How to Effectively Design and Create a Concept Mobile Application to Aid in the Management of Type 1 Diabetes in Adolescents

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ABSTRACT

Diabetes is one of the eight most prevalent chronic health conditions in the World; therefore there is a wide range of diabetes-related mobile applications available to the public to aid in glycaemic control and self-management. Statistically, adherence to medication is extremely low in adolescents with Type 1 Diabetes Mellitus (T1DM), therefore it is crucial that adolescents adhere to their medication from a young age and adopt good medication regimes. This paper focuses on the research and design of an interactive and educational concept mobile application aimed at adolescents, aged 11 to 16 years old, to aid in their understanding of T1DM. As visual elements are an essential part to the design of a mobile application, this research outlines how the visual components of the application were designed specifically for the target audience of adolescents with T1DM.

Keywords: education, gamification, mHealth, Diabetes Mellitus, technology, graphics

Introduction

Advances in technology, including mobile devices, has become integrated into the healthcare system, with health information readily available to the public. Diabetes Mellitus is one of the eight most prevalent health conditions in the World (WHO, 2008) with 3.05 million people affected in the United Kingdom (Diabetes.co.uk, 2017). Due to the prevalence of Diabetes Mellitus there is a vast array of mobile health (mHealth) applications (apps) available to download to aid in patients understanding and blood glucose (BG) level monitoring. The way in which technology and mHealth can improve a patient's adherence to medication is being thoroughly researched, especially for adolescents with chronic health conditions, such as Type 1 Diabetes Mellitus (T1DM).

The research presented in this paper was carried out as a collaborative between the University of Glasgow, The Glasgow School of Art and Costello Medical Consulting Ltd (Costello Medical), with the idea of re-invention of the concept of mobile apps in healthcare, by research, design and development of a prototype app aimed at adolescents with T1DM. The design of the app would look at basing the design and functionality on educating the patient about T1DM and aiding them to understand the importance of medication adherence.

After discussions between the research team it was decided that the focus would be on the creation of a concept app aimed at patients in their early adolescences, after reviewing the current literature surrounding the different stages of adolescence and their use of mobile apps in relation to T1DM. This research was focused on adolescents as medication adherence in adolescents is extremely low, with statistics reporting 50-80% of non-adherence to medication in this age group (Bass, Farhangian, & Feldman, 2015).

Project Aims and Objectives

It is important that individuals with chronic conditions maintain adherence to their medication, especially during their adolescent years, where they can create good adherence regimes, therefore the aim of this research was to research, design and develop an interactive concept mobile app aimed at adolescents, aged 11 to 16 years old, to aid in their understanding of the anatomy of T1DM and the importance of medication adherence.

The objective of this research was to design and create a working prototype of the concept mobile app using game engine software that aids to positively encourage adolescents to use the app daily. The creation of the concept app was based on research in the most effective ways to engage adolescents in educational material through the use of mobile apps.

Materials and Methods

Before developing a prototype of the concept mobile app it was important to first understand how the design and content of an app encourages use and provides positive reactions from the user. The current literature on app development and design, along with literature on gamification was reviewed before the content of the app was developed.

Materials

To create the concept app a selection of software programs were used, allowing for optimal development, including high resolution images and interactivity. Adobe® Illustrator CC and Photoshop CC, 2015, were used to create high resolution colourful vector images for use within the apps navigation. Adobe® Color CC, 2015 was used to create the concept colour schemes for the app. The game engine Unity3D©, version 5.1.2fl, was chosen to create the concept app as it was the most familiar game engine software to the author, allowing for optimal development.

Methods and Development

This research focused on the creation of a concept mobile app for iOS platform, with the app design created for the iPhone5. At the time this research was carried out, the iPhone5 was the most popular model (Business Insider, 2014) and was the most likely phone that adolescents would own. Development of the app in Unity3D© allowed for potential further development of the app for other platforms, such as Windows and Android. In a review by Hamine, Gerth-Guyette, Faulx, Green & Ginsburg (2015), the iterative design process involving system and content development, along with the multiple stages of user experience testing, was recommended as a template for future mHealth technology. Therefore development guidelines, including the iOS Human Interface Guidelines by Apple Inc. (2015) were consulted to aid in the development of the concept app for this research.

Wireframe Design

Before the app was constructed, factors such as visual components, colour, text and interactivity of the app had to be considered. After reviewing the current literature surrounding the use of mobile apps for adolescents with T1DM, elements for the app were brought together in a wireframe, to focus on the content of each screen and how navigation

through the app will work (ChaiOne, 2013), making the development of the app a more visual process. Many apps available for T1DM adolescents are focused on increasing their medication adherence, many of which include an additional function where the user can record their blood glucose (BG) levels, either manually or via Bluetooth®. Due to the time restrictions of this research a different approach to encouraging good medication adherence was taken, one focusing on the education of the adolescent user. The development of an educational concept app leaves room for further development of the app to include elements such as a BG recording function.

Components of the app were considered in relation to the target audience of early to mid-adolescents (11 to 16 years old), therefore it was important to understand what elements of an app the target audience would respond positively to, and how best to create these components. The age of the target audience, the theme of the app and the types of interactivity featured in the app should determine the look and feel of the application (Naranjo-Bock, 2011). The wireframe was used to bring ideas of the content app together and allowed for a decision to be made on what content was relevant to include in relation to the target audience. To fulfil the aim of aiding in the users understanding of T1DM and the importance of self-care, the sections included in the concept app within the wireframe were:

- Information section
  - Links to relevant websites
- Educational section
  - Comprising a game through which the user would learn more about T1DM
- Avatar section
  - In this section, the user could personalise their avatar with rewards gained from the educational game.

Children and adolescents are more likely to read instructions on a website or an app than an adult, therefore 'help' sections were an additional element added to the design of the app (Thomason, 2002), to aid in the users understanding and navigation through the app when first downloading the app.

The inclusion of an avatar into the design of the app was added to give a more personal and interactive experience for the user. In a pilot study by Maranda, Lau, Stewart & Gupta (2015), a novel approach to improving adolescents' adherence to diabetes medication was found to be the structured care of a pet fish. The aim of the additional avatar was to provide

the user with a personal attachment to the app and therefore encouraged to play the educational game to earn rewards to personalise their avatar, whilst gaining a better understanding of T1DM.

After confirming the contents of the wireframe, an interactive Personal Document Format (PDF) was created in Adobe® InDesign 2015 using the components of the app, allowing for testing of the navigation through the different screens of the app. An additional feature considered whilst developing the wireframe was the discreetness of the app, allowing adolescents, who may feel embarrassed about accessing information on their condition in public, to use the app whenever and wherever they want. In a study by Cafazzo, Casselman, Hamming, Katzman & Palmert (2012), adolescents were interviewed as part of the user-centred design, found that several of their participants commented that social embarrassment was a key factor leading to their avoidance of BG testing in public. It was therefore felt necessary to add this element into the design of the concept app, allowing users to feel comfortable using the app whenever they wished.

Colour Scheme

After finalising the content of the app, the next step was to create visual components suitable for early to mid-adolescents. Visual components of an app are an important element as they can intrigue a user or dissuade an individual from using the app. It is essential to create visual components that are engaging and aid in the users understanding of T1DM. Prior to constructing the visual components of an app, a colour scheme was created. The colours within the app were to be appealing to both male and female adolescents, and work well without distracting the user from the important information. Colour is an important element of an app as colour helps to create an interactive experience and provides visual continuity and enhances communication (Apple, 2015), whilst badly chosen colour schemes can detract from the overall design of the app (Thomason, 2002). The majority of mobile apps use a family of colours that look great individually and in combination, but colours that also look good on both light and dark backgrounds.

Adolescents are drawn to bright and bold colours along with neon colours (Thomason, 2002), therefore a bold shade of blue was chosen as the primary colour with experimentation of a variety of secondary colours and complimentary colours for possible colour schemes. The colour blue is one of the most popular colours used in branding, such as Facebook© and Twitter©. Blue is also the colour of trust, peace, order and loyalty (KISSmetrics, 2015) and produces feelings of calmness and serenity (About Education, 2015). The psychology of

colour and the feelings the colour blue creates is used widely across many brands to create a feeling of trust when individuals view their brand. In a survey on colour, both men and women stated that blue was one of their favourite colours (KISSmetrics, 2015). In 2006 the International Diabetes Federation (IDF) created the Blue Circle, shown in Figure 1, to symbolise diabetes and to create an internationally recognised symbol for diabetes and to help raise awareness of the condition (IDF, 2014).

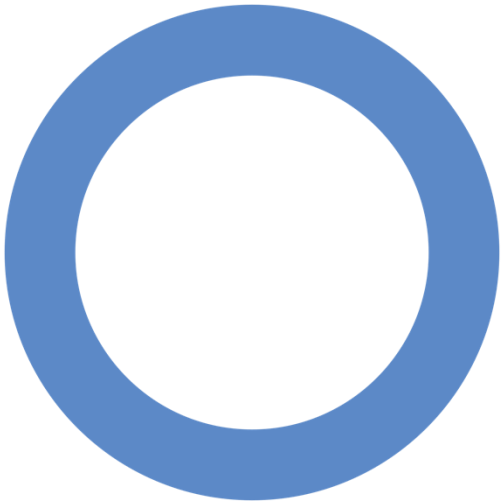

Figure 1. Blue Circle symbol created by the International Diabetes Federation

The final colour scheme chosen for the app was a spectrum of blue, allowing for different shades to be used in different aspects in the apps design (Figure 2). A primary shade of blue was chosen and changing the hue and saturation of the primary blue to create secondary colours created the complimentary shades. Whilst creating the colour scheme, the font and text colour were taken into consideration. Microsoft (2015) recommends using black text on a white background as it is the most effective colour combination for legibility. Blue and white work well together, as well as creating legible text; therefore white was added to the colour scheme. The font Roboto was chosen and downloaded from Google Fonts (2015) as it is an easy to read font, even when on small resolution screens. White was chosen as the font colour so that it would stand out from the blue background, making it legible.

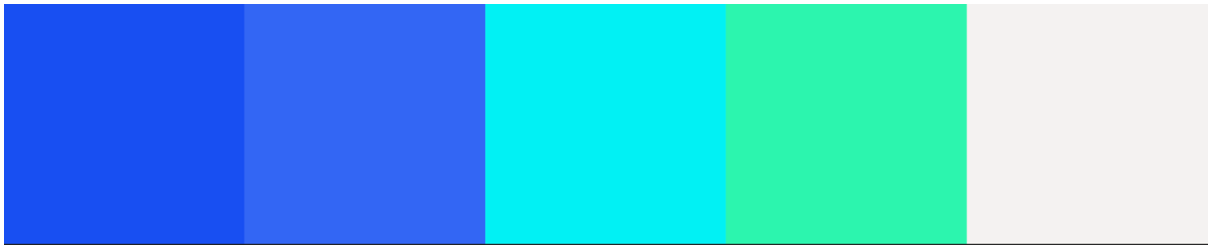

Figure 2. Colour scheme created in Adobe® Color CC

Visual Components

In a study by Frøisland, Årsand & Skårderud (2012) focusing on the use of a visual diabetes diary with the use of a smartphone versus a web-based service where adolescents could contact their caregiver, the study reported better visual understanding of diabetes self-management through the use of images. This gave the adolescents a visual and tangible understanding of how physical activity, food intake and the insulin dosage interact and affect their blood glucose measurements. The overall finding of this study showed that the participants had a new visual understanding of their diabetes, therefore with this in mind it was essential to create visual components that were understandable and that would aid in the users understanding of their condition.

An important element of any brand is their logo as it is the first point of contact an individual has with it, therefore it must give individuals a sense of what that brand stands for and what it offers them (Entrepreneur, 2015). When creating a logo it is essential that the logo can be resized without losing its clarity, therefore simple vector images work best as they do not become pixelated when resized (Entrepreneur, 2015). The logo for the concept app also had to work well with the colour scheme and was to be aimed at the target audience (HubSpot, 2015), therefore the chosen logo was a simple vector image of a star, using bright colours. The logo was integrated into the app as part of the rewards system, where the user would collect stars in the educational game section in order to be able to customise their avatar. This multi-use of the star image meant that when the user saw the logo of the star in their phone they would think about rewards and their avatar, creating a personal connection with the app. The concept app was also given a name, one that would tell the users what the app did and one that was recognisable to users. A simple and effective name was chosen, the abbreviation for Type 1 Diabetes ‘T1D’, which worked well for the app as it had a discrete element and was also easily recognisable to individuals with the condition. The name of the app was included within the logo, shown in Figure 3.

Figure 3. T1D star logo in Adobe® Illustrator CC

Icons

Icons are part of the overall visual look of an app and therefore need to be simple and easy to understand, aiding the user in understanding what each icon means. Simplistic icons were designed for the concept app 'T1D' that were easy to understand, using universal symbols, and aimed at the target audience. Keeping in mind the research on what the target adolescent audience would respond positively to, the icons created were simple, clean vector images using bright colours in keeping with the colour scheme of the app.

Simple universal images were used for the Home, Help, Back and Next buttons, with the internationally recognised 'i' for information used as the icon for the information section of the app. A head with a square academic cap was chosen as the Education icon as it presented a clean image that was easily interpreted at small screen resolution. Further development of the app may include a wider range of icons for additional sections.

Avatars

Research by Chomutare Fernandez-Luque, Årsand, & Hartvigsen (2011), confirmed that personalised education is an under-represented feature within diabetes mobile apps, and that well designed mobile apps with decision support features, such as personalised education,

have demonstrated potential to enhance self-management outcomes. This research along with the pilot study carried out by Maranda, Lau, Stewart & Gupta (2015) using structured pet care to improve glycaemic control, can aid in the development of a digital pet or avatar that the user can personalise whilst learning about the importance of medication adherence. After researching the types of graphics early to mid-adolescents respond positively to, a range of simple vector ideas were drawn up. The idea of using animal avatars was chosen, based on the idea of caring for a pet, and created using Adobe® Illustrator CC. A selection of images were digitised, with the cat being chosen for further development for the concept app, shown in Figure 4. The eyes of the cat were increased in size and additional colours were added to the eyes and nose, making the image more engaging and brighter, and adding to the image's contrast against the background colour scheme. It was important that users knew that the avatar was interactive, therefore a bright turquoise outline was added to the image within Adobe® Photoshop CC, thus creating a glow around the avatar, making it stand out from the background.

Figure 4. Cat avatar

In future development of the app more avatars would be created and tailored to suit the target audience, being more suitable to male and female users, as the cat could be considered more feminine than masculine. The initial idea of the inclusion of an avatar was to have the option

of two animals, such as a cat and dog that the user would choose from when they first downloaded the app. The chosen avatar would then be personalised by the user with rewards gained from the educational game, and with a certain number of trophies the avatar could be upgraded to a larger animal, for example if the user had a cat, they could upgrade the avatar to a lion. This interaction with the app and advancement of the avatar would encourage repeated use of the app, thus aiding in the users understanding of their condition.

Development of the Application

A prototype of the concept app was created using the game engine Unity3D©. The screen resolution of the prototype app was adapted to fit an iPhone5, 640 x 1136, within Unity3D©. The visual components of the wireframe were positioned into each screen with the screen layouts being adjusted to the screen resolution and extra components added to make the design of the app more appealing to the user. The colour scheme was modified once in the game engine as it was found that the shade of blue chosen for the background was too bright to look at for prolonged periods of time. For navigation through the app to run smoothly coding was added for objects to create interactivity within the app. Coding was written in C# in MonoDevelop© 2015, a scripting program used within Unity3D©. The scripts created interactivity allowing the user to navigate through the prototype app.

To add a personal experience to the prototype the avatar screen was developed to allow for the user to customise their avatar with accessories. Two summer accessories were included in the prototype app that the user could press to add to their avatar (Figure 5), with the option of the removal of the accessory included in the options bar located at the bottom of the screen.

In the Education section of the prototype was an informative game focusing on T1DM and how it affects the body, to aid in the users understanding of their condition. Children and adolescents are fascinated by what their bodies can do and wonder how it works (Smart Apps for Android, 2014), therefore it was decided to place the educational game within the pancreas. A three-dimensional anatomical model of the human pancreas was added to this section from BodyParts3D©, modified and textured in Autodesk© 3DS Max, Figure 6. The pancreas was interactive, allowing the user to zoom in and out, and rotate the pancreas, giving them a better understanding of its structure and its anatomical relation to surrounding organs, such as the stomach. The idea for the educational game was that the user would progress through each level learning about different aspects of T1DM, starting at the head of the pancreas and moving towards the tail. Using this idea of progressing through the organ allows for additional development of the game to extend to other organs that are affected by

T1DM, such as the muscles and the heart. The first level of the game contained information for newly diagnosed adolescents, and flashes letting the user know where to start the game. Throughout level 1 the pancreas is interactive and with further development of the app different elements would be added to make the learning process more visual.

Figure 5. Avatar screenshot from Unity3D© showing how the avatar can be customised

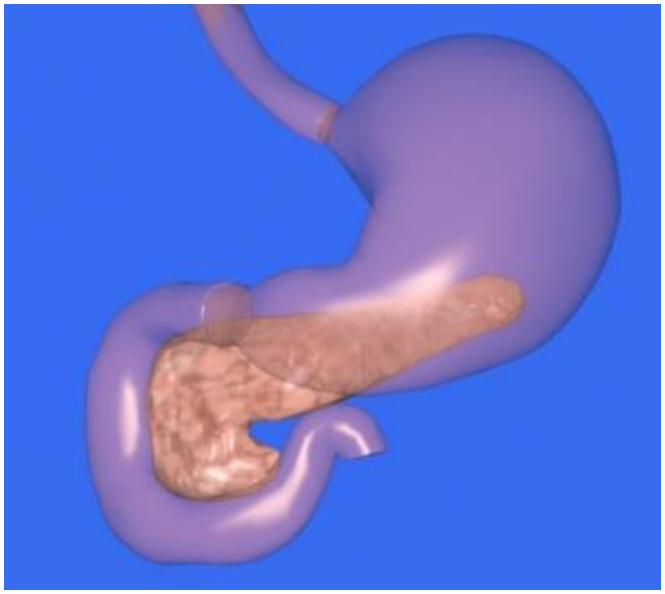

Figure 6. Three-dimensional abdominal organs from BodyParts3D©

A prototype app was created using a range of software to provide optimum development and high resolution images. Once the components of the app were imported in to the game engine Unity3D©, modifications to the layout and colour scheme were carried out to improve the aesthetics and functionality of the app. During the development phase of this research a working prototype was created from the current research and designed with the target audience of early to mid-adolescents in mind. The aim of this research was to create a working prototype of the concept app, therefore not all features of the app were created to work, however all elements of the design were included to show users the different features included within the design.

Results

After development of the prototype app was completed the app was published for desktop viewing with the same screen resolution as the iPhone5. Although the app was designed for the iPhone5, the components of the app were modified so they would fit any screen resolution, allowing for future development of the app for other platforms. The next phase of this research was to carry out usability testing with the target audience to provide feedback on the design and functionality of the prototype app.

Usability Testing

A number of diabetes related charities in the United Kingdom, including Diabetes UK, were contacted by the authors to recruit participants in the target age range of 11 to 16 years old to test the prototype app. Due to the time of year this research was carried out it was not possible to recruit participants to test the prototype app with the target age group, therefore usability testing was carried out with non-diabetic participants outwith the target age range as it was important to gain feedback on the usability and functionality of the app. Usability testing is carried out to gather information regarding how people react to an app and how well they understand the navigation through an app. Problems usually become apparent during the testing phase therefore it was essential to carry out testing on a small group of users.

A small group of users were recruited to test the prototype app and asked to complete a short survey on their initial thoughts on the visual components of the app and on navigation

through the app.

Feedback

The results of the survey provided positive feedback, showing that the icons were easy to understand and the visual components of the app were visually pleasing to the users. Using a Likert scale participants were asked on a scale of 1 to 5, 1 being 'very hard' and 5 being 'very easy', how the app was to navigate through? The results showed that 1 out of the 5 users stated that they found the navigation 'easy', with the remaining users stating the app was 'very easy' to navigate through.

The survey included a question asking what users would change in the prototype app, with one user suggesting they "would include further levels with more features about the treatment of T1DM." Further development of the app would include more levels within the educational game and would look at providing more detail and specific information for adolescents with T1DM. A comments box was included, allowing users to add additional comments about the app. One user commented that the app was "very user friendly and easy to understand. The icons are very intuitive and don't need any text to know what they mean." The survey provided positive feedback on the prototype app, with users giving ideas for future development of the app. No technical problems were found during usability testing.

Although it was not possible to reach the target audience of 11 to 16 year olds with T1DM, usability testing of the prototype app was carried out with non-diabetic participants. Usability testing provided positive feedback regarding the functionality and aesthetics of the app, along with useful comments for additional features for future development.

Discussion

The aim of this study was to research, design and create a concept mobile app aimed at early to mid-adolescents, aged 11 and 16 years old, with T1DM, which would aid in their understanding of their condition, and with further development would help improve their medication adherence. The current literature surrounding the use of mHealth to improve adherence to medication and how the design of an app can aid in this process was reviewed. The process of designing the concept app involved the creation of a wireframe in Adobe® Illustrator CC to layout the components of the app and visually design the look of the app. For future development of the prototype app the target audience would be involved in the

design process, allowing for the design to be user-centred and tailor made for early to mid-adolescents with T1DM.

Although the target audience was not able to be reached during the period in which this research was carried out, usability testing was still carried out with non-diabetic individuals, outwith the target age range, to provide initial pilot feedback on the design and functionality of the prototype app. Results of the usability testing provided positive feedback, however in future development the target audience would be used to test the app, providing feedback suited to their age range.

Limitations

Several limitations were found during this research. Although usability testing was carried out with a small group of non-diabetic participants, providing positive feedback, future development of the app requires usability testing with the target audience to allow for changes to be made suitable for adolescents aged 11 to 16 years old. A larger sample size wuld obviously be needed to draw valid conclusions from.

The chosen avatar image was felt to be more suited to female adolescents, and may be preferred by them rather than males. The visuals used in an app are an important feature, which if they are more suited to one gender over the other it may dissuade adolescents from engaging with the app. Therefore, further development of the avatars available in the app would be required with the aid of the target audience, allowing for avatars to suit both male and female adolescents.

Conclusion

Advances in mobile technology over the years and the development of mHealth apps has been enormous, providing users with information about a condition at the touch of a button whenever and wherever they are. There are a vast range of diabetes-related apps available for iOS and Android platforms, with the majority providing a digital log book for users BG testing data. However, it is the education of chronic conditions that is being overlooked and information for adolescents being aimed at their caregivers, rather than the patient. This research looked at the current literature surrounding the use of mHealth apps and the novel approaches being developed to aid in adolescents' adherence to medication and to aid in their understanding of the condition. We have clearly and simply identified a worlflow methodology to aid future developers in this field. Due to the wide availability of the

softarwe, this can actually be applied to any medical condition, and any target audience with ease.

Positive feedback was received during the usability-testing phase of the research on the overall design of the prototype app, with comments and ideas from users that can be examined for future development. This is an area that does certainly need pursued further however.

Further development of the app would focus on the creation of a range of avatars for users to choose from, more levels in the educational game and the inclusion of more detailed information regarding T1DM. With adolescents' non-adherence to medication being 50-80%, novel approaches must be developed to aid in the improvement of adherence to medication (Bass et al, 2015). Lack of adherence to medication in adolescents is not just a problem solely for this patient group with T1DM, but is an issue concerned with all chronic conditions. With further development of the prototype app created, an educational app could be created for "prescription" to newly diagnosed adolescents. With further development of this app, along with usability testing with the target audience, improvement in adherence may be on the horizon.

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