Is there a one size fits all for mobile health? Investigating applications to support diabetes self-care

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ABSTRACT

Diabetes is a long-term condition that requires a great deal of personal responsibility to manage a complex interplay of different factors. A number of applications for personal devices, such as smartphones, have been designed to help people with diabetes to manage their condition. Previous studies have evaluated these applications, but overlook the applications people with diabetes choose to use to manage their condition. This study uses two online surveys to find out what applications, if any, people with diabetes use, why they use them and how. Findings suggest that people with diabetes use a range of applications with different functionality to suit their personal needs and preferences. Developers of applications, designed to support diabetes self-care, need to provide choice and the ability to personalise in order to cater for a variety of needs.

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CHAPTER 1. INTRODUCTION

Diabetes is a significant global health challenge. It is estimated that 382 million people have this disease worldwide and it is expected to increase to 592 million by 2035 (International Diabetes Federation, 2013). In the UK, it is estimated that three people will be diagnosed with diabetes every ten minutes (Diabetes UK, 2014a).

The chronic condition is characterised by either a lack of insulin production or insulin resistance causing an inability to regulate glucose levels within the blood (National Health Service [NHS], 2012a). Currently there is no cure for diabetes (Diabetes UK, 2014b), so people self-regulate their blood glucose level by what they consume, the activities they take part in and the medications they take (International Diabetes Federation, 2013). Poor self-management of blood glucose can lead to an increase in the risk of developing complications (Diabetes UK, 2014a). For example, over time, high glucose in the blood damages the body's organs and tissues leading to complications such as cardiovascular disease, kidney disease, retinopathy and amputations (International Diabetes Federation, 2013). Complications are prevalent in the diabetes population (International Diabetes Federation, 2013), and it is thought there are 24,000 unnecessary deaths each year from complications associated with diabetes in the UK (Department of Health, 2012).

Diabetes not only has a substantial effect on people's lives, but it also has a significant financial impact. The cost of prescription drugs, inpatient and outpatient treatment for diabetes forms a significant part of NHS spending (Department of Health, 2012). In total, it is estimated that the NHS spends 10 billion on diabetes (Diabetes UK, 2014a).

In order to improve quality of life, and to reduce the financial impact, it is imperative that people with diabetes have are able to self-manage their condition (Diabetes UK, 2009). Taking regular blood glucose readings from a blood glucose meter is a prominent part of diabetes self-management, but it is

also important to understand the impact that other aspects, such as diet, exercise, medication and stress, can have on blood glucose levels (Smith, Frost, Albayrak & Sudhakar, 2007). Understanding the whole picture helps a person with diabetes to make appropriate decisions regarding their health (Smith et al 2007). To manage this complex interplay of factors effectively during everyday life, applications on personal devices, such as smartphones, have the potential to be a useful tool for people with diabetes (Breland, Yeh & Yu, 2013). For example, they could use this technology to record information in real-time (Breland et al, 2013), store large amounts of information and transfer it wirelessly (Waite, Martin, Curtis & Nugrahani, 2013). One of the main benefits of these applications is the ability to view and analyse information over time, so that patterns and interactions between different aspects of daily life can be spotted and, if necessary, acted upon (Whitlock & McLaughlin, 2012).

The growing number of people with diabetes coupled with the advantages of mobile technologies has been recognised by application developers (Breland et al, 2013). This has led to a significant increase in the number of diabetes-related mobile health applications over recent years (Arnhold, Quade & Kirch, 2014). It is intended that these applications will not only support people with diabetes to improve their health and wellbeing but also reduce the financial impact of this condition (Jahns, 2014). However, these benefits will only come to fruition if these applications are successful in supporting diabetes self-management.

In the literature, a number of reviews have investigated applications for diabetes, such as smartphone applications and applications to support the use of blood glucose monitors (e.g. Rao, Hou, Golnik, Flaherty & Vu, 2010). Previous reviews have examined the marketplace of mobile applications on IOS (e.g. Breland et al, 2013) and other platforms (e.g. Chomutare, Fernandez-Luque, Arsand & Hartvigsen, 2011). In these reviews, the authors categorise their functions, and assess their limitations and benefits (e.g. Rao et al, 2010; Chomutare et al, 2011; Breland et al, 2013; Eng & Lee, 2013; Arnhold et al, 2014). In addition, usability evaluation studies have been performed on a small sample of diabetes applications by experts (e.g. Arnhold et al, 2014) or by

people with diabetes (e.g. Rao et al, 2010; Lyles et al, 2011; King et al, 2012; Waite et al, 2013). However, no studies have been found that investigate the applications that people with diabetes choose to help manage their condition.

The goal of this study is to explore what applications people with diabetes use, how they use them and why - or if they do not use applications, why not. In addition, this study aims to understand individual needs, behaviours and attitudes and how this impacts the usefulness of the applications for diabetes on personal devices.

In the next chapter of this dissertation, an overview of the relevant literature will be provided. The different types of diabetes will be reviewed and the complex nature of living with diabetes, a chronic condition, will be highlighted. This is followed by a discussion of the part that technology can play in supporting people with diabetes, and in particular, focuses on the existing usability studies and reviews of diabetes-related applications.

CHAPTER 2. LITERATURE REVIEW

2.1. Diabetes

There are a number of different types of diabetes. The most well-known being type 1 diabetes and type 2 diabetes. People with type 1 diabetes regularly require insulin - an essential hormone for regulating glucose within the blood - in order to counteract increases in blood glucose caused by natural processes such as the breakdown of food (NHS, 2012b). These doses of insulin are taken through injections or insulin pumps (Diabetes UK, 2014c), and without which they would die (International Diabetes Federation, 2013). Type 2, on the other hand, is more closely connected to unhealthy lifestyle and obesity (Diabetes UK, 2012). Insulin therapy is not always necessary for the management of type 2 diabetes (International Diabetes Federation, 2013), and can be treated through a healthy lifestyle and other medications such as Metformin (NHS, 2014b).

2.2. Technology for Diabetes

There are many different types of technology that have been traditionally used to help with treating diabetes. For example, insulin pens or insulin pumps are used to administer insulin, and blood glucose meters are used to analyse the amount of glucose in the blood (Fowler, 2008). For type 1 diabetes or insulin dependent type 2 diabetes it is essential to take blood glucose readings in order to calculate the correct amount of insulin, but there is some debate whether self-monitoring of blood glucose for non-insulin dependent type 2 has any health benefits (Welschen et al, 2005). Therefore, the frequency with which blood glucose readings are taken and recorded vary with the type of diabetes and the perceived need.

Log books, a type of paper diary, are also traditionally used for manually recording blood glucose readings (Ciemins, Coon & Sorli, 2010). Although low cost, these log books are heavily dependent on people recording accurate information. In point of fact, Kalergis, Nadeau, Pacaud, Yared and Yale (2006) found them to contain a number of errors. Alternatively, some blood glucose meters potentially remove the problem of human error by automatically storing

a large number of readings (Rao et al, 2010). However, viewing these results over time can be difficult on these devices due to a small, and sometimes, poor quality screen (Rao et al, 2010).

Measuring blood glucose is only one facet of diabetes management. Other factors such as diet, exercise, stress and medication can significantly affect a person's blood glucose level (Smith et al, 2007). In addition to this, a number of other health checks - delivered by healthcare professionals annually - are also recommended in the UK to detect and prevent complications (Department of Health, 2012). For example, blood tests check the average blood glucose level over the last 3 months (HbA1c), kidney function and blood fats to help detect complications such as kidney disease and cardiovascular disease (Department of Health, 2012). Although these many items needs to be monitored by healthcare professionals, people with diabetes are generally required to manage their condition in the community and at home with relatively infrequent contact with healthcare services (Diabetes UK, 2009). In addition, healthcare resource is often stretched in terms of time and money (Sneha & Varshney, 2009).

In summary, there is a need to monitor numerous items to effectively manage diabetes. There are difficulties with existing technologies and there are pressures on healthcare resource. Therefore, it is no surprise that technology, such as the internet, mobile phones and telemedicine, has been seen as a viable and appealing option for supporting people with a chronic condition such as diabetes (Sneha & Varshney, 2009).

2.3. Applications for Diabetes

In recent years, there has been significant growth in software applications for diabetes, particularly for mobile devices. To understand this marketplace, researchers have carried out reviews and evaluations. From these studies, it has become evident that there is a huge variety of software applications in this area. There are applications for people with diabetes to use, and there are applications directed at healthcare professionals, such as medical reference

applications (Eng & Lee, 2013). Applications can be downloaded to a number of devices such as smartphones, tablets, laptops or they can be accessed via the internet. There are applications solely to support the use of diabetes devices, such as downloading readings from blood glucose meters (Rao et al, 2010). Other applications are less focussed on people with diabetes but may be used to help manage the condition, such as fitness applications (Eng & Lee, 2013).

Arnhold et al (2014) found numerous functions in diabetes related applications for IOS and Android. These included tracking and analysing data which reminders to take medication; advice and information about diabetes; recipe suggestions and data sharing options. Their review also revealed that most of the applications had very similar functionality and in the main only had one function - tracking blood glucose. Interestingly, those that contained more than one function were considered to be less usable by expert evaluators.

Eng and Lee (2013) conducted a review of IOS and Android applications directed at diabetes. They also found that the majority of applications focussed on diabetes data tracking, but others focussed on social interactions with peers and food reference databases. These databases allow users to ascertain the nutritional content of food. For people who use insulin, it is particularly important to know the carbohydrate content in order to calculate the correct dose (Diabetes UK, 2014c). Other nutritional values, such as calories, could be important to people with diabetes in order to maintain a healthy lifestyle.

Chomutare et al (2011) reviewed the features of mobile applications for diabetes, designed by developers from a number of commercial stores as well as those developed by academic institutions. They also found that the functionality of these applications mainly centres on the ability to track data, or more specifically, input a variety of time-stamped data such as blood glucose readings, medication taken, carbohydrates consumed and exercise completed. Although useful for people with diabetes to record these readings and results, it is also important to understand how to use this information to inform what they should do next in order to manage their condition (Diabetes UK, 2009).

Chomutare et al (2011) argued that this personalised education was underrepresented in these apps, even though it is a major component of managing diabetes effectively. Similarly, Chen (2010) argued that it is the unique everyday experiences in managing their condition that are more valuable to a person with diabetes as opposed to general guidance and education, and proposed that a diabetes management system needs to accommodate this individuality.

Friends and family can play an integral part in the psychological support for people with diabetes (Diabetes UK, 2009). Therefore, one clear advantage of using applications for diabetes is the ability to integrate with social media channels so that users can efficiently and remotely share data or experiences with others (Chomutare et al, 2011). However, Chomutare et al (2011) suggested that the full integration of social media in mobile applications had not been fulfilled and remained an opportunity to be explored.

Chomutare et al (2011) also noted that manual input of data into applications dominates the commercial sector even though the technology is available to provide automatic input. Automating data uploads is important both in terms of saving the user time and increasing the accuracy of the data (Arnhold et al, 2014). The need to manually input data has also been suggested as one of the reasons for the poor uptake of diabetes applications by users (Jahns, 2014). In the same way, Ciemins et al (2010) criticised current smartphone applications for not matching the functionality of blood glucose meters as users often have to manually enter blood glucose readings into applications. However, they also highlighted that viewing data over time and spotting anomalies and patterns is easier with applications compared to meters.

The ability to share their data remotely from applications could be of real benefit to people with diabetes by increasing contact with, and therefore support from, healthcare professionals. However, Eng and Lee (2013) found that, although users can sometimes export data and therefore share their data with their healthcare team, many apps were not fully integrated with healthcare

providers. Another criticism of these applications by Eng and Lee (2013) was the lack of evaluation, in terms of their clinical effectiveness and safety. In addition, the authors argue that some applications are potentially dangerous to both health and security. For example, in their review, they found that many insulin-dose calculator applications were not regulated. These applications calculate the appropriate amount of insulin based on an individual's carbohydrate to insulin ratio which has been entered into the application by the user. The authors felt that their presentation as medical applications may give a false impression to consumers that these applications have been approved by an appropriate organisation. Eng and Lee (2013) also had concerns over the privacy of the data collected in diabetes applications. They thought that the information provided by developers, regarding how the data collected was being used and protected, was unsatisfactory.

Breland et al (2013) recent review of the Apple App store revealed many applications directed at people with diabetes did not follow evidence-based guidance. Although it was found that some applications were useful in highlighting to a user when they were outside target ranges, many did not provide guidance and structure on how to rectify the situation. Less than 20% of the applications reviewed in this study compared diet and exercise to blood glucose through data visualisations.

These applications have also been criticised for not considering the accessibility issues that may be present in the diabetes population. For example, Arnhold et al (2014) highlighted the impact of complications from diabetes, such as loss of vision, on the use and uptake of diabetes applications. Waite et al (2013) also noted that the small screen size of mobile devices could be a negative aspect when coupled with the poor vision and dexterity that some people with diabetes may have.

2.4. Summary and Research Questions

In summary, the literature has demonstrated that diabetes is a complex condition that requires a great deal of dedicated self-care with the support of healthcare professionals and family members. The literature also suggests that applications designed for diabetes have not reached their full potential and the benefits of this technology have not been fully realised in the marketplace. Both expert reviews and user studies have shown that, although technically feasible and highly sought after by users, automatic transfer of data to eliminate manual input and integration with healthcare services is missing (e.g. Ciemins et al, 2010; Chomutare et al, 2011; Eng & Lee, 2013; Waite et al, 2013; Arnhold et al, 2014). Other criticisms include a lack of clinical evidence that using applications can improve the health of people with diabetes (e.g. Eng & Lee, 2013; Arnhold et al, 2014); and not following recognised guidelines such as the American Association of Diabetes Educators seven self-care behaviours (e.g. Breland et al, 2013). Accessibility issues have been raised, especially concerning people with complications from diabetes (e.g. Whitlock & McLaughlin, 2012; Waite et al, 2013; Arnhold et al, 2014). There is also a lack of research into the privacy and protection of data stored in these applications (e.g. Chomutare et al, 2011; Eng & Lee, 2013).

A common limitation present in many studies is the evaluation of these applications from the perspective of the researcher as opposed to people with diabetes. Some studies, particularly usability studies, involve the assessment of applications by people with diabetes. However, in these studies, there is still a strong influence from the researcher, as they select the application to be reviewed. Considering the importance of understanding the applications that people with diabetes choose to use, it is surprising that no reviews have been found that investigate this. This is not to say that previous studies have completely ignored the preferences and opinions of people with diabetes. For example, Waite et al (2013), in addition to their usability study, investigated what would motivate the use of applications for people with diabetes and the features that they would want in these applications in general. King et al (2012)

explored what people with type 2 diabetes wanted from an E-health program designed to support self-care. However, an understanding of the current use of applications selected by people with diabetes to help manage their diabetes is missing.

This study aims to address gaps in the literature. In particular, it aims to understand what applications people with diabetes use to help manage their condition or, if they do not use applications, why not. It aims to examine the features and functions of these applications and how are they are used. It aims to understand what people with diabetes like or dislike about applications for diabetes, and how their individual needs, characteristics and concerns impact the choice and use of these applications.

To explore these research questions the study was organised into two stages. First, instead of conducting a review of the available applications, an initial online survey was distributed to reveal the applications that a person with diabetes uses, or had used in the past, to help manage their condition. Individual characteristics and behaviours were also collected. Respondents to the first survey were then invited to provide an email address if they were happy to take part in a follow-up survey. This second stage was focussed on understanding how the applications were used and what users thought about them. The questions were tailored by the responses from the first survey and gave an opportunity to explore interesting results revealed by the first survey.

The study focussed on adults (18 or over) with diabetes, such as type 1 and type 2, and those who use applications for themselves rather than somebody they are caring for. Therefore, parents or carers of people with diabetes were excluded from taking part in the study. Women with gestational diabetes were also excluded in order to focus the study. This type of diabetes only appears during pregnancy (Diabetes UK, 2014a) and therefore, due to the relatively short term nature of this type of diabetes, applications may not be used at all or used very differently. People at an elevated risk of developing diabetes in the future were invited to take part in the study as well. The literature reveals that there are a

large number of people at risk of developing diabetes in the future (e.g. International Diabetes Federation, 2013). It was thought that there was a possibility that this group could use applications to decrease their risk, and so was included speculatively in the study.

The literature highlights that there are many different types of application, ranging from smartphone 'Apps' to software that can be downloaded to a laptop or PC to support downloads from a blood glucose meter. In this study, the term 'application' refers to smartphone and tablet 'Apps', web applications, software downloaded to a laptop or PC and any software that support devices such as blood glucose meters, insulin pumps and pedometers. The study also includes any application that may not be focussed on diabetes, such as diet or fitness applications, but could be of use to people with diabetes.

By understanding the needs of people with diabetes (or those at an elevated risk of developing it in the future) and how they use applications, recommendations can be made to improve the design of these applications. Improving these applications could benefit the lives of people with diabetes and reduce the financial impact of this condition.

In next chapter the methods used to explore this area of research are described. The creation and distribution of the two surveys, the rationale behind the questions asked, the methods used and the participant recruitment process is explained. This is followed by the quantitative and qualitative results from the surveys. In the final chapter, the results are summarised and reflected upon. The limitations and the lessons learned from the methodology are discussed. The implications of the study on the development of applications for diabetes and the directions for future studies are also discussed.

CHAPTER 3. METHOD

Both stages of the study involved online surveys created and distributed via SurveyMonkey SELECT Monthly (SurveyMonkey, California, USA) - an online survey software tool.

Online surveys were selected as a method for this study because they are fast and inexpensive to administer (Singh, Taneja & Mangalaraj, 2009), they can reach a large number of people spread over a wide area (Van Selm & Jankowski, 2006) and data is collected automatically (Singh et al, 2009). The number of people with diabetes who use applications to support the management of their diabetes could be relatively small and geographically widespread. Therefore, the ability to quickly administer an online survey over a wide area increases the likelihood of recruiting people with diabetes making this method practical for data collection. An online survey was also selected for the second stage of the study because responses could be automatically recorded ready for analysis. The time savings generated from the automatic data collection allowed for a higher quantity of second surveys to be administered.

Due to the methodology used, a non-probability sample was taken for the first survey. Respondents volunteered to take part in this self-selection survey. In addition, a screening process was employed, via the questions in the survey, to exclude certain groups (e.g. gestational diabetes). Although a non-probability sample cannot be generalised to entire population, they may represent a subgroup (Kaye & Johnson, 1999).

An off-the-shelf software tool, such as SurveyMonkey, was selected because it provides a secure and robust system in which to design and distribute surveys, and transmit and store responses. Respondents may have found this appealing and consequently non-completion would be minimised.

3.1. Survey Content and Development

The first survey was created using a standard template from SurveyMonkey. It contained an introduction page and consent form; the main survey questions; a request for the respondent's email address and feedback regarding the content of the survey. These main sections are discussed in more detail below.

Introduction page and consent form

The first page that respondents would see after clicking on the link to the survey was the information page and consent form. For full details of the contents of the information page and consent form please see Appendix A. Respondents had to complete the consent form before continuing to the questions in the survey. Respondents could leave at any point and were free to move forwards and backwards through the survey to edit responses before submitting.

Main Questions

Each page of the survey contained one question. Respondents were able to skip some questions without providing an answer, but other questions required an answer. Required questions were kept to a minimum and were only used to tailor the questions to the respondent or to disqualify respondents from the survey in a screening process. Required questions were marked with an asterisk in the survey, and respondents were informed about the significance of this asterisk.

Questions seeking information about the respondents, their behaviours and the applications they use or have used, were included in this survey. Some questions contained tick boxes from which respondents could select the most appropriate answer and others free text boxes or open responses. A summary of the types of questions and the rationale for their inclusion is discussed below. Please see Appendix B for the full set of questions including the response format and options.

In order to understand and describe the sample, respondents were asked about their age, gender, nationality and health status (e.g. what type of diabetes they had and for how long). These responses were useful to understand how individual characteristics impact the choice and use of applications. In addition, monitoring health status was important for screening purposes. For example, any respondents who were parents or carers of people with diabetes and women with gestational diabetes were prevented from taking part. Different countries have different healthcare systems which may affect the applications used. Recording nationality allowed this to be monitored.

Respondents were asked about the use (or non-use) of applications to help manage their diabetes. This helped to understand one of the key research questions of the study - to understand what applications are used and why applications are not used. Guidance was provided to respondents as to what was meant by an 'application'. Respondents were required to list the applications they were using or had used by name. This enabled the applications to be researched and follow-up questions to be asked in the second survey. Respondents were provided with a set of options, based on themes from the literature, and also a free text box to describe the reasons why they did not use applications.

The literature has suggested that there is little research into privacy issues of diabetes applications (e.g. Chomutare et al, 2011). In the first survey, privacy concerns were initially investigated by asking about reading privacy policies for these applications. Questions were adapted from a survey conducted by Milne and Culnan (2004) regarding consumer attitudes towards privacy notices on e-commerce websites.

Respondents were asked what devices they owned or used. Applications for diabetes can be used on a number of different devices, and data from different devices can also be uploaded or manually entered into these applications. A respondent's access to these devices could have an impact on the type of applications that they may use.

Questions were included about how diabetes (or the risk of developing it in the future) was managed. This was useful for understanding the sample, and could have affected the types of applications used. For example, people who self-test their blood glucose regularly may use applications that support the automatic download of blood glucose readings.

Accredited and structured education courses for people with diabetes, such as Dose Adjustment For Normal Eating (DAFNE) and X-PERT, have been recognised as vital in providing the necessary tools and confidence to make self-care decisions (Diabetes UK, 2009). Respondents were therefore asked about whether they had attended a diabetes education course. This helped to understand the level of knowledge of diabetes within the sample and may have an impact on the choice of application.

The literature has suggested that complications are prevalent within the diabetes population (International Diabetes Federation, 2013) and that these complications could impact the use of applications (e.g. Waite et al, 2013). Respondents were therefore asked if they had any complications from diabetes. This was also useful for understanding the characteristics of sample.

Figure 1 shows a high-level overview of the different pathways through the survey. It highlights the order of the questions and how they were tailored according to responses.

Email Address

Respondents could voluntarily provide their email address in a textbox so that they could be contacted for the follow-up survey (see Appendix C).

Feedback

The final page of the survey allowed respondents to provide feedback regarding the survey and its questions. This was monitored and some feedback provided by the respondents was implemented during the data collection phase. For

example, one of the first respondents remarked that neither their type of diabetes, latent autoimmune diabetes of adulthood (LADA), nor maturity onset diabetes of the young (MODY) was available as an option in the survey. These were added immediately as options, so that future respondents could select these if appropriate. After completing the survey, the respondents were redirected to a SurveyMonkey webpage.

The survey was piloted and the questions were sense-checked with other researchers, one of whom previously worked for a diabetes charity. The survey was tested on different devices and browsers so that technical difficulties were kept to a minimum and appropriate data analysis could be completed on the output. Once the survey was released, the responses were monitored daily. It was through this monitoring that the privacy questions were found to be inappropriate. In particular, one question asked respondents to rate their agreement with a set of statements regarding the applications they used to help manage their diabetes or reduce their risk of developing it (see question 9 in Appendix B for the full set of statements). Due to the fact that respondents used a variable number of applications, it was unclear whether respondents were answering these statements from the perspective of using a particular application or applications for diabetes in general. In order to prevent misleading results, this question was removed. In addition, the other privacy questions were changed to be more straightforward (e.g. question 7 and 10 in Appendix B were changed to questions 8 and 11 respectively). The responses to these two questions were then followed-up in the second survey where a particular application was targeted avoiding the ambiguity introduced by multiple applications.

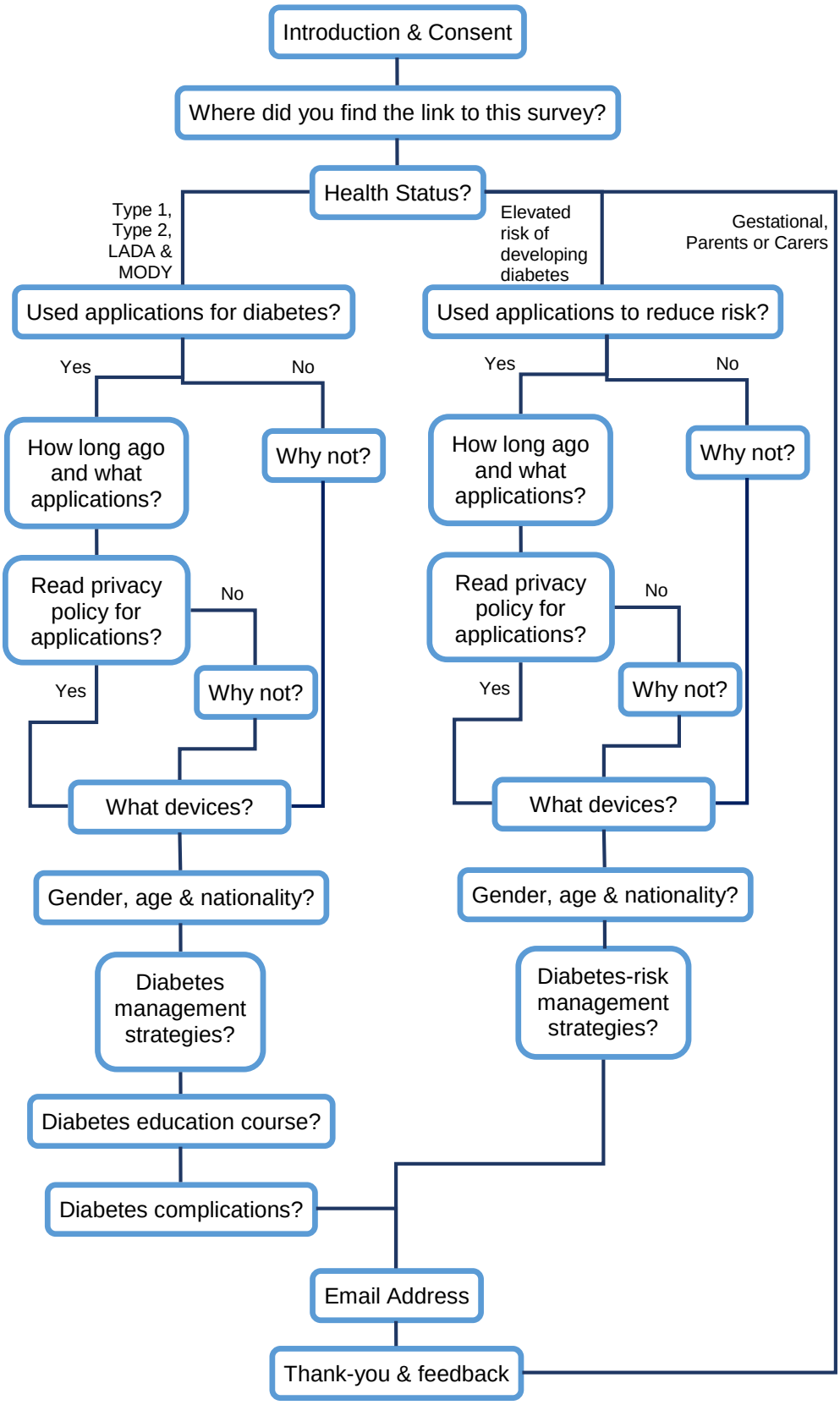

Figure 1: A high-level overview of the pathways through the first survey.

Approximately a week after the first survey was released, the second survey was developed. Applications used by respondents from the first survey (who had provided their email address) were researched, using online sources such as company webpages or information from online application stores. It was decided that only one application per respondent could be investigated otherwise the amount of time required from respondents to complete the survey would be too long. A variety of different types of applications, in terms of operating system, functionality and focus, were targeted for the second survey in order to understand the use of these different applications to help manage diabetes.

The second survey was also created using a standard template from SurveyMonkey, and contained an introduction page, the main survey questions and an opportunity to provide feedback regarding the content of the survey.

Introduction page

The page contained information about the purpose of the second survey and reiterated some of the information provided in the first survey, such as contact details. Please see Appendix D for the full content of this page. As with the first survey, respondents could leave at any point and were free to move forwards and backwards through the survey to edit responses before submitting if necessary.

Questions

The questions for the second survey were developed to answer the research questions and were sense-checked by another researcher. Some questions contained tick boxes from which respondents could select the most appropriate answer, but most contained free text boxes or open responses. The main topics, including a summary of the types of questions included in each topic, are shown in Table 1. Please see Appendix E for the full set of questions, including all variations, and the response format and options.

Table 1. Second Survey: Main question topics and summary of associated questions.

Topic	Summary of Questions
Download	How long ago did you download to this application? How did you download it? Why did you decide to download it?
Create	How long ago did you create this application? Why did you decide to create your own application?
Privacy Policy	Did you read the privacy policy for this application?
	Why did you read the privacy policy for this application? Was the privacy policy easy to understand? Was the privacy policy easy to find? Why didn't you read the privacy policy for this application?
Use	Do you still use the application?
	How long have you been using the application for? Please describe how you use this application to help manage your diabetes, including the type of information you store and enter, how often you use the application and when you use it. Why did you stop using the application? When did you stop using it and how long did you use it for?
Sharing	Do you share the information you record in this application with others such as friends, family or healthcare professionals?
	Who do you share the information with and why? When do you share the information from the application and how do you share it? Why don't you share the information you record in the application?
Features and Functions	What are the most important features or functions of the application to you? Are there any features or functions that you don't use regularly or at all? If so, please describe what these features are and why you don't use them. What features or functions could be added that would improve the application for you?
Difficulties and Concerns	Do you have any difficulties using this application? If so, please describe what these are. Do you have any concerns regarding the privacy of your information stored in this application? Do you have any concerns regarding the accuracy of the information provided to you from the application? Do you have any concerns regarding the accuracy of the information you enter into the application?

Table 1. Continued:

Topic	Summary of Questions
Cost and Upgrades	Have you bought any in-app purchases or upgrades for this application? Please describe what you purchased and why, or why you haven't bought any. Do you think the application was value for money? Please describe the reasons behind your answer.
Device	Which device do you most often use for this application and why? What do you like, or dislike, about using this device for this application? Did you use any other devices for this application? Please describe what these were and why you used them, or why you didn't use other devices.
Other applications	How does this application compare to other applications you have used to help manage your diabetes? Have you ever considered using other types of applications to help manage your diabetes?
Applications in general	What do you think about applications to help people manage diabetes in general?

Each survey was tailored to the respondent and the application, and therefore not all questions in Table 1 were included in every survey. For example, some respondents had created their own application or spreadsheet, and therefore the 'Download' questions (see Table 1) were not appropriate and were replaced by the 'Create' questions (see Table 1). The number of questions contained on each page of the survey varied from one to four. Respondents were able to skip some questions without providing an answer, but other questions required an answer. Required questions were kept to a minimum and were only used to tailor the questions to the respondent. Required questions were marked with an asterisk in the survey, and respondents were informed about the significance of this asterisk. Figure 2 shows the different pathways through the survey and the order of the questions, although this would vary depending on which questions were included.

Feedback

Similar to the first survey, the final page of the second survey gave the respondents the opportunity to provide feedback.

Each survey was checked to ensure that it worked correctly and the content was appropriate for each respondent.

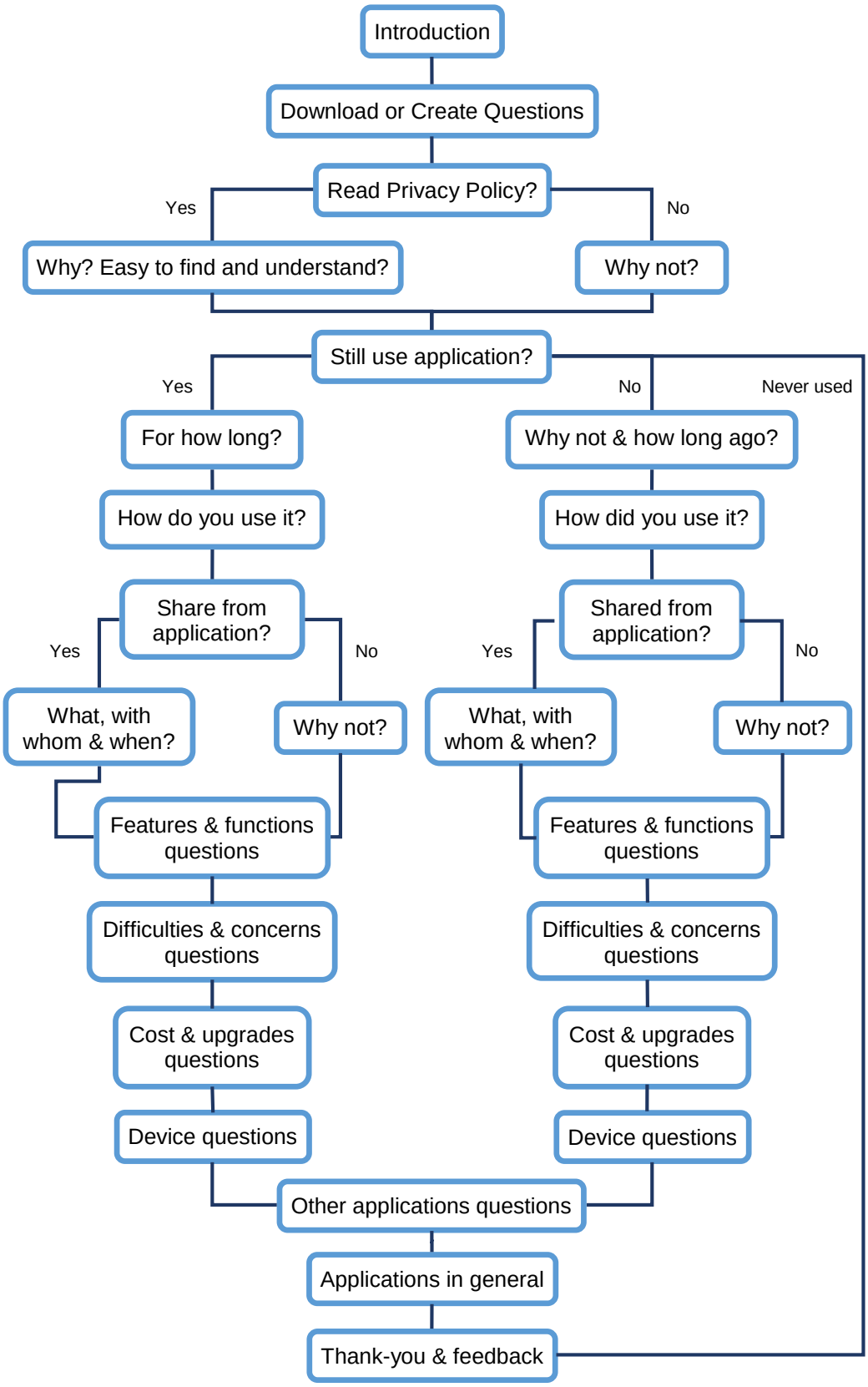

Figure 2. A high-level overview of the pathways through the second survey.

3.2. Data Collection

Respondents were recruited from a number of online sources. Administrators from three popular UK-based diabetes forums and social media sites were contacted for permission to advertise the survey via posts. One positive response was obtained (for a forum). The survey was also advertised through a blog and twitter account of a connected university programme, and a personal email invitation sent to an individual with diabetes known to the research team. Web links to the survey were created for each source of respondent recruitment so that the number of respondents per source could be monitored. Monitoring recruitment sources was important to do in order to highlight potential biases in the sample (Singh et al, 2009). Although only certain UK-based sources were targeted, there was a potential for the links to be shared and propagated to other sources and countries. Therefore, in order to monitor the recruitment sources more effectively, one of the questions in the survey asked respondents to provide where they found the link to the survey. In addition, the nationalities of the respondents were monitored. The web links were included in a blog, a tweet, a forum post and in an email along with introductory text describing the purpose of the survey. Both people with diabetes and those at high risk of developing diabetes in the future were invited to take part.

For the second survey, respondents were re-recruited from the first survey. They were selected on the basis of their decision to provide their email address for follow up questions and whether they used applications. Each survey for the second phase, was sent to the respondents using SurveyMonkey's email collector functionality. This allowed an email to be sent to each respondent containing a unique link to the survey along with some text inviting them to take part and describing the purpose of the second survey. After five days, a reminder email was sent to those respondents who had not completed the survey.

No incentives were provided to respondents to take part in either surveys. IP addresses were not collected to protect the identity of the respondents and SSL

encryption was enabled for the security of the responses. Full anonymity (e.g. the identity of the respondents was unknown to the researcher) was difficult to provide as respondents were expected to provide their names in order to consent to take part and also, possibly, their email address. However, confidentially was assured and responses were reported anonymously. In total, the study ran for approximately four weeks over the end of July and the beginning of August 2014.

3.3. Data Analysis

The data for all surveys was exported from SurveyMonkey into spreadsheets and prepared for further analysis.

For the first survey this included:

- Columns that contained no data or data irrelevant to the analysis were removed and some column titles were shortened.
- Some columns were combined. For example, the list of applications used was combined into one column.
- A column was added for 'Respondent Number' and a unique, sequential number was assigned to each respondent.
- Likert scale responses were assigned numerical values. For example, strongly agree = 4, agree = 3, neutral = 2, disagree = 1 and strongly disagree = 0.
- The following data was changed:
    - Based on feedback, one respondent's current health status was changed to LADA.
    - One respondent reported that they did not use applications to help manage their diabetes, but later remarked they used Excel. For the purposes of this study, Excel was considered an application and therefore the respondent's answer was changed to reflect this. In addition, the number of respondents using Excel was increased by one.
    - The first seven respondents also completed the original privacy questions. Some of their responses were removed from analysis

(e.g. question 9 in Appendix B) and others were converted due to similarities in meaning (e.g. question 7 and 10 in Appendix B could be converted into question 8 and 10 respectively). For example, responses 'Always', 'Often', 'Sometimes', 'Rarely' were converted to 'Yes', and 'Never' was converted to 'No'.

For the second surveys:

- Columns that contained no data or data irrelevant to the analysis were removed and some column titles were shortened.
- Two columns were added for 'Respondent Number' and 'Application Name'. The respondent number assigned in the first survey and the name of the application that was targeted in the second survey were added.
- One respondent only completed the first few question of the survey. These responses were removed from analysis.
- Some respondents contradicted their responses in the first survey. For example, in the first survey a respondent may have reported only using one application but in the second survey they mentioned using other applications to help manage their diabetes. To avoid ambiguity, changes were only made to the data if the respondents mentioned an application by name and the version they used. This resulted in two changes. The number of respondents who used MyFitnessPal for the iPad was reduced by one, and Diabetes Pilot for the iPhone and the iPad were added to the list of applications used by respondents.

The demographic and characteristic data from the first survey was summarised and analysed in Excel 2013 (Microsoft, Washington, USA) using formulae and pivot tables. The figures produced from this were compared to the original data in SurveyMonkey as a check to ensure the accuracy of the exported data.

Data from both the first and second survey were imported into NVivo 10 (QSR International, Victoria, Australia) - a qualitative data analysis software package. In addition, screenshots of web pages, including App Store information, Google

Play information, application website and online application reviews, were taken with NCapture for NVivo 10 - a web browser extension to capture content - and imported into NVivo.

Nodes (or codes) were created for each application listed in the first survey. Sources of imported data were assigned to each of these application nodes. In order to understand the types of applications being used by respondents, attributes were also assigned to each application node. These included the platform of the application, its main focus, who it is targeted at and whether a second survey was requested for it. Additional attributes were added to any application that had a second survey associated with it in order to understand how they were being used. These included if the application was currently being used, how long ago it had been downloaded or created, if the privacy policy had been read, if data from the application was shared and how long the application had been used for. The number of applications used per respondent were also coded into three nodes: 'More than one application', 'One application' and 'No applications'.

In order to examine the features and functions of the applications used by respondents, the web page information collected for each application was coded into different functions. A node for each function was created and adapted as the information was coded. These nodes were then reviewed and changed or combined as necessary. Web information was not always possible to find due to the lack of information provided by respondents in the survey regarding the application name, and so the functions of these applications were not assessed. Due to resource constraints, the functionality analysis of the applications was based solely on relevant content online, and not by downloading and exploring the application. Any applications or spreadsheets created by respondent were not included in the functionality analysis due to lack of online information and difficulties in making comparisons.

A thematic analysis (Braun & Clarke, 2006) was completed on the open responses from both the first and second surveys. This technique was used to

analyse the data because its versatility was suitable for the exploratory nature of this study. Initially, the data was auto-coded (using NVivo functionality) by question and then grouped by topic, such as ‘Privacy’, ‘Device’ or ‘Key features’. These nodes were then re-assessed and cross-coded, creating a higher level, overarching theme. The nodes (or themes) and associated attributes were then queried to explore research questions.

CHAPTER 4. RESULTS

4.1. Sample Characteristics

Twenty people responded to the first survey over eight days. Eighteen respondents were recruited from a forum, one from Twitter and one from a personal email invitation. Eighteen respondents were female, two were male and all were UK nationals. The age of respondents, including a breakdown by type of diabetes, is shown in Figure 3. Every age group was represented apart from 18 to 24 and 75 or older.

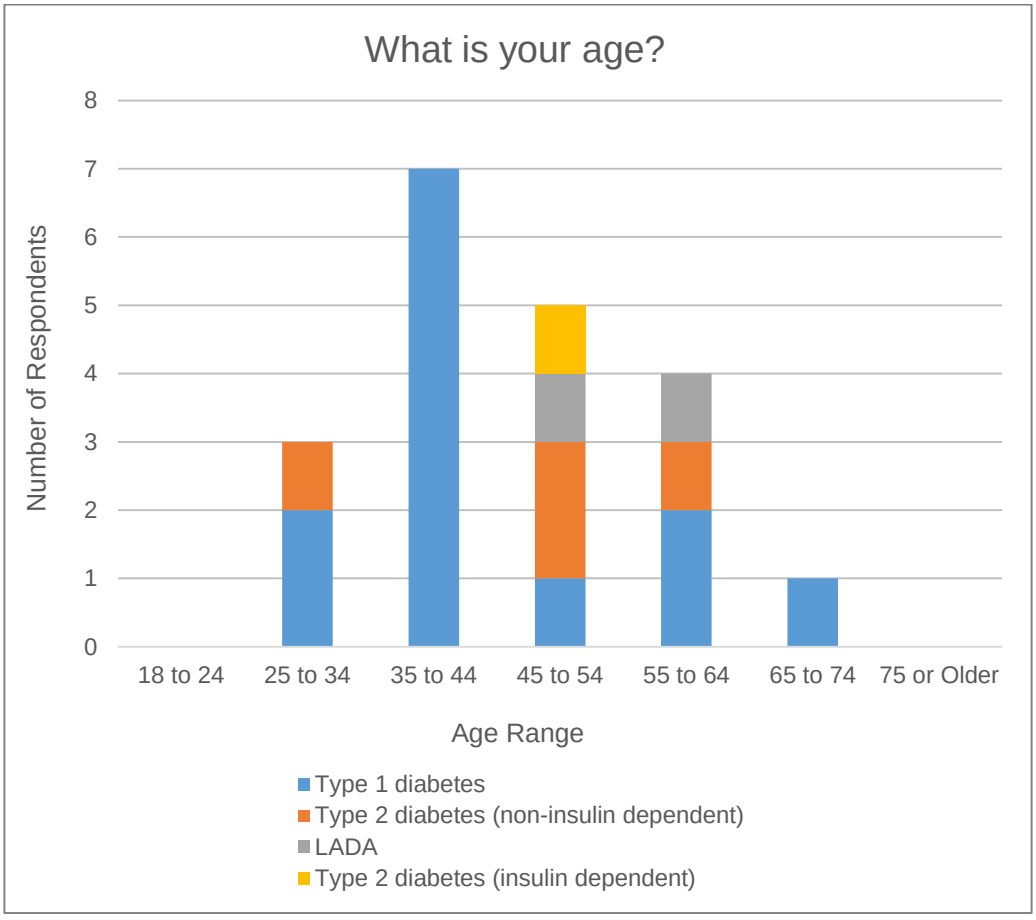

Figure 3. The age of respondents in the first survey including diabetes type.

No people with MODY or who were at an elevated risk of developing diabetes took part in the survey. No women with gestational diabetes or parents or carers of people with diabetes attempted to take part in the survey. The majority of respondents were people with type 1 diabetes (13), followed by type 2 non-insulin dependent (4), LADA (2) and type 2 insulin dependent (1). Figure 4

shows the length of time respondents have been diagnosed with diabetes, with over half of the respondents having been diagnosed five or more years ago.

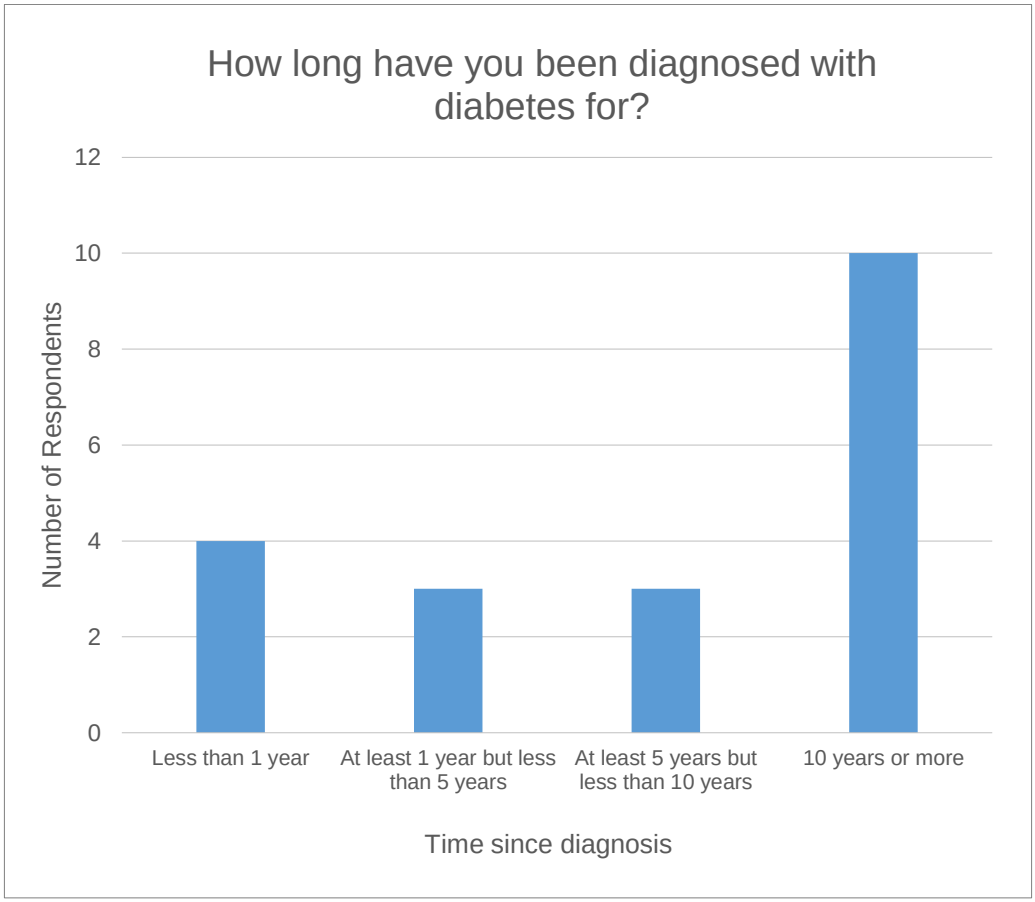

Figure 4. Length of time since diabetes diagnosis.

All respondents self-test their blood glucose and half of respondents manage their condition through a combination of diet, exercise and medication. Nearly all respondents used medication. Figure 5 shows the number of respondents who use different methods of self-management.

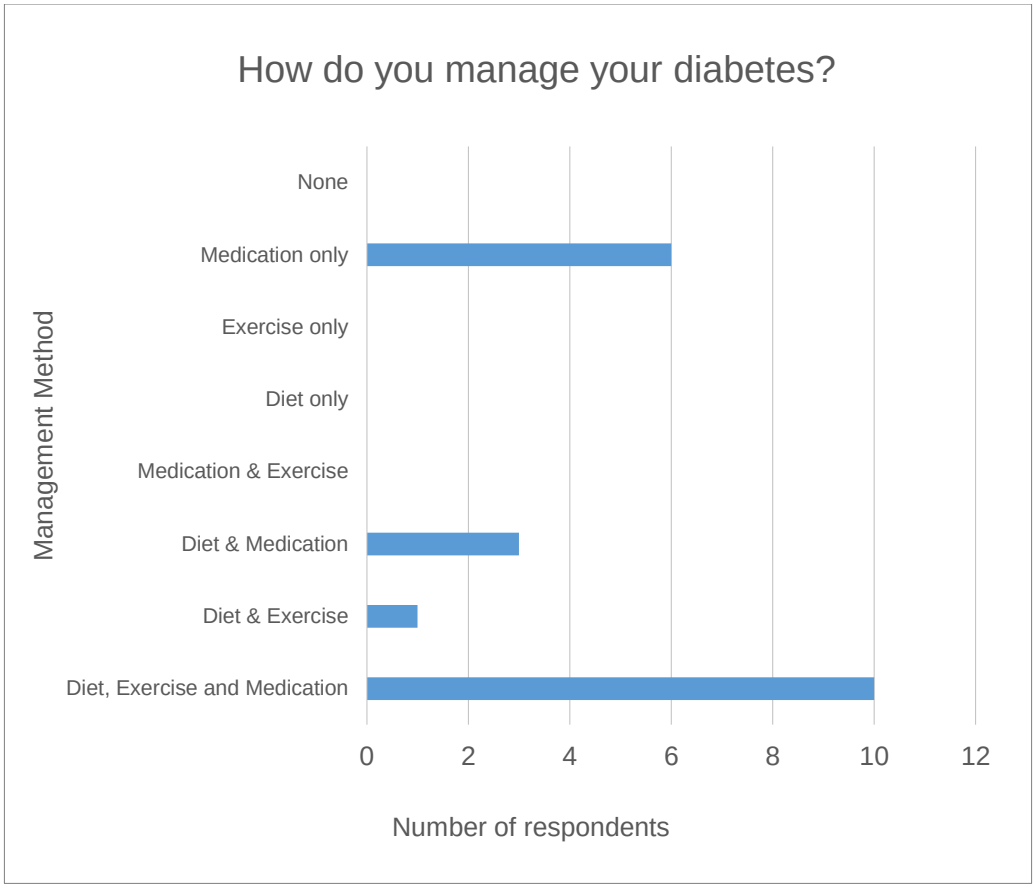

Figure 5. The method of self-management by the number of respondents.

Figure 6 shows the type of diabetes by how often respondents self-test their blood glucose. All respondents with type 1 diabetes, LADA and insulin dependent type 2 diabetes test their blood glucose four times a day or more. Respondents with non-insulin dependent type 2 diabetes varied the number of times they tested.

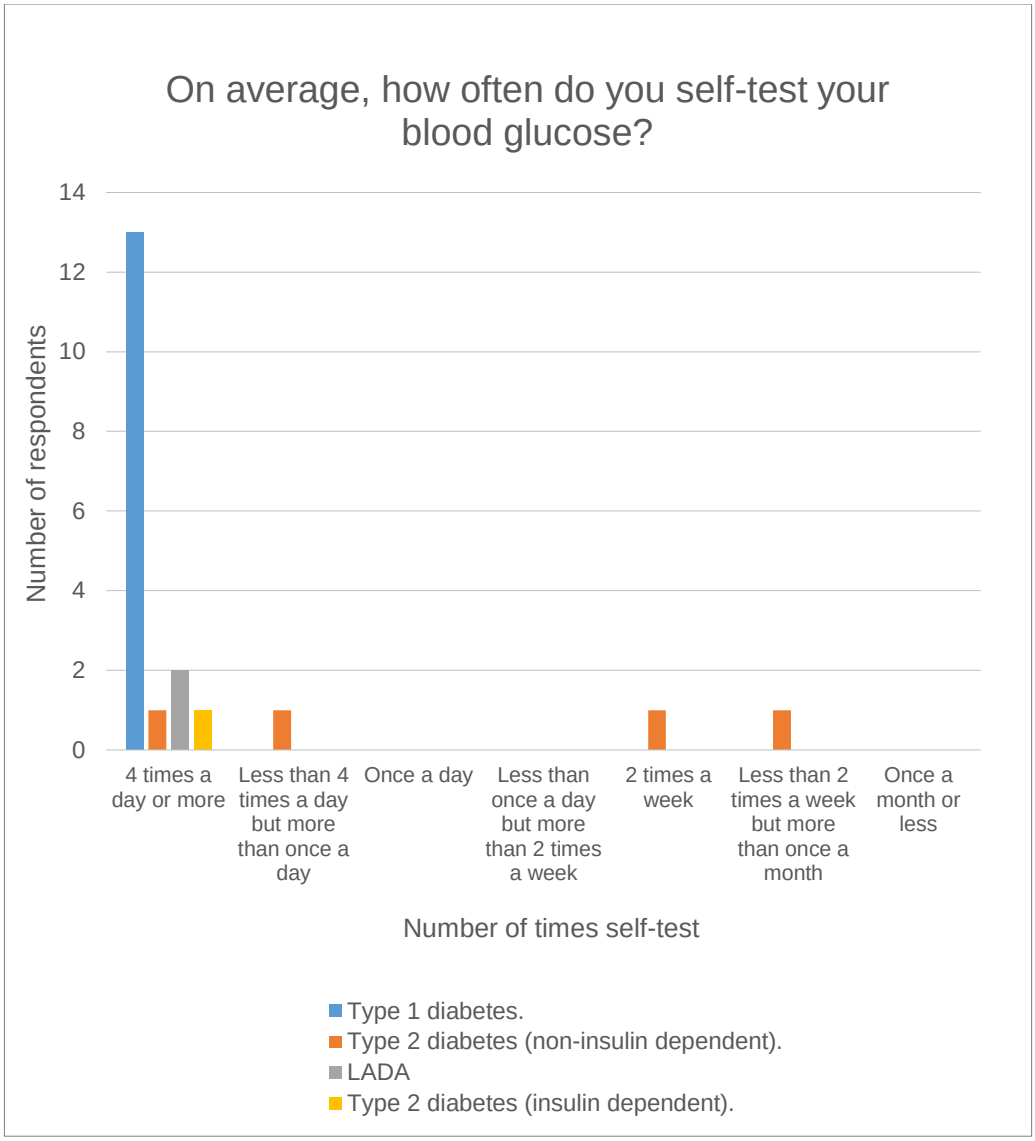

Figure 6. Type of diabetes by how often respondents test their blood glucose.

Thirteen respondents had attended a diabetes education course, the majority of which occurred the last five years (12). These courses consisted of mainly locally run courses (8) with four DAFNE courses and one X-PERT course. Only two respondents had complications from diabetes which included kidney disease and retinopathy. Figure 7 shows the number of respondents who owned or used different devices, including a breakdown of respondent's type of diabetes. All insulin pump owners had type 1 diabetes.

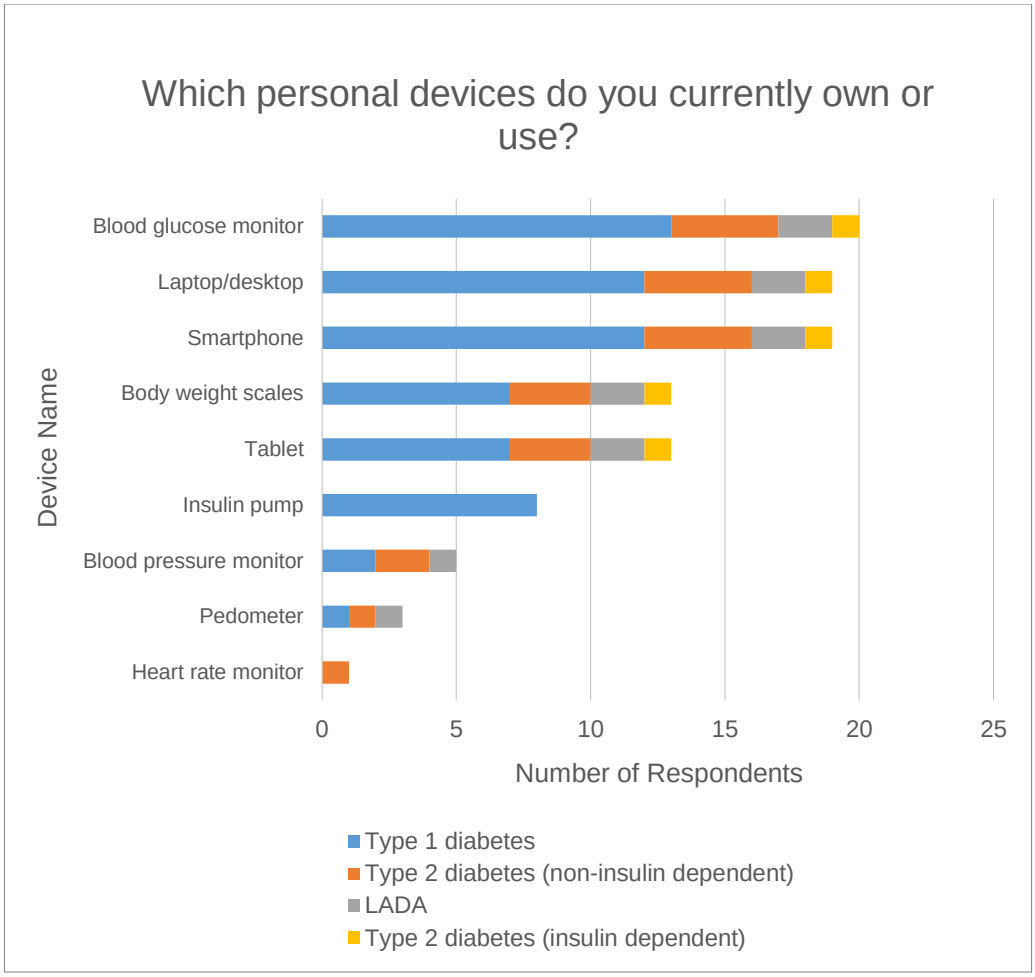

Figure 7. The devices owned by respondents and their type of diabetes.

Sixteen respondents provided their email address in the first survey, and of these 15 used applications. These 15 were sent a second survey via email to which 13 responded over two and a half weeks. One of the responses was incomplete and therefore was removed from analysis, leaving 12 respondents in total for the second survey. Ten of these respondents were female and two were male. Seven had type 1 diabetes, three had non-insulin dependent type 2, one had LADA and one had insulin dependent type 2.

4.2. Applications

Eighteen respondents were using or had used applications to help manage their diabetes, the majority of which started using them in the last four years (16). Table 2 shows a list of these applications, how many respondents are using or have used them, what the application's main focus is and who the application is

targeting. It also shows which applications were selected for the second survey. Out of the 28 applications, 12 were focussed on data tracking and analysis. These were used by 14 respondents and all except one were developed specifically for people with diabetes. Six applications focussed on diet or nutrition, none of which were specifically for people with diabetes. These were used by 16 respondents. Five applications supported diabetes devices such as blood glucose meters and were used by nine respondents. There were two applications focussed on exercise and two focussed on medication. Each of these applications was used by one respondent. The medication applications were developed specifically for people with diabetes, but the exercise applications were targeted at the general public. Only application focused on social aspects and was used by one respondent. It was targeted at people with diabetes.

Table 2. List of applications that respondents are using or have used to help manage their diabetes.

Application	Second Survey Request	Number of Respondents	Main Focus	Target Group
Carbs & Cals (iPhone)	Yes	6	Diet	For both people with or without diabetes
Accu-Chek® 360° (Windows)	Yes	4	Diabetes device support	People with diabetes
Carbs & Cals (for Android)	Yes	4	Diet	For both people with or without diabetes
MyFitnessPal (iPhone)	Yes	3	Diet	General public
Excel	Yes	2	Data tracking and analysis	General public
Diabetes UK Tracker (Android)	Yes	2	Data tracking and analysis	People with diabetes
iBGStar Application (iPhone)	Yes	2	Diabetes device support	People with diabetes
Diabetik (iPhone)	Yes	1	Data tracking and analysis	People with diabetes
SiDiary (Windows)	Yes	1	Data tracking and analysis	People with diabetes
Diabetes Companion (iPad)	Yes	1	Data tracking and analysis	People with diabetes
Glucose Buddy (Android)	Yes	1	Data tracking and analysis	People with diabetes
Self-written Application	Yes	1	Data tracking and analysis	People with diabetes
FreeStyle Auto-assist (Mac/Windows)	Yes	1	Diabetes device support	People with diabetes
Fitbit (iPhone)	Yes	1	Exercise	General public
Insulin Calculator - by fridayforward (iPhone)	Yes	1	Medication	People with diabetes
Diabetes Companion (iPhone)	No	1	Data tracking and analysis	People with diabetes
DiabetesDiary (iPhone)	No	1	Data tracking and analysis	People with diabetes
OnTrack Diabetes (Android)	No	1	Data tracking and analysis	People with diabetes
Diabetes Pilot (iPhone)	No	1	Data tracking and analysis	People with diabetes
Diabetes Pilot (iPad)	No	1	Data tracking and analysis	People with diabetes
Abbott download software	No	1	Diabetes device support	People with diabetes
Accu-Chek® Mobile download	No	1	Diabetes device support	People with diabetes
MyFitnessPal (iPad)	No	1	Diet	General public
Cook & Count Carbs (iPhone)	No	1	Diet	For both people with or without diabetes
MyFitnessPal (Online)	No	1	Diet	General public
Fitbit (Online)	No	1	Exercise	General public
Insulin-On-Board - Pancreum (iPhone)	No	1	Medication	People with diabetes
Diabetes Forum (iPhone)	No	1	Social	People with diabetes

Figure 8 shows the number of respondents and their type of diabetes who use or have used more than one application, only one application and no applications at all.

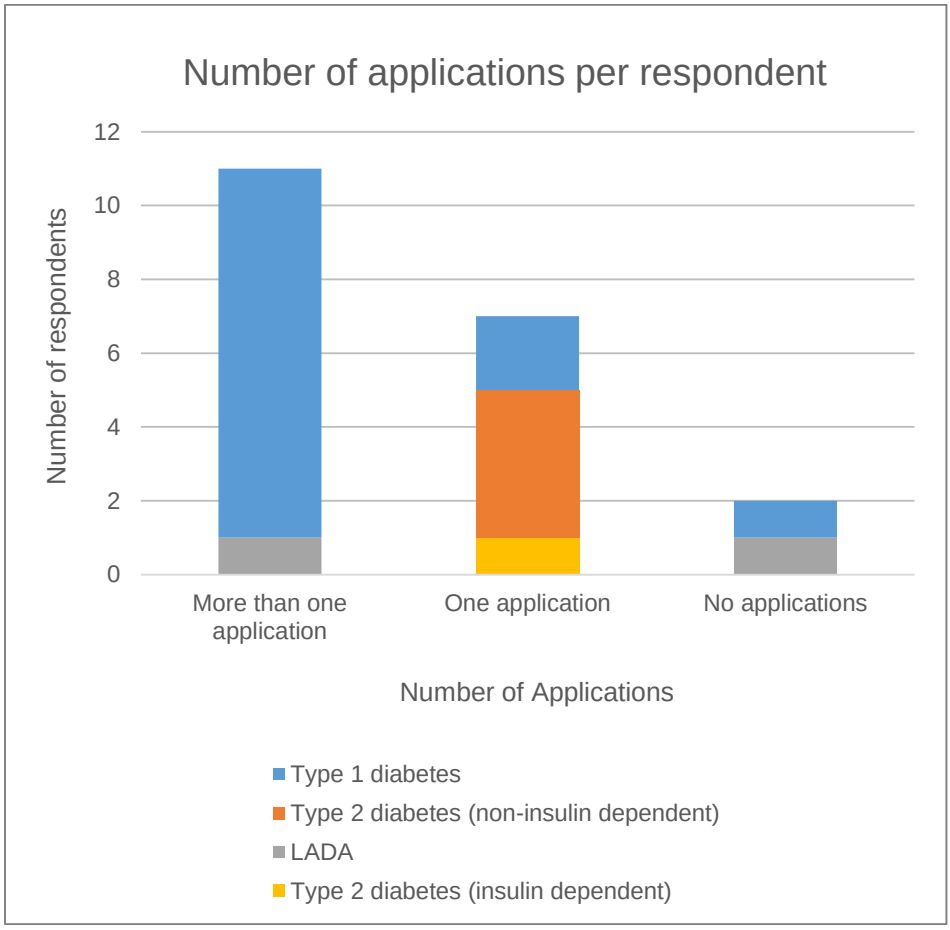

Figure 8. The number of applications that each respondent is using or has used to help manage their diabetes including respondent's type of diabetes.

Table 3 shows the functions and features present in each of the applications (functionality analysis). A definition of each function is provided in Appendix F. The following applications were excluded from this analysis due to lack of online information or inability to make comparisons:

- Abbott download software
- Accuchek mobile download
- Excel
- Self-written application

Table 3. Functionality Analysis of Applications.

	Data Logging & Tracking	Data Analysis & Visualisation	Multiple Devices	Annotations	Data Export	Social Media Integration	Goal & Target Setting	Data Storage & Backup	Food Database	Search Function	Different Units
MyFitnessPal (iPhone)	✓	✓	✓			✓	✓	✓	✓	✓	✓
Fitbit (iPhone)	✓	✓	✓			✓	✓	✓	✓	✓	
Diabetes Pilot (iPhone)	✓	✓	✓	✓	✓			✓	✓	✓	✓
Diabetes Pilot (iPad)	✓	✓	✓	✓	✓			✓	✓	✓	✓
MyFitnessPal (iPad)	✓	✓	✓			✓	✓	✓	✓	✓	✓
Diabetes Companion (iPhone)	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Diabetes Companion (iPad)	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Fitbit (Online)	✓	✓	✓		✓	✓	✓				
OnTrack Diabetes (Android)	✓	✓		✓	✓			✓			✓
SiDiary (Windows)	✓	✓	✓	✓	✓		✓		✓		✓
Accu-Chek® 360° (Windows)	✓	✓		✓	✓		✓				
Diabetes UK Tracker (Android)	✓	✓	✓	✓	✓	✓					
Diabetik (iPhone)	✓	✓	✓	✓	✓			✓		✓	
DiabetesDiary (iPhone)	✓	✓		✓	✓		✓	✓			✓
iBGStar Application (iPhone)	✓	✓		✓	✓		✓				
MyFitnessPal (Online)	✓	✓	✓				✓		✓		
Glucose Buddy (for Android)	✓	✓									
Carbs & Cals (Android)	✓						✓		✓		
Cook & Count Carbs (iPhone)	✓		✓	✓		✓			✓		✓
Carbs & Cals (iPhone)	✓			✓			✓		✓	✓	
FreeStyle Auto-assist (Mac/Windows)	✓	✓			✓						
Insulin Calculator (iPhone)											✓
Diabetes Forum (iPhone)			✓								
Insulin-On-Board (iPhone)											

Table 3. Continued:

	Reminders & Alerts	Smart Functions	Uploading Results	Motivational Features	Insulin Calculator	Social Features	Add Custom Trackers	Exercise Database	Premium Functionality	Education	Offline Mode	Personal Information	Injection Site Monitoring
MyFitnessPal (iPhone)	✓	✓	✓	✓		✓		✓		✓		✓	
Fitbit (iPhone)	✓	✓	✓	✓		✓	✓					✓	
Diabetes Pilot (iPhone)					✓				✓				
Diabetes Pilot (iPad)					✓								
MyFitnessPal (iPad)		✓		✓		✓		✓		✓			
Diabetes Companion (iPhone)	✓		✓	✓					✓				
Diabetes Companion (iPad)	✓		✓	✓					✓				
Fitbit (Online)				✓		✓	✓		✓				
OnTrack Diabetes (Android)	✓	✓					✓						
SiDiary (Windows)		✓	✓				✓						
ACCU-CHEK® 360° (Windows)	✓		✓										
Diabetes UK Tracker (Android)													
Diabetik (iPhone)	✓	✓			✓								
DiabetesDiary (iPhone)		✓											✓
iBGStar Application (iPhone)			✓				✓						
MyFitnessPal (Online)		✓		✓		✓		✓					
Glucose Buddy (for Android)	✓												
Carbs & Cals (Android)					✓			✓			✓		
Cook & Count Carbs (iPhone)										✓	✓		
Carbs & Cals (iPhone)										✓	✓		
FreeStyle Auto-assist (Mac/Windows)			✓										
Insulin Calculator (iPhone)					✓				✓				
Diabetes Forum (iPhone)						✓							
Insulin-On-Board (iPhone)					✓								

Table 4 shows the names of the 12 applications where responses were received for the second survey. It also includes some of the information collected from the second survey regarding their use. Seven of the applications were currently used. Six privacy policies were read and eight respondents shared data from the application.

Table 4. The applications that formed part of the second survey, along with summary information regarding their use.

Application Name	Is the application currently being used?	Was the privacy policy read for this application?	Did the respondent share data from this application?
Diabetes UK Tracker (Android)	Yes	Yes	Yes
FreeStyle Auto-assist (Mac/Windows)	Yes	Yes	No
Excel (Spreadsheet)	Yes	Not Applicable	Yes
Insulin Calculator - by fridayforward (iPhone)	Yes	Not Applicable	Yes
Self-written Application	Yes	Not Applicable	Yes
Carbs & Cals (iPhone)	Yes	Not Applicable	No
Glucose Buddy (Android)	Yes	No	Yes
Diabetik (iPhone)	No	Yes	Yes
MyFitnessPal (iPhone)	No	Yes	Yes
SiDiary (Windows)	No	Yes	Yes
Diabetes Companion (iPad)	No	Yes	No
Accu-Chek® 360° (Windows)	No	No	No

Note: 'Not applicable' in this table means that these applications had no privacy policy or the respondents had already stated that they do not read privacy policies at all in the first survey, and therefore they were not asked this question in the second survey.

The following sections are the results from the thematic analysis of the qualitative data collected mainly from the second survey but also from the first. These results are also supplemented with quantitative data collected from both surveys.

Downloading or Creating Applications

Out of all the respondents in the first survey, two had created spreadsheets in Excel to help manage their diabetes and one respondent had even developed their own application (see Table 2). From these three respondents, one completed a second survey about Excel and another completed a survey regarding the application they had created. The self-written application had been developed over several of years. The Excel spreadsheet had been created within the year and contained Excel features such as pivot tables and formulae. Both the spreadsheet and the self-written application were currently being used to manage diabetes (see Table 4). There were two key reasons for creating their own spreadsheet or application - flexibility and technical ability. Both respondents were IT literate and remarked on the flexibility that creating their spreadsheet or application gave them.

"Excel gives me the flexibility to view the results of my blood glucose testing as I think and learn about how to control and review control of my diabetes."

(Survey 2, Respondent 4)

The rest of the respondents to the second survey downloaded applications, developed by other organisations, to devices in a variety of ways. Mainly via 'App stores', such as iTunes or Google Play, and also from organisations' websites. The reasons for downloading applications were varied but centred on the ability to support better management of their condition and on the recommendations of others.

In addition, the trigger point for some respondents to download or create applications was at the time of diagnosis.

"When diagnosed I did experiment with a couple of smartphone apps..."

(Survey 2, Respondent4)

Not using applications at all or stopping the use of applications

Two respondents from the first survey did not use applications at all. Applications had not been used because they were either not required for diabetes management or they had just not had time to use any. Respondents generally disagreed with concerns over privacy and the lack of technical ability as reasons to not use applications for diabetes. They also disagreed that they were not using them because they did not have the correct device or were not interested in using them.

Out of the twelve applications from which responses were received in the second survey, five respondents had stopped using them (see Table 4). Reasons for this were varied. They ranged from the application not supporting their diabetes self-management in the way that they wanted, to the introduction of a new device and therefore a new application was required.

"Because the information is just printed as a list, not as a log book, so unhelpful for spotting patterns."

(Survey 2, Respondent 13)

How the applications are used or were used

Logging and storing relevant information, in particular blood glucose levels, medication and food, was the main way that the applications were used. Analysing trends in the data and supporting insulin dose calculations were also mentioned.

"The software creates a selection of reports which I use to see trends in results."

(Survey 2, Respondent 2)

Features and functions

A wide variety of responses were given regarding the important, unused and missing features of the applications targeted in the second survey.

Features that were important ranged from all of the features present in the application to specific types of charts produced by the application, such as average blood glucose charts. Overall, however, features that were most positively remarked on were the ability to record and analyse data, such as blood glucose, and the support provided for calculations. For example, some applications helped respondents to calculate the amount of carbohydrate in food and drink via a food reference database:

"Also really useful are the carb counts for foods in restaurants/takeaways as I would find it really difficult to calculate carbs for those foods manually."

(Survey 2, Respondent 14)

Some respondents used all the functions available. Features that were available in the application but not used by respondents were very specific to each individual, but included not recording particular items of data, such as weight or feelings, and not using certain functions such as the ability to tag data with labels or set reminders. Although they had the opportunity to use these features respondents did not want to use them.

> “I don't use the weight or exercise bits much as they aren't important to me.”
>
> (Survey 2, Respondent 1)

Features that were considered missing from the applications were also very specific to each individual. However, the responses could be grouped into two categories: adding functionality and improving existing functionality. For example, one respondent wanted the ability to delete inaccurate blood glucose readings uploaded from their blood glucose meter:

> “The ability to delete readings which are obviously wrong (e.g. contaminated by something on finger) so that they don't skew the average.”
>
> (Survey 2, Respondent 2)

The impact of these poor readings on data visualisations and statistics would make it difficult for people with diabetes to spot trends in their blood glucose data and therefore make appropriate self-care decisions.

Devices used with the applications

Overall, there were a variety of devices used in connection with the applications. Although the type of device varied with the application being used. In total, respondents mentioned eight different types of devices. These included blood glucose meters, insulin pumps, laptops, PCs, smartphones, tablets, a blood pressure meter and even a server. Some applications were used through these devices. For example, some were mobile ‘apps’ and were used via a smartphone or tablet. Others applications were used in connection with some of these devices. For example, some applications were downloaded to a laptop or desktop and retrieved readings from devices such as blood glucose meters, insulin pumps or blood pressure meters. The server was used by a

respondent who had created their own android application. The convenience of using mobile devices, such as smartphones and tablets, were generally remarked on positively:

"It is easy as my phone is with me all the time and I use it constantly."

(Survey 2, Respondent 13)

Upgrades

None of the respondents upgraded their application or bought 'in-app purchases'. Most were unaware of any upgrades, with some adding that the extra functionality was not required anyway.

"No, haven't been aware of or required anything extra."

(Survey 2, Respondent 1)

Difficulties

Nearly all respondents stated they had no difficulties with using the applications.

Accuracy

The vast majority of respondents had no concerns regarding the accuracy of the information provided from the application or the information entered into the application by the respondent. Most respondents gave no further information about their lack of concern for accuracy, but at least some respondent's concerns seemed to be diminished by comparisons with other data sources, the ability to correct and an acceptance of a margin of error. For example, one respondent used an application that contained a food reference database. They used this application to look up the carbohydrate content of food items, which allowed them to calculate the appropriate amount of insulin to take. In order to

check the accuracy of the carbohydrate content provided by the application, the respondent compared the figures from the nutritional content labels on the packaging of food items. This alleviated concerns regarding the accuracy of the information provided from the application.

"Not really as I check labels to see whether they are broadly similar to the figures given on the app."

(Survey 2, Respondent 14)

Privacy

In the first survey, six respondents had not read the privacy policy for any of the applications they were using or had used to help manage their diabetes. There were a mixture of reasons for not reading the privacy policy which centred on a lack of motivation to take the time to read them and the attitude that it was unnecessary.

"There is no sensitive data I'm worried about."

(Survey 1, Respondent 18)

This was also explored in the second survey, where only two respondents out of a possible eight did not read the privacy policy for a particular application. The other four respondents were not asked the privacy policy questions. This was because for two of the applications it was not relevant to ask and the other two respondents had already stated that they had not read the privacy policy for any of the applications in the first survey. The reasons for not reading the privacy policy were similar to the first survey - lack of motivation and a belief that it was unnecessary.

"Too long and complicated."

(Survey 2, Respondent 3)

Out of the six respondents who did read the privacy policy, most found it easy to find. However, there was less consensus on it being easy to understand. The privacy policy was read mainly as a matter of course.

"I read it for all applications."

(Survey 2, Respondent 13)

Sharing

Out of the 12 applications from which responses were received in the second survey, eight respondents shared data from the application with others. Respondents shared data with either or both healthcare professionals, such as diabetes nurses and consultants, and family and friends. Data was shared for a variety of reasons, for different circumstances and in different ways. For example, in order to receive support from healthcare professionals as regards to managing their diabetes, data was shared from the application during appointments via email, print-outs, verbally or just showing the data on the phone. Data was shared online, verbally or through direct access to the application with family and friends for support and advice, to educate them about their condition and in case of emergency:

"...if something should happen they know that everything is on the app on my phone."

(Survey 2, Respondent 5)

Reasons for not sharing data include a lack of interest from healthcare professionals, not using the application for long enough in order to be able to share and using other applications to share instead.

Other Applications

Some respondents were using or had used other types of applications, including applications on other devices. Most of the respondents commented positively about the application, targeted in the second survey, in comparison to others they had used. Both positive and negative comparisons centred on the suitability of the application to their individual needs.

"It does what I want, no unnecessary frills and is adaptable."

(Survey 2, Respondent 16)

A couple of respondents mentioned refraining from using applications on a mobile phone due to their small size:

"Don't want Apps on my phone, the screen is way too small to do anything for me."

(Survey 2, Respondent 6)

Attitudes towards applications for diabetes in general

Overall, there seemed to be a recognition that the usefulness of these applications was dependent on the individual:

"For some people it helps. For others, it doesn't."

(Survey 2, Respondent 3)

Some respondents found the technology convenient for managing their diabetes and felt empowered by the knowledge they gained through tracking:

"Understanding is good, it helps you to act correctly."

(Survey 2, Respondent 16)

Others remarked on poor or missing functionality:

"Very few cater to T2s and their needs..."

(Survey 2, Respondent 1)

Individuality and Personalisation

Cross-coding revealed that individuality and personalisation were the key over-arching themes. For example, respondents use a wide variety of applications that focus on different aspects of diabetes management highlighting their individual preferences and needs. In addition, the importance of different features within the applications varied a great deal between respondents. Respondents shared data from the application with different people and in different ways that suited their personal requirements. The need for personalisation had even led some respondents to create their own application. Many positive remarks focussed on the suitability of the application to respondent's needs and, in general, respondents recognised the importance of individual preferences and requirements for the use of applications to be successful in the management of diabetes.

"I think as well more things to personalise the appearance and add and sections that suit us more. Being able to customise for me personally is brilliant."

(Survey 2, Respondent 5)

CHAPTER 5. DISCUSSION

5.1. Research Findings

Sample Characteristics

Figures suggest that 90% of people with diabetes have type 2, and slightly more men (56%) have diabetes than women in the UK (Diabetes UK, 2014a). However, in this study 65% of respondents had type 1 diabetes and 90% were female. The onset of type 1 tends to appear in younger people whereas for type 2 it more commonly appears in people over the age of 40 (Diabetes UK, 2012). Due to the high proportion of respondents with type 1 diabetes, the age was distributed more evenly in the sample compared to the general population of people with diabetes.

The experience with and the potential knowledge of diabetes seems to be relatively high in the sample, as 65% of the respondents have had diabetes for more than five years and 65% have attended a diabetes education course. Comparing this to the population of people with diabetes in the UK between 2011 and 2012, where 1% of people with type 1 diabetes and 1.4% of people with type 2 diabetes were recorded as having attended diabetes education courses (Health & Social Care Information Centre, 2013), the attendance in the sample is high.

All the respondents tested their blood glucose and, in keeping with the literature (e.g. Welschen et al, 2005), the frequency of self-testing was associated with their type of diabetes. For instance, those who used insulin tended to test more frequently. A high percentage of respondents with type 1 diabetes owned an insulin pump (62%) when compared to the 6% of people in the UK with type 1 diabetes that was estimated (in June 2012) to be using insulin pumps (Diabetes UK, 2013).

The majority of the sample use or have used applications to help manage their diabetes in the last four years. The relative recency of using applications is

probably a reflection of the recent introduction of smartphone applications for diabetes (circa 2008) and the subsequent rapid growth (see Arnhold et al, 2014).

Overall, the respondents seemed to be highly motivated and well-practiced in diabetes management. They were mainly females with type 1 diabetes. They were also experienced in using technology in the management of diabetes. These could be characteristics of a sub-group of people with diabetes who use applications to manage their diabetes. However, it could also be a reflection of the methods used and the main recruitment source – a diabetes forum. For example, it could be argued that highly motivated individuals with diabetes are more likely to use forums and take part in surveys.

Use of applications for diabetes

The majority of respondents were using or had used more than one application. As the question in the first survey did not examine the number of applications being used at any one time, it is difficult to say whether respondents were using more than one application in parallel or they stopped using applications in favour of other applications. Certainly, the second survey revealed that at least some applications had been replaced in favour of other applications. It was interesting that people with type 1 diabetes tended to use or had used more than one application whereas those with type 2 only reported one. It could be that people with type 1 diabetes require a greater range of functionality due to the use of insulin and insulin pumps. It also suggests that the finding that many respondents used more than one application is likely to be due to the comparatively large number of respondents with type 1 diabetes in the sample.

Features and Functions

A wide range of applications were used by respondents which is consistent with the wide range of applications available in the market place (e.g. Rao et al, 2010; Eng & Lee, 2013; Arnhold et al, 2014). There were applications that supported diabetes devices, such as blood glucose meters, and applications that focussed on data tracking, diet, exercise, medication or social aspects. Some

applications were directed at people with diabetes only and others were targeted at the wider public. Applications that focussed on diet were the most popular and in particular the Carbs & Cals application for IOS and Android. This UK-based application contains a database of images of food at different portion sizes so that the nutritional content of food can be easily calculated when out and about. The popularity of this type of application is probably a reflection on the prevalence of insulin-users in the sample, as it is necessary to calculate the carbohydrate content of food in order to calculate the correct insulin dosage. However, it also emphasises the need for effective ways to calculate carbohydrate content when out and about for people who use insulin. Applications that focused on exercise, medication and social aspects were the least popular. This may have been because the other types of applications included this functionality and therefore a separate application was not necessary. It was also interesting to note that the diet and exercise applications were not solely targeted at people with diabetes but, in the main, device support, data tracking, medication and the social applications were. This could suggest that there is a lack of diet and exercise applications tailored to the specific requirements of people with diabetes. Alternatively, it could be that the principles of a healthy lifestyle are relevant to everyone, and therefore, there are no special requirements.

Data logging, tracking and analysis were the most prevalent functions available within the applications, and unsurprisingly, this was mainly how the applications were used. The ability to analyse and visualise data was a key feature for many respondents and this is consistent with findings from other user studies (e.g. Lyles et al, 2011; Waite et al, 2013). Although Arnhold et al (2014) found that most of the applications in their review contained only one function, the applications in this study had many, suggesting that people with diabetes prefer to choose applications that have multiple functionalities.

In keeping with findings from Chomutare et al (2011), education was not a prevalent feature in any of the applications nor social media integration. However, contrary to Chomutare et al's (2011) assertion that these could be

important features, respondents did not mention education or social media integration as critical or missing from the applications.

Consistent with other reviews (e.g. Eng & Lee, 2013), none of the applications were directly integrated with healthcare providers. As Chomutare et al (2011) suggests, this is probably due to 'legislative and organisational barriers'. However, many had the ability to export data allowing users to share data with their healthcare team via email or printouts.

None of the applications provided advice or guidance to the users about what actions they should take in response to blood glucose readings - an important feature according to Breland et al (2013). Again, this is probably due to legal issues and the difficulty in providing the necessary personalised advice that would be required.

In the literature, manual input of readings as opposed to automatic upload of results was seen as a negative aspect of diabetes applications (e.g. Ciemins et al, 2010; Rao et al, 2010; Chomutare et al, 2011; Waite et al, 2013). However, none of the respondents noted this as an issue. This could be considered surprising as many of the respondents self-test their blood glucose more than four times a day. However, it is also important to note that eight of the applications had this functionality, and nine respondents had used or were using applications that focussed on supporting diabetes devices, such as blood glucose meters. Therefore, it is possible that the need for this functionality was being fulfilled so respondents did not feel the need to raise it as an issue.

Devices used with the applications

Respondents own or use a wide range of devices, however they do not always use these in connection with applications they use to manage their diabetes. For example, all respondents owned a blood glucose meter but not everyone had used software that supported these devices. This could be because there were no applications supporting their particular device but also it seemed that at least some respondents preferred to manually enter data elsewhere.

The usefulness and familiarity of mobile devices was a strong theme in the qualitative data. Respondents already carried mobile devices, such as a smartphone, and therefore using them for diabetes applications was convenient and easy. This is in keeping with the literature which suggests that mobile technology could be beneficial to people with diabetes (e.g. Breland et al, 2013; Waite et al, 2013). In addition, Lyles et al (2011) found issues with unfamiliar mobile technology in their assessment of a technology based diabetes management programme. Together with the findings in this study, it seems imperative that any device needs to be familiar to people with diabetes in order for it to be successfully adopted as part of diabetes self-management.

Upgrades

The fact that none of the respondents upgraded or bought 'in-app purchases' was probably due to a lack of these within the application. However, a small number of applications did offer 'premium functionality'. It seemed that respondents were either not aware of these or did not require the extra functionality.

Difficulties and Concerns

There was little mention of difficulties in using applications. A small number of respondents did refrain from using mobile phone applications due to the small screen size, which is consistent with findings by Waite et al (2013). However, there was a lack of accessibility issues raised in this study compared to the literature (e.g. Whitlock & McLaughlin, 2012; Waite et al, 2013; Arnhold et al, 2014). This could have been due to the characteristics of the sample. For example, no respondents had complications that could interfere with the use of applications, and only four respondents were 55 or over in the second survey. However, it could also be that previous literature has over emphasised the accessibility issues with mobile phone applications.

Although Eng and Lee (2013) had concerns regarding the regulation of diabetes applications, and Breland et al (2013) found that many diabetes applications did

not follow evidence-based guidance, there was little concern from respondents regarding the accuracy of the applications. Poor accuracy was also not a reason to stop using applications or refrain from using applications at all. Their concerns could have been diminished by the ability to double-check against other sources of data and also the endorsement of some applications by well-respected organisations or healthcare professionals. Contrary to Waite et al's (2013) study, there was little concern regarding the accurate input of data. This could have been minimised by the ability to correct and the improved accuracy of the automatically uploaded of results (Kalergis et al, 2006), that some of the applications had the ability to do.

There was a general lack of concern regarding privacy in the sample. For instance, a concern for privacy did not seem to be a reason to not use applications at all. Respondents who did read the privacy policy for applications did so out of habit than for any particular concern for privacy. In contrast, in their study regarding privacy policies for e-commerce website, Milne and Culnan (2004) found that concern for privacy and reading privacy notices were positively correlated. The lack of concern for privacy may have been due to the main recruitment source of the sample. For example, people who have concerns regarding their privacy are less likely to engage with a forum.

Sharing

Support from others, such as healthcare professionals, friends and family, is an essential part of good diabetes self-care (Diabetes UK, 2009). Many respondents followed this good practice and shared data with others. It seemed that respondents capitalised on one of the main benefits of using this technology for diabetes. Rao et al (2010) also found that the participants in their study frequently shared blood glucose data with healthcare professionals. However, none of the applications were directly integrated with healthcare providers, and contrary to findings in other studies (e.g. Lyles et al, 2011; Waite et al, 2013), none of the respondents stated this was an important feature to them.

Interestingly, a lack of interest from healthcare professionals in viewing the information shared from applications was mentioned. This is also highlighted as an issue in the literature. For example, Peel, Douglas and Lawton (2007) found that people with type 2 diabetes reduced self-monitoring of blood glucose due to lack of interest from healthcare professionals in these results. It is important to note however, that the respondents in this study did not stop using the applications altogether because of a lack of interest from healthcare professionals.

Individuality and Personalisation

The fact that respondents had used or were using many applications with multiple functions or had created their own application or spreadsheet, demonstrates the need for choice and flexibility to personalise. The way they used these applications and what was important to them seemed to be down to personal choice and individual preference.

These findings are congruent with the literature regarding diabetes and the applications designed to help manage it. People with diabetes are individuals with a long term condition that requires a great deal of personal responsibility to manage in a way that is suitable to their lives (Diabetes UK, 2009). There is no single way to manage diabetes successfully. People with diabetes have different experiences with managing the condition and therefore manage diabetes differently (Chen, 2010). Previous studies have recommended that technologies designed to be used by people with diabetes need to take into account individual differences and provide choice (e.g. Chen, 2010; King et al, 2012).

5.2. Design Implications

The key recommendation to developers of applications for diabetes is to incorporate flexibility within the features offered, so that users can tailor the application to their individual requirements. Developers should provide users with the ability to record different items of data and to analyse the data in a way

that is relevant to them. Applications should contain functionality that allows users to share information stored within the application in a way that suits their needs. Users should be able to edit data if necessary and have the choice whether to automatically upload or manually enter results into an application. However, it is also recognised that developers would have to invest a significant amount of time and money to provide and maintain access to the numerous devices that people with diabetes may want to upload from. It is important that developers investigate the needs of their users to make sure that this functionality is required.

In this study, most of the respondents used medication. Functionality that allows users to record and analyse medication, plus reminders or alerts to take medication, could be important to include. If an application is aimed at people who use insulin, it is important to include the ability to calculate carbohydrate content within food and drink as well. Users should also be able to use the application on or with a device that is familiar and convenient.

Developers should think about the lack of awareness or perceived need for upgrades. They may also find it interesting that many of the respondents who used applications had been on a diabetes education course and diagnosis of diabetes was a trigger point to try applications. Finally, to improve credibility, developers could collaborate with healthcare professionals and diabetes organisations when designing applications for diabetes.

5.3. Limitations

Due to the small sample size, it was difficult to make assertions about how individual characteristics, such as the type of diabetes, influenced the choice and use of applications. For example, due to the small number of respondents who did not use applications, it was difficult to understand the differences between those who use applications and those who do not.

Using online surveys was a fast and easy method to distribute and collect data. A diabetes forum was found to be a good place to recruit people with diabetes rapidly. It was also useful for gathering feedback about the content of the survey. Changes were easily made to the survey as responses and feedback were collected. Respondents may have found this method more convenient as they were able to complete the surveys in their own time, and the absence of a researcher may have relieved any pressure to provide responses. However, it was not always easy to accommodate every circumstance and therefore some questions were less relevant to some respondents. The software restricted the design of the survey making it difficult to present the survey in the best way. It was also not possible to clarify questions or ask respondents to elaborate on their answers, which in some areas would have been useful. For example, due to the restrictions in the way the survey could be designed, two surveys were created. This resulted in some respondents changing their answers from the first to the second survey which made data analysis difficult. A different method, such a semi-structured interview, would have resolved some of these issues. For example, respondents could have been asked about what applications they used and this could be immediately followed by more detailed questions regarding their use. In addition, respondents could have been prompted to provide further information and questions could have been better tailored to responses.

Using a self-selected online survey to collect the data may have influenced the characteristics of the sample. For example, although the survey was advertised as for both users and non-users of applications, it may be that application users were more likely to take part in the survey. In addition, the main source of recruitment could have influenced the characteristics of respondents. For example, concern for privacy was likely to be low amongst forum users. The forum was also focussed on people with diabetes, and not those who had an elevated risk of developing the condition in the future. This probably led to no respondents with this health status taking part in the survey. Other forums could have been better at recruiting this group of people. Even with this influence however, some findings in this study were in keeping with the literature. For example, the need for choice, the individual nature of diabetes and the

convenience of mobile devices were all strong themes in this study and were consistent with the literature (e.g. Chen, 2010; King et al, 2012; Breland et al, 2013).

The functionality analysis of the applications was only based on online promotional material and reviews, which may not include all functions. Downloading and using each application would have been more reliable as suggested by Breland et al (2013). However, this could be expensive and require access to different devices. In addition, as applications are updated over time, it may not reveal the functions that are available to respondents.

5.4. Future Studies

Future research could use different methods to ask similar questions of a wider range of people to gain a greater understanding of how individual characteristics and concerns affect application use. For example, semi-structured interviews and a diary study could be used to understand how application use changes over time and how people with diabetes use different applications. Perhaps future studies could also aim to collect data from those who are more averse to using the technology that surrounds diabetes. For example, offline recruitment through organisations such as the NHS could provide a better understanding of privacy or accessibility issues. Other studies could also focus on other countries or groups of people such as the newly diagnosed, gestational diabetes or parents or carers of those with diabetes.

5.5. Conclusion

In conclusion, this study found that people with diabetes use or have used a range of applications with a variety of functions. Logging and analysing data were the main ways these applications were used. The features and functions that were important varied between respondents, and were sometimes inconsistent with previous studies. There was a general lack of concern over accuracy and privacy. Using an application on a device that was convenient and familiar was important. Sharing data from the application was popular and respondents had little difficulties in using the applications. A strong theme

throughout the data was a need for choice and flexibility. Diabetes is a highly individualistic condition, and developers should cater for this in applications designed to help manage diabetes. The main limitation of this study was the size of the sample and the influence of the methodology used to collect data. Differences in attitudes and preferences compared to the literature could be explained by this limitation. However, major themes, such as individuality and personalisation, are in keeping with the literature. Application types and functions were also consistent with previous reviews. Future studies should try to overcome some of the limitations in this exploratory study. They should also expand to other groups of people and use other methods to investigate interesting results highlighted by this study.

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APPENDIX A – INFORMATION SHEET AND CONSENT FORM FOR THE FIRST SURVEY.

We would like to invite you to participate in our exciting research study.

Before you decide to take part we would like you to understand why the research is being done and what it would involve for you.

You should only participate if you want to. Choosing not to take part will not disadvantage you in any way. Even after agreeing to take part, you can still withdraw at any time and without giving a reason by clicking on the 'Exit' button which appears at the top of each page.

Please read the following information carefully and discuss it with others if you wish.

What's the purpose of this survey?

The purpose of this study is to explore the use of software applications to help manage diabetes and general health and wellbeing. Even if you do not currently use applications, we are interested in your opinions. Taking part in this study will help us understand the needs and preferences of people with diabetes or those who have been told they are at high-risk of developing diabetes in the future. Recommendations can then be developed to improve applications that you may use.

What will happen if I take part?

We would like you to complete an online survey and answer some questions about:

- you and how you manage your diabetes or your risk of developing it.
- the types of devices and software applications that you may use.
- your attitudes towards the privacy policies for these software applications.

You do not have to answer some questions, however, there are others which will require a response so that the survey is appropriate for you. Required questions are marked with an asterisk.

At the end of the survey, you will be given the opportunity to provide your email address if you are happy to be contacted by us for a short follow-up interview or survey. You are under no obligation to provide your email, and you will not be disadvantaged in any way if you do not provide your email address.

This survey could take up to 20 minutes to complete depending on your responses.

What will happen to my data?

All the responses you provide will be aggregated with other people's responses and analysed. The data will be used in a report. This report will not contain any data by which an individual could be identified.

All data will be collected and stored in accordance with the Data Protection Act 1998.

SurveyMonkey has been used to create, distribute and collect data for this survey. Please see their Privacy Policy and Security statement for information about how they handle your data on our behalf.

SSL encryption has been enabled for this survey to ensure that your responses are communicated securely to SurveyMonkey's servers.

Your IP address will not be stored for this survey, but a cookie will be placed on your browser to prevent more than one response from a person.

Can I take part?

We are looking for adults (aged 18 or over) with either type 1 or type 2 diabetes and those who have been told that that are at high risk of developing diabetes in the future.

Do I have to take part?

It is up to you to decide whether or not to take part. If you choose not to participate, you won't incur any penalties or lose any benefits to which you might have been entitled. However, if you do decide to take part, you will need to read and complete the consent form below. Even after agreeing to take part,

you can still withdraw at any time and without giving a reason by clicking on the ‘Exit’ button which appears at the top of each page.

What if I have questions?

Please email us if there is anything that is not clear or you would like more information.

This study has been approved by the UCL Research Ethics Committee as Project ID Number: UCLIC/1213/015.

Name and contact details of investigators:
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APPENDIX B – FULL LIST OF QUESTIONS AND RESPONSES FOR THE FIRST SURVEY

1. Where did you find the link to this survey?

   Format: Multiple choice tick boxes (only one answer) with a free text box for 'Other'.
   Options:
   - Diabetes Support forum
   - Diabetes.co.uk forum
   - Diabetes UK Facebook page
   - UCLIC Facebook page
   - CHI+MED Blog
   - CHI+MED Twitter
   - Other (please specify)

2. What is your current health status?

   Format: Multiple choice tick boxes (only one answer).
   Options:
   - I have Type 1 diabetes.
   - I have Latent autoimmune diabetes of adulthood (LADA or T1.5)
   - I have Type 2 diabetes (non-insulin dependent).
   - I have Type 2 diabetes (insulin dependent).
   - I have Maturity onset diabetes of the young (MODY).
   - I have Gestational diabetes.
   - I have been told that I am at high risk of developing diabetes in the future.
   - I am parent or carer of someone with diabetes.

3. Do you or have you ever used one or more software applications to help manage your diabetes? Or Do you or have you ever used one or more software applications to help reduce your risk of developing diabetes?

   Format: Multiple choice tick boxes (only one answer).
   Options:
   - Yes
   - No

4. How long ago did you start using software applications to help manage your diabetes?
   Or,
   How long ago did you start using software applications to help to reduce your risk of developing diabetes?

   Format: Multiple choice tick boxes (only one answer).
   Options:
   - 1 year or less
   - 2 to 4 years ago
   - 5 or more years ago

5. Please select all the applications you have used or are currently using to help manage your diabetes:
   Or,

Please select all the applications you have used or are currently using to help to reduce your risk of developing diabetes:

Format: Multiple choice tick boxes (multiple answers) with a free text box for 'Other'.
Options:

A range of different applications were provided as examples, such as:
Carbs & Cals (for iPhone)
Carbs & Cals (for Android)
Fitbit Online account (Free)
Fitbit Online account (Premium)
Other (please specify the application name and the version(s) that you use i.e. iPhone/iPad/Android/Online)

6. Why don't you use applications to help you manage your diabetes?
   Or,
   Why don't you use applications to help you to reduce your risk of developing diabetes?

Format: Multiple choice tick boxes (only one answer per row - Likert scale with the options Strongly agree, Agree, Neutral, Disagree and Strongly disagree) with a free text box for 'Other'.
Options:

I'm concerned about the privacy of my data.
I don't feel like I have the technical skills to use these applications.
I don't have the device that would be necessary to use the application(s) that I would want to use.
I'm not interested in using applications to help manage my diabetes. (Or, I'm not interested in using applications to help to reduce my risk of developing diabetes).
Please list any other reasons why you don't use applications to help you manage your diabetes. (Or, Please list any other reasons why you don't use applications to help you to reduce your risk of developing diabetes).

7. How frequently do you read privacy policies for applications that you have used or are using to help manage your diabetes?
   or
   How frequently do you read privacy policies for the application(s) that you have used or are using to help you to reduce your risk of developing diabetes?

Format: Multiple choice tick boxes (only one answer).
Options:

Always
Often
Sometimes
Rarely
Never

8. Have you read the privacy policies for any of the application(s) that you have used or are using to help manage your diabetes?
   Or,
   Have you read the privacy policies for any of the applications that you have used or are using to help you to reduce your risk of developing diabetes?

Format: Multiple choice tick boxes (only one answer).
Options:

Yes
No

9. Please select the most appropriate answer for the following statements for applications that you have used or are using to help manage your diabetes:
   Or,
   Please select the most appropriate answer for the following statements for the application(s) that you have used or are using to help you to reduce your risk of developing diabetes:

   Format: Multiple choice tick boxes (only one answer per row - Likert scale with the options Strongly agree, Agree, Neutral, Disagree and Strongly disagree) with a free text box for 'Other'.
   Options:

   I usually read the privacy policy before downloading or signing up to the application.
   I usually read the privacy policy if I believe the policy has been updated or changed.
   I usually read the privacy policy if I am using an application to record personal health data such as blood glucose readings or weight.
   I usually read the privacy policy to learn if the application shares my personal information with other companies or organisations.
   I usually read the privacy policy to learn if the application sells my personal information to other companies or organisations.
   I usually read the privacy policy to learn how the application uses the information it collects from me.
   I usually read the privacy policy if the application is free.
   I usually read the privacy policy if I have to pay for the application.
   Privacy policies for applications are easy to understand.
   Privacy policies for applications are often too long.
   Privacy policies for applications are easy to find or access.
   If I have experience with a company, I usually do not read the privacy policy for their application.
   I usually do not read the privacy policy if the application belongs to a well-known company.
   If the application displays a privacy seal, I usually do not read the privacy policy.
   I trust companies to fulfil the promises they make in their application privacy policy.
   It bothers me to enter personal information into applications, I sometimes think twice.
   Please use the text box below to enter any other information that you think relevant regarding your attitudes towards privacy for the application(s) that you use or have used:

10. Why do you never read privacy policies for the application(s) that you have used or are using to help manage your diabetes?

    Format: Free text box.

11. Why have you not read the privacy policies for any of the applications that you have used or are using to help manage your diabetes?
    Or,
    Why have you not read privacy policies for any of the applications that you have used or are using to help you to reduce your risk of developing diabetes?

    Format: Free text box.

12. Do you currently own or use any of the following devices?
    Smartphone,
    Tablet,
    Laptop or desktop,
    Blood glucose monitor,
    Insulin pump,
    Blood pressure monitor,
    Pedometer,
    Body weight scales,
    Heart rate monitor.

    Format: Multiple choice tick boxes (only one answer).
    Options:
        Yes
        No

13. Which personal devices do you currently own or use?

    Format: Multiple choice tick boxes (multiple answers).
    Options:
        Smartphone
        Tablet
        Laptop/desktop
        Blood glucose monitor
        Insulin pump
        Blood pressure monitor
        Pedometer
        Body weight scales
        Heart rate monitor

14. Are you male or female?

    Format: Multiple choice tick boxes (only one answer).
    Options:
        Male
        Female

15. What is your age?

    Format: Multiple choice tick boxes (only one answer).
    Options:
        18 to 24
        25 to 34
        35 to 44
        45 to 54

55 to 64
65 to 74
75 or older

16. What is your nationality?

Format: Free text box.

17. How long have you been diagnosed with diabetes for?
Or,
How long ago have you been told that you were at high risk of developing diabetes?

Format: Multiple choice tick boxes (only one answer).
Options:
Less than 1 year
At least 1 year but less than 5 years
At least 5 years but less than 10 years
10 years or more

18. Have you tried to reduce your risk of developing diabetes?

Format: Multiple choice tick boxes (only one answer).
Options:
Yes
No

19. How do you manage your diabetes? Please select all that apply to you.
Or,
How have you tried to reduce your risk of developing diabetes? Please select all that apply to you.

Format: Multiple choice tick boxes (multiple answers) with a free text box for 'Other'.
Options:
Through what I eat or drink.
Through exercise.
Through the medications that I take.
Other (please specify)

20. Do you self-test your blood glucose?

Format: Multiple choice tick boxes (only one answer).
Options:
Yes
No

21. On average, how often do you self-test your blood glucose?

Format: Multiple choice tick boxes (only one answer).
Options:
4 times a day or more
Less than 4 times a day but more than once a day
Once a day
Less than once a day but more than 2 times a week
2 times a week

Less than 2 times a week but more than once a month
Once a month or less

22. Have you ever attended a diabetes education course?

Format: Multiple choice tick boxes (only one answer).
Options:
Yes
No

23. Which course(s) have you attended? Please select all that apply to you.

Format: Multiple choice tick boxes (multiple answers) with a free text box for 'Other'.
Options:
DAFNE
DESMOND
X-PERT
Other (please specify)

24. How long ago was the last diabetes education course you attended?

Format: Multiple choice tick boxes (only one answer).
Options:
Less than 1 year
At least 1 year but less than 3 years
At least 3 years but less than 5 years
5 years or more

25. Do you have any of the following complications from diabetes?
Cardiovascular disease
Kidney disease (nephropathy)
Eye-sight problems (retinopathy)
Nerve damage (neuropathy)
Upper limb amputation
Lower limb amputation

Format: Multiple choice tick boxes (only one answer).
Options:
Yes
No

26. Which of the following complications from diabetes do you have? Please select all that apply to you.

Format: Multiple choice tick boxes (multiple answers)
Options:
Cardiovascular disease
Kidney disease (nephropathy)
Eye-sight problems (retinopathy)
Nerve damage (neuropathy)
Upper limb amputation
Lower limb amputation

APPENDIX C – REQUEST FOR EMAIL ADDRESS.

If you are happy to be contacted for an additional short interview or survey, based on the responses you have given, please provide your email address in the text box below.

You are under no obligation to provide your email, and you will not be disadvantaged in any way if you do not provide your email address.

APPENDIX D – INFORMATION SHEET FOR THE SECOND SURVEY.

Thanks for providing a response to the previous survey. We've found your responses very helpful and we understand that you have used [app name] for [device]. In this survey, we would like to ask you about how you use this application.

As with the previous survey, you should only participate if you want to and choosing not to take part will not disadvantage you in any way. You can withdraw at any time and without giving a reason by clicking on the 'Exit' button which appears at the top of each page.

You do not have to answer all of the questions, but there are some which will require a response so that the survey is appropriate for you. Required questions are marked with an asterisk.

All responses will remain confidential and the data will be collected and stored in accordance with the Data Protection Act 1998. The data will be used in a report but it will not contain any data by which an individual could be identified.

SurveyMonkey has been used to create, distribute and collect data for this survey. Their Privacy Policy and Security statement contains information about how they handle your data on our behalf.
SSL encryption has been enabled for this survey to ensure that your responses are communicated securely.
Your IP address will not be stored for this survey, but a cookie will be placed on your browser to prevent more than one response from a person.

Please email us if there is anything that is not clear or you would like more information.

APPENDIX E – FULL LIST OF QUESTIONS AND RESPONSES FOR THE SECOND SURVEY.

Topic	All Questions	Response Format and Options
Download	How long ago did you download to this application? Please give an estimate or approximate value. How did you download it? For example, which device did you use and where did you download it from. Why did you decide to download it?	Format: Free text box.
Create	How long ago did you create this application? Why did you decide to create your own application? Why did you decide to use Excel to help manage your diabetes?	Format: Free text box.
Privacy Policy	Did you read the privacy policy for this application?	Format: Multiple choice tick boxes (only one answer). Options: Yes No
	Why did you read the privacy policy for this application? Was the privacy policy easy to understand? Was the privacy policy easy to find? Why didn't you read the privacy policy for this application?	Format: Free text box.

Topic	All Questions	Response Format and Options
Use	Do you still use the application?	Format: Multiple choice tick boxes (only one answer).
	How long have you been using the application for? How long have you been using it for? How long ago did you start using Excel to help manage your diabetes? Please describe how you use this application to help manage your diabetes, including the type of information you store and enter, how often you use the application and when you use it. Please describe how you used this application to help manage your diabetes, including the type of information you stored and entered, how often you used the application and when you used it. Please describe how you use Excel to help manage your diabetes, including the type of information you store and enter, how often and when you use it. Please describe the features and functionality of your application, including how the application helps you manage your diabetes, the type of information you store and enter, how often you use the application and when you use it. Why did you stop using the application? When did you stop using it and how long did you use it for?	Format: Free text box. Options: Yes No I have never used this application

Topic	All Questions	Response Format and Options
Sharing	Do you share the information you record in this application with others such as friends, family or healthcare professionals?	Format: Multiple choice tick boxes (only one answer). Options: Yes No
	Who do you share the information with and why? Who did you share the information with and why? When do you share the information from the application and how do you share it? When did you share the information from the application and how did you share it? When do you share the information from Excel and how do you share it? Why don't you share the information you record in the application? Why didn't you share the information you recorded in the application?	Format: Free text box.

Topic	All Questions	Response Format and Options
Features and Functions	What are the most important features or functions of the application to you? What were the most important features or functions of the application to you? What are the most important features or functions of Excel to you to help manage your diabetes? Are there any features or functions that you don't use regularly or at all? If so, please describe what these features are and why you don't use them. Were there any features or functions that you didn't use regularly or at all? If so, please describe what these features were and why you didn't use them. What features or functions could be added that would improve the application for you? What features or functions could have been added that would have improved the application for you? Are there any features or functions missing from Excel that would help you manage your diabetes? If so, what are they? Are there any features or functions that you have not been able to create in the application that you would like to? If so, what are they?	Format: Free text box.

Topic	All Questions	Response Format and Options
Difficulties and Concerns	Do you have any difficulties using this application? If so, please describe what these are. Did you have any difficulties using this application? If so, please describe what these were. Do you have any difficulties using Excel to help manage your diabetes? If so, please describe what these are. Do you have any concerns regarding the privacy of your information stored in this application? Please describe the reasons behind your answer. Did you have any concerns regarding the privacy of your information stored in this application? Please describe the reasons behind your answer. Do you have any concerns regarding the privacy of your information stored in Excel? Please describe the reasons behind your answer. Do you have any concerns regarding the accuracy of the information provided to you from the application? Please describe the reasons behind your answer. Did you have any concerns regarding the accuracy of the information provided to you from the application? Please describe the reasons behind your answer. Do you have any concerns regarding the accuracy of the information provided to you from Excel or the accuracy of the calculations performed by Excel? Please describe the reasons behind your answer. Do you have any concerns regarding the accuracy of the information you enter into the application? Please describe the reasons behind your answer. Did you have any concerns regarding the accuracy of the information you entered into the application? Please describe the reasons behind your answer. Do you have any concerns regarding the accuracy of the information you enter into Excel for managing your diabetes? Please describe the reasons behind your answer.	Format: Free text box.

Topic	All Questions	Response Format and Options
Cost and Upgrades	Have you bought any in-app purchases for this application? Please describe what you purchased and why, or why you haven't bought any. Have you purchased any upgrades for this application? Please describe what you purchased and why, or why you didn't upgrade. Did you buy any in-app purchases for this application? Please describe what you purchased and why, or why you didn't buy any. Did you buy any in-app purchases or upgrades for this application? Please describe what you purchased and why, or why you didn't buy any. Did you purchase any upgrades for this application? Please describe what you purchased and why, or why you didn't upgrade. Do you think the application was value for money? Please describe the reasons behind your answer.	Format: Free text box.

Topic	All Questions	Response Format and Options
Device	Which device do you most often use for this application and why? Which device did you most often use for this application and why? Which device do you most often use for Excel to help manage your diabetes and why? What do you like, or dislike, about using this device for this application? What did you like, or dislike, about using this device for this application? Did you use any other devices for this application? Please describe what these were and why you used them, or why you didn't use other devices. What do you like about using an iPhone for this application? What did you like about using an iPhone for this application? What do you dislike about using an iPhone for this application? What did you dislike about using an iPhone for this application? What do you like about using an iPad for this application? What did you like about using an iPad for this application? What do you dislike about using an iPad for this application? What did you dislike about using an iPad for this application? How did the MyFitnessPal iPhone application compare to the MyFitnessPal iPad application? Did you use the MyFitnessPal iPhone application differently to the MyFitnessPal iPad application? If so, please describe these differences. Did you use the MyFitnessPal iPhone application in combination with the MyFitnessPal iPad application? If so, please describe how you used these together.	Format: Free text box.

Topic	All Questions	Response Format and Options
Other applications	How does this application compare to other applications you have used to help manage your diabetes? Have you ever considered using applications from other organisations to help manage your diabetes? For example, applications which can be downloaded to a laptop or desktop, smartphone or tablet applications or those which support the automatic download of readings from blood glucose monitors. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, applications which can be downloaded to a tablet, laptop or desktop. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, applications which can be downloaded to a laptop or desktop, or those which support the automatic download of readings from blood glucose monitors. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, applications which can be downloaded to a laptop or desktop, or those which support the use of insulin pumps. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, applications which can be downloaded to a laptop or desktop, smartphone or tablet applications or those which support the automatic download of readings from blood glucose monitors. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, applications which can be downloaded to a tablet, laptop or desktop, or those which support the	Format: Free text box.

Topic	All Questions	Response Format and Options
	automatic download of readings from blood glucose monitors. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, applications which support the use of insulin pumps. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, smartphone applications or applications which can be downloaded to a laptop or desktop. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, smartphone applications, or applications which support the use of insulin pumps. Please describe the reasons behind your answer. Have you ever considered using other types of applications to help manage your diabetes? For example, smartphone or tablet apps. Please describe the reasons behind your answer.	
Applications in general	What do you think about applications to help people manage diabetes in general?	Format: Free text box.

APPENDIX F – DEFINITIONS OF FUNCTIONS

Data Logging & Tracking – includes the following sub-groups:

Food Logging & Tracking - the ability to store and track food and drink intake over time, with some applications focussing on the carbohydrate content and/or the amount of calories.

Medication Logging & Tracking - the ability to store and track the medications taken over time, most frequently focussing on insulin. The time taken and the dose could sometimes be recorded. Some applications also had the ability to track insulin pump events such as battery changes.

Exercise Logging & Tracking - the ability to store and track the exercise and activity completed over time.

Blood Glucose Logging & Tracking - the ability to store and track blood glucose readings over time.

Physical Measurements Logging & Tracking - the ability to record and/or track body measurements such as weight, height, BMI, waist and hips over time.

BP & HR Logging & Tracking - the ability to store and track blood pressure and/or heart rate over time.

Other Tests Logging & Tracking - the ability to store and track other test results such as HbA1c, blood lipids and ketones. There was no mention of eye and foot check results but it is possible that some application had functionality for this.

Sleep Logging & Tracking - the ability to store and track sleep.

Wellbeing Logging & Tracking - the ability to store and track feelings and emotions.

Symptom Logging & Tracking - the ability to store and track symptoms of hypoglycaemia and hyperglycaemia.

Data Analysis & Visualisation - any reports, graphs, charts or statistics that the application produces from the data entered by the user, usually for the purpose of spotting trends.

Multiple Devices - the application is available to use or download on a number of devices such as smartphones, tablets and laptops. Sometimes there is also the ability to sync data between devices.

Annotations - the ability to add additional information such as notes, photos, labels, tags and/or locations, allowing for enrichment of the data stored in the application for the purposes of sharing, searching and reminding.

Data Export - the ability to export data, print or email reports allowing for data to be shared with others.

Social Media Integration - the ability to integrate with social media channels allowing for data to be shared with others.

Goal & Target Setting - the ability to set personalised goals or target ranges for the data that is recorded. This is often coupled with data analysis, alerting or feedback functions that highlight the progress towards goals or limits, or when data is out of target ranges - and some even provide recommendations on what the targets should be, how to reach them and feedback on progress.

Data Storage and Backup - the application provided the facility to back up the data. Some applications automatically backed-up the data, and some backed-up to an online storage service such as Dropbox. Some highlighted the security of these data back-ups.

Food Database - a list of food and drink items (including their nutritional content) from which a user can search and find items to log their food intake and/or calculate nutritional content. Applications with this function may also (but not necessarily) include the ability to add food items to the database and calculate the nutritional content of meals and recipes.

Search Function - the ability to search the data stored in the application. This could include a barcode scanner feature to find and log food entries, or to search and filter all the data entered by a user within a particular category.

Different Units - the application allows the user to select different units for data such as blood glucose and weight that is appropriate for them.

Reminders & Alerts - the ability to set reminders, alerts or notifications to remind the user of such things as appointments, to take medication or a blood glucose reading, and/or to alert them of their progress towards goals.

Smart Functions - the application has the ability to learn the habits of the user and take actions based on this knowledge and/or provides functionality to make data entry fast and easy. This includes auto-complete functions, automating reminders based on date and location, adjusting targets based on your activities, providing frequently used items first and the ability to add multiple items at once.

Uploading Results - the ability to upload results, such as blood glucose readings, insulin dose, number of steps, calories burned, sleep, weight, blood pressure readings, from another device into the application.

Motivational Features - the application provides features to increase motivation such as comparing yourself with others, competing with friends or completing challenges (sometimes in return for rewards).

Insulin Calculator - a tool to calculate the appropriate amount of insulin to take.

Social Features - the ability to communicate with peers such as access to forums or other member's communities.

Add Custom Trackers - the ability to store and track any data the user would like to track.

Exercise Database - a list of exercises or activities (including an estimate of calories burned) from which a user can search and find items to log their activities and/or calculate the calories burned. Applications with this function may also (but not necessarily) include the ability to add custom exercises (and calories burned) to the database.

Premium Functionality - the application includes functionality that requires a payment in order to access. All the functions are included in this analysis regardless of whether they were free or required payment - however, if this feature is ticked then some of the functions may require payment to access.

Education - any information, tips or guidance provided by the application, including recipe suggestions, blogs and articles.

Offline Mode - the ability to use features of the application when there is no access to the internet.

Personal Information - the ability to store personal information such as date of birth, name, gender, location and/or meter details.

Injection Site Monitoring - ability to monitor the number of times or amount of insulin injected into certain areas of the body.