watch than it was on the phone?
[F]: Yeah it was, I actually didn't look at my phone all that much today <laugh>
[O]: Um, so that's it hey? You didn't use it for anything else?
[F]: Yeah, also generally I don't really wear a watch so, I always look at my phone for

time, but it was great.
[O]: Have you used other smart watches ever before?
[F]: No never
[O]: Is it, is there any particular reason for that?
[F]: No, no particular reason.
[O]: You just haven't been exposed to them or?
[F]: No, I just generally don't wear watches I guess, so.
[O]: You weren't even curious?
[F]: <laugh>I'd like to, at least to play around with but I wouldn't personally use it on a daily basis.
[O]: Alright, do you feel that it like sort of impeded you from doing any specific tasks today, did it get in the way of anything?
[F]: No, nothing.
[O]: Is it, alright. Um, that question is moot. Alright what further functionality would you want to see on a watch like this? Like if you were to use it?
[F]: Um, the whatsapp thing, um calendar thing is a good app, I like that but it would be good if you can actually see, like on the days that you actually do have something then you click and decide to go through each single date. It didn't show up.
[O]: Okay, so it didn't highlight them?
[F]: Yeah it didn't highlight them. Um, also it could show you your recent, if you have tasks and stuff like that to do, cos that would be great for that. Uh yeah, I'd say that's about it. Also a bigger screen, cos I mean there's so much border but very little screen.
[O]: So do you have any general criticisms towards the watch?
[F]: Well no, well maybe, I don't know if maybe it's taking it too far but maybe a touch screen as opposed to buttons, I don't know.
[O]: Okay, so you'd prefer a touch screen interface?
[F]: Yeah, then buttons, but that's just because I like touch screen. It just makes it feel fancier.
[O]: Is there any particular reason? Do you feel that it's easier to access it?
[F]: Yeah it would be so much easier.
[O]: Did you feel the buttons were a little bit awkward to press?
[F]: Yeah and then, they weren't really awkward but now opposed to the touch screen, buttons are so hard.
[O]: Alright well that's about it then.
[F]: Okay

Appendix B

Ethics

B.1 Requirements Gathering Consent Form (CS-14-01)



Consent Form

Project Title: An investigation into the usefulness of the Smart Watch Interface for university students and the types of data they would require.

Researcher: Kyle Mills Johnson

Supervisors: Prof. Hannah Thinyane, Mrs. Ingrid Siebörger

The purpose of this research project is to investigate the usefulness of smart watches for university students, and to determine the types of data they would require and the interfaces which they would use.

Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research survey, you may withdraw at any time.

The procedure involves filling an online survey that will take approximately 5 minutes. Your responses will be confidential and we do not collect identifying information such as your name.

Clicking on the "agree" button below indicates that:

- I have received information about this research project.
- I understand the purpose of the research project and my involvement in it.
- I understand that I may withdraw from the research project at any stage.
- I understand that participation in this user study is done on a voluntary basis.
- To the best of my knowledge I have no physical impediments that will stop me from completing this study.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button. *

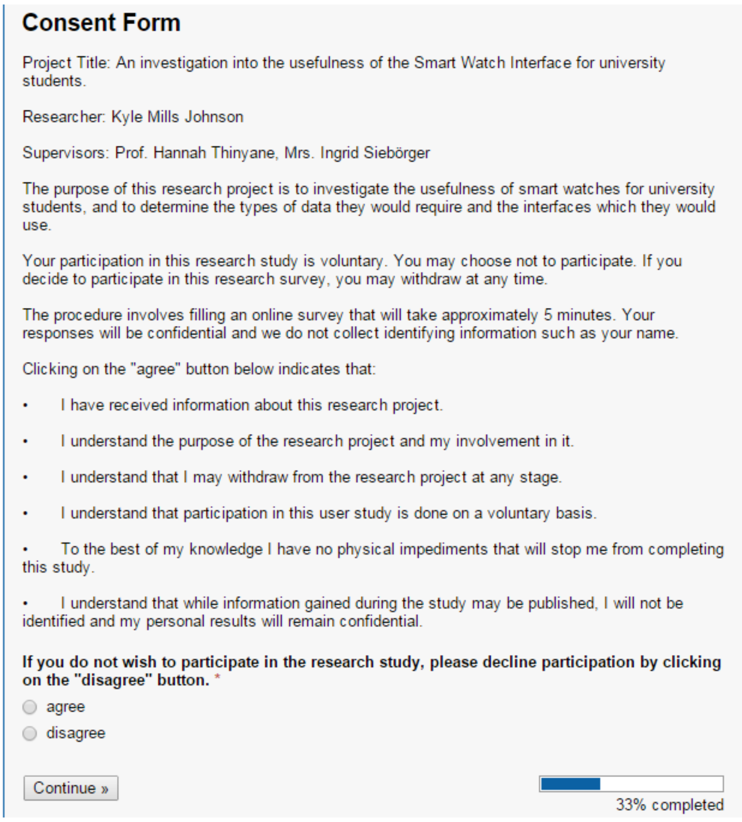
agree

disagree

Continue »

33% completed

B.2 Usability Study Consent Form (CS-14-07)



Consent Form

Project Title: An investigation into the usefulness of the Smart Watch Interface for university students.

Researcher: Kyle Mills Johnson

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- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

If you do not wish to participate in the research study, please decline participation by clicking on the "disagree" button. *

- agree
- disagree

Continue »

33% completed

Appendix C

Source Code

C.1 Basic Pebble Application Structure in C

```c
#include <pebble.h>

static Window *window;
static TextLayer *a_text_layer;

static void init(void){
    /* Create window */
    window = window_create();
    /* Push window onto the Pebble screen.
       Animated parameter allows the transition to appear as if it slides onto the screen */
    window_stack_push(window, true /* Animated */);
    /* Get root layer */
    Layer *window_layer = window_get_root_layer(window);
    /* Get boundaries of the window */
    GRect bounds = layer_get_frame(window_layer);
    /* Allocate memory of the text layer with appropriate dimensions */
    a_text_layer = text_layer_create((GRect){ .origin = { 0, 30 }, .size = bounds.size });
    /* Set the text to display */
    text_layer_set_text(a_text_layer, "some text");
    /* Add text layer as a child of the window root layer */
    layer_add_child(window_layer, text_layer_get_layer(a_text_layer));
}

static void deinit(void){
    /* Deallocate resources for text layer */
    text_layer_destroy(a_text_layer);
    /* Deallocate resources for window */
    window_destroy(window);
}

int main(void){
    init();
    app_event_loop();
    deinit();
}
```

Figure C.1: Basic Pebble application structure in C using the CloudPebble IDE

C.2 C Functions handling Message Passing

```
void out_sent_handler(DictionaryIterator *sent, void *context);

void out_failed_handler(DictionaryIterator *failed, AppMessageResult reason, void *context);

void in_received_handler(DictionaryIterator *received, void *context);

void in_dropped_handler(AppMessageResult reason, void *context);
```

Figure C.2: Functions used for Message Passing in the PebbleKit SDK

C.3 Bypassing Android Modality

```
<receiver
    android:name="com.example.phonefinder.PebbleMessageReceiver"
    android:exported="true">
    <intent-filter>
        <action android:name="com.getpebble.action.app.RECEIVE" />
    </intent-filter>
</receiver>

<service android:name="com.example.phonefinder.RingerService" />
<receiver
    android:name="com.example.phonefinder.StopRingingReceiver"
    android:exported="true">
    <intent-filter>
        <action android:name="com.example.phonefinder.RingerService.STOP_RINGING" />
    </intent-filter>
</receiver>
```

Figure C.3: Extract from AndroidManifest.xml allowing Android multi- modality support

C.4 Watch Vibration Strength and Duration

```
void vibes_pwm(int32_t strength, uint32_t duration) {
  // strength: pwm ranges from 1 - 7, 0 is fully off, 7 is fully on
  // duration: duration in milliseconds (must be > 0)
  uint32_t pwm_segments[MAX_PWM_DURATION/7], pwm_seglen;
  if(strength < 0) {
    vibes_cancel();
  } else if(strength > 10) {
    pwm_segments[0] = duration;  // on for [duration] (in ms)
    VibePattern pwm_pat = {.durations = pwm_segments, .num_segments = 1};
    vibes_enqueue_custom_pattern(pwm_pat);
  } else {
    if(duration > MAX_PWM_DURATION) duration = MAX_PWM_DURATION;
    duration /= 7;  // Trial&Error found 7
    for(pwm_seglen = 0; pwm_seglen < duration; pwm_seglen++) {
      pwm_segments[pwm_seglen] = strength;      // on duration (in ms)
      pwm_segments[++pwm_seglen] = 10 - strength; // off duration (in ms)
     }
    VibePattern pwm_pat = {.durations = pwm_segments, .num_segments = pwm_seglen};
    vibes_enqueue_custom_pattern(pwm_pat);
  }
}
```

Figure C.4: Function used to determine vibration strength and duration

```
// Narrow in on the phone proximity
strength = getBtStrength(deltams);
duration = getBtDuration(deltams);
for (int n = 0; n < 3; n++){
    vibes_pwm(strength, duration);
}
```

Figure C.5: Function call for strength and duration of vibration in the in_received_handler function

Appendix D

Contents of Electronic Appendix (CD-ROM)

1. Project Proposal
2. Literature review
3. Short Paper
4. Final Presentation
5. Final Write Up
6. Results
7. Application Source Code