

Post-diagnosis Management of Diabetes through a Mobile Health Consultation Application

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Abstract—Diabetes currently ranks among the highest threats to human life given the increase in the number of diagnosed cases worldwide. This sudden increase has been linked to changes in human lifestyle since the majority of cases diagnosed are that of type 2 diabetes. Mobile health (m-health) technologies are being implemented in all areas of the health industry to aid patients in their pursuit of healthier lives. The society chosen for our study has a population predominately of African descent and is in crisis, as it possesses one of the highest rates of diabetes and amputation worldwide. Work was therefore conducted to promote proactive behaviour among members of the society by placing relevant technology in their hands to take control of their health. The purpose was to determine if the development of an m-health application would influence people diagnosed with diabetes to adopt healthier lifestyles, and reduce the impact of the disease on this part of the African diaspora. A mobile application was developed based on a preliminary study of m-health application availability and people's attitudes towards mobile applications. People who had diabetes or caretakers of people with diabetes tested the mobile application over a two-week period. Average participation among all users was low but notably there were a few persons who used the application frequently. The frequent users were compliant with the expected behaviours of a diabetes patient. The other participants used the application infrequently and generally had bad health regimes.

Keywords—m-health; diabetes; type 2; mobile application

I. INTRODUCTION

Environmental and behavioural factors such as sedentary lifestyles, obesity and unhealthy eating habits are some of the major causes of the worldwide increase in the incidences of adult onset (Type 2) diabetes [1]. The high incidences of Type 2 diabetes can also be linked to the genetic susceptibility of various minority ethnic groups [1]. More specifically, diabetes and its related complications among those of African descent (black) are much more prevalent than among any other ethnicity in the world, which places the black populations at high risk. Hennis et al. speak to the excessive complications among Afro-Americans who experience visual loss, extreme amputation and renal disease at rates that are times higher than seen in other ethnic groups found around the world [2]. Over the years, the number of obesity cases in this population has increased significantly and these cases of obesity have directly influenced diabetes, hypertension, cardiovascular disease and general mortality [1]. This is a threat to largely black populations' well-being and needs to be addressed.

Type 1 diabetes is rare within the Caribbean but type 2 diabetes has documented high rates in populations of African-origin. In the English-speaking Caribbean, there is an estimated overall prevalence of 11% [9]. It has also been documented that populations of African descent in the United Kingdom and the USA, have significantly higher rates of diabetes-related complications when compared to Caucasian populations. Clinical impressions imply that such complications exist in the Caribbean as well, but the data is limited [9]. In Caribbean health systems, up to 15% of diabetics will have a limb amputated, which significantly affects a patient's quality of life [9]. This is due to limited access to prosthetic devices, little to no rehabilitation services, and the high economic costs in the health care systems.

We examined existing mobile health technologies to identify deployment and usage gaps to inform our development of a new health management tool. The different technologies explored spanned several areas including persuasive techniques [3], dietary evaluation [4], education through interaction [5], and motivation to participate in physical activity [6].

After completing our evaluation, we identified the necessary research question: "With the high and increasing number of diabetics diagnosed in the Caribbean, and the negative effects the disease has on the African-origin population; can mobile technology influence regimen compliance of diabetics in this population?"

In determining the answer to this question we designed and implemented a mobile health management tool to influence persons into changing their daily unhealthy behaviours. Our results showed that people, who engaged in healthy behaviours, used the application regularly and even modified some of their other unhealthy behaviours. However, people with unhealthy behaviours tended not to use the application regularly and showed no signs of improvement. To discuss the motivation for and the findings of the research, the paper is presented as follows: In section two we give an overview of previous work that helped to direct our development of an initial solution pertinent to the society under study. In section three the characteristics of this particular population relevant to the development of an m-health solution are given. In section four we describe the mobile health management application created and used in our study. Section five discusses the information collected by the application and the conclusions from these findings. Finally, in sections six and seven, the major contributions of this work and expected future directions are presented.

II. RELATED WORK

A. Persuasive Technologies

Kaptein et al. discuss the use of tailored persuasive text messages to curb snacking habits [3]. Snacking is an important part of a diabetic's daily activities (used to control blood sugar levels). Correcting these snacking habits is quite important. The researchers created a questionnaire to measure to what degree individuals are susceptible to different social influence strategies and the results were used to profile each person in the study.

Kaptein et al. follow the general template for creating mobile health applications. In their work, persuasive text messages were implemented using social influence strategies. These are basic rules which consider how persons from disparate background respond to different types of communication. The text messages take three forms; *topic messages*, *questions* and *tips*. A *topic message* is fundamentally important information that the user should be made aware of. *Questions*, however, require a response to gauge the person's comprehension of the information given to them in the topic messages. *Tips* provide information which is not readily available that the user may deem useful. This work concluded that persuasive text-messages can be very effective in changing a specific behaviour in a person and even their attitude [3]. However, the success of such a change depends on if the right influence approach (providing information from an expert in an area, whose opinion is respected) was chosen given the different circumstances of each participant. This research is limited because it seeks only to change one type of behaviour (snacking). Although important, it does not cover enough to critically affect someone with diabetes or a non-communicable disease. However, the profiling of the users done in this study can be useful when trying to tailor a solution to every individual using it.

Another implementation of a persuasive system is *Playful Bottle* created by Chiu et al. to motivate healthy water intake [5]. Water intake is one of the fundamental components of healthy living, and Playful Bottle addresses this. The system was designed to be implemented on a mobile phone which would then be attached to a drinking mug or water bottle. The camera and accelerometer sensors in the mobile phone are used to create a vision or motion-based water intake tracker to detect the quantity and regularity of water consumed by the user. In addition to the tracker, the mobile application implemented a series of games focused around the use of drinking actions as inputs to further motivate the user into healthy water drinking habits. The only drawback to the research is the need for the mobile phone to be connected to the water bottle at all times. The constant connection between the two items could prove impractical for someone who for instance, does not work in an office sitting behind a desk all day. The premise however, could be useful in monitoring a person's behaviours once the monitoring device does not have to be permanently tethered to the monitored item or person.

B. Personal Mobile Health Systems

The *SapoFitness* application created by Silva et al. takes a different approach to addressing healthy exercise regimes

among users [4]. The user is required to keep a daily record of food intake and exercise, which is evaluated and personalises *SapoFitness* to the user's specific lifestyle. According to Silva et al. "*SapoFitness* includes the ability to share personal achievements with social networks, a very intuitive human-device interaction and control weight, applying not only to control obesity but also to malnutrition problems." The application also utilises an alert system which sends messages to the user concerning his/her dieting program and takes into account the user's physical activity as well. The application actively involves the user in controlling their health choices thereby motivating for a healthier lifestyle. *SapoFitness* was originally designed for the Android operating system but the developers intend on extending the functionality to iOS and Blackberry as well since the market is not limited to a single operating system. The benefits of making the application available across all platforms are undeniable. The novelty in this technology is in the use of social networks to aid the motivation of the users as they reach milestones in their journey to health lifestyles.

C. Health Data Management

The work done by Al-Taei et al. takes a different approach to the management of chronic diseases by focusing on health data [8]. The system aims at improving chronic disease management using low cost mobile phones. It uses Bluetooth to transfer health data from a mobile device to an intermediary device and then eventually transmitted to a remote server. The proposed system is comprised of a data acquisition module (DAM), a mobile phone and a health data server. The DAM measures the patient's data by means of a number of sensors and sends that data to the mobile device via Bluetooth. Once the readings reach the mobile phone, they are sent over an IP network (like the Internet) to a remote health data centre. The health care professionals can then view the readings and react appropriately. The system provides 24/7 monitoring of the patients which, as the authors suggest, could replace the need for face-to-face meetings between doctors and patients. This allows for patients to receive the care they need from the comfort of their homes. Unlike most of the research explored, this solution can be implemented without the users needing to own a smart phone. Most of the persons suffering from chronic diseases are generally older persons who may find smart phones complicated and this research gives an alternative to the use of expensive smart phones.

The research shows that many mobile health applications have been developed for the health industry. These applications provided a wide variety of features and functionalities which would directly benefit persons with varying diseases. The applications however, are for the general population and are not adapted for diabetes compliance in the African Diaspora with its specific characteristics. Due to the significance of the issues from diabetes in this population [2], this particular focus is necessary. We have noted work that discusses the possibility and appropriateness of using such applications in developing countries [13]. However, the actual applications of the technology have been solely a program in India that investigated the usefulness of short message services (SMS) to improve compliance with the use of medication by diabetic patients in India [14]. Shetty et al. focussed on long-term Type 2 diabetic

patients and messages on principles of diabetes management were sent to them once every three days. Message frequency and content were chosen based on the patient. Here blood sugar and lipid levels improved for users of the SMS application. There is knowledge to be gained here in terms of methodology, but as identified in [14], the specifics of the populations needs must be incorporated for success. For example, the type of mobile technology must cater to the populations' savviness and cell use.

III. HYPOTHESIS

Based on our research question, we propose the following hypothesis: "An application which provides tips on how to better manage diabetes and offer mobile consultations on daily activities can improve regimen compliance of diabetics in the population of a Caribbean country."

We surveyed a subset population at the University of the West Indies Cave Hill Campus, which is predominately of African-descent. We will describe this population in section IV.

IV. INVESTIGATION INTO THE POPULATION

We did an initial convenience sample of 45 participants at the University of the West Indies Cave Hill Campus in Barbados from the staff and student population to determine their willingness to use technology and more specifically mobile devices to manage diabetes and other non-communicable diseases. The participants were chosen randomly based on a request made to the campus through the Office of Public Information (OPI) and the volunteers that responded. We chose this particular environment because of the diversity in ages as well as the representation from the population of interest in the African diaspora from the Caribbean countries [11].

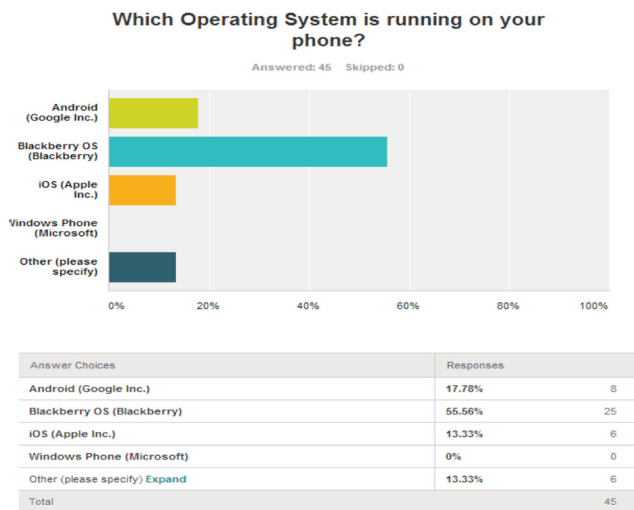


Fig. 1. Chart showing Mobile Operating System usage among participants

A. Survey

In order to evaluate the relevance of the applications and of the application's features which were intended to directly benefit users with health problems, a questionnaire was designed to determine what current technologies are common among the target audience. The questionnaire also sought to identify the audience's stance on using a mobile health application and how

willing they would be to reveal personal information for use in the application. Dependent upon the responses returned from the questionnaires, the features and technologies to be implemented would be included in the design of the mobile application.

The application consisted of ten questions aimed at determining the direction development would take. Each question helped to understand the demographic which the application would seek to influence. Questions asked about age, mobile device, operating system running on users' mobile devices, as well confidence level in using mobile device. This information helped us to understand the type of application to be built. The questionnaires were distributed to the entire university population via the OPI of the university. It was an anonymous online survey (unless the respondent indicated they wished to participate further in the study, in that case their email address was recorded for future correspondence).

B. Survey Findings

The results (Figure 1) show there was gravitation towards Blackberry devices among the sample, with Android and iOS not far behind. Thirteen per cent (13%) of persons also selected the "Other" option and they identified Symbian and Nokia as the other operating systems they were running on their mobile phones. These responses indicated that the majority of the persons in this sample would be able to run an application built with relatively new technologies. Seven per cent (7%) of persons said they did not use an Internet connection (Neither data plan or Wi-Fi). The rest of persons used either a Data Plan or they utilised a Wi-Fi connection. Majority of the persons indicated however, that they use both.

This is a good indication, as it allows for the information provided in the application to be dynamic and easily updated or changed. Another important aspect of the respondents' answers showed how comfortable they were with operating their device. This was important to this research because dependent on their answers, the application's complexity would have to be increased or decreased. The majority of persons found that they were "Very Comfortable" or "Comfortable" using their mobile device (showing technical savviness), with only thirteen per cent (13%) of persons indicating that they were of average comfort. No one said they were "Uncomfortable", implying that mobile devices could be used for the purposes of the study.

Ninety per cent (90%) of the persons indicated they would be open to using a mobile application to help manage their disease. When asked about their willingness to provide an application with private information, Seventy per cent (70%) were willing. Even though a large percentage of the respondents would willingly provide personal information to the application so that the application could help them, 30% of the persons rejected that notion. This indicates that even though there is significant possible gain to be had from using the application, because personal information is requested, some persons might shy away from the application.

V. THE MOBILE HEALTH CONSULTATION APPLICATION

A. Development

Based on the extensive background research done and the responses received from the questionnaires, a Mobile Health

Consultation Application (MHCA) was designed and developed with the sole aim of influencing the health behaviours and decisions of its users.

Although there was a fifty-six per cent (56%) inclination in favour of Blackberry devices, there were persons who used Apple, Android, Symbian and Nokia devices. It was therefore decided that designing a cross-platform application was the best; course of action in order to accommodate all users across all the devices.

The application was created using HTML5, CSS, AJAX, PHP and using the JQuery framework. These languages were chosen because they were already known and would allow for a rapid development period. The JQuery framework offered useful animations and would allow them to show on all platforms, which also decreased development time.

The information provided in this application is stored in a MySQL database located on the same server where the application resides. The information entered by the user into the application is also stored in the aforementioned database. In this initial study, the MHCA is not accessible to users if they do not have access to an Internet connection, if there is a power outage or if the server is out of order. The functionalities and features of the application were developed based on common features and functionalities found in applications covered in the background research and from the responses to the questionnaire.

Although the application was developed as cross-platform, it performs best on fully touch screen devices like the iPhone, iPod Touch, Tablets etc. The application still works on devices that aren't fully touch screen (hybrids) or devices that are not touch screen at all. The device being used to access it directly affects performance of the application. The prototype was developed using an Apple iPhone 5 and a Blackberry 8520 as the test devices. The iPhone 5 was the most recent mobile device to be released from Apple's cutting edge assembly line, while the Blackberry 8520 has been on the market for at least 5 years. The diversity between the two operating systems (OS) provides a range of testing conditions, since these two technologies were the most used OS.

The respondents from the survey who indicated they were interested in participating further in the study were given the opportunity to test the application. Eleven persons signed up and used the application throughout the two week testing period. The participating respondents were sent an email containing a link to the application, which they had to access via their browser. The link pointed to a server located on site at the University of the West Indies Cave Hill Campus in Barbados where the application was hosted.

B. Architecture of the Mobile Application

- The first component of the health management application is the mobile device. The mobile device can be any current smart phone on the market, as long as the device has an Internet browser and is capable of accessing the Internet.
- The web application is a mobile website created using HTML5, Java Script, and JQuery. The web application

is designed to replicate the feel (speed of processing and responsiveness) of a native application even though it is accessed through the browser.

- A MySQL database holds all confidential user data as well as all the information given to the user by the MHCA. The database also stores the information on how the user uses the application.
- The server is where the web application and the database reside. The mobile device and the server interact allowing the MHCA to function.

C. Features of the MHCA

- Create an Account – The “create an account” feature allows the user to register and create a digital record for themselves or someone they care for. The account contains the user's personal information and stores information about them that the application has collected and evaluated.

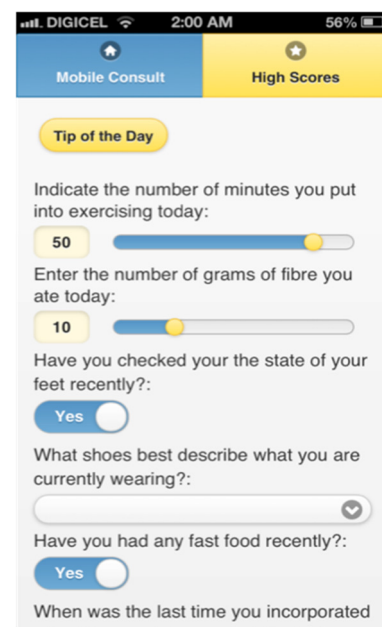


Fig. 2. Mobile consult page in the application

- Mobile Consult – The mobile consult (Figure 2) is the feature which drives the entire application. It consists of questions the user must answer about their daily activities based on the guidelines of the American Diabetes Association [12]. The user is only allowed to take one consult per day, that consult is evaluated and they are awarded points which go towards identifying how well the user is complying with the proper management of their disease (e.g. Users are asked to enter their fibre intake and information on taking this measurement is provided in a popup help window).
- Leader-board – The Leader-board feature is the area where the user goes to check his/her scores from the consults. The Leader-board also displays the top five persons with the highest scores using the application.

- Tip of the Day – The tip of the day feature provides the user with an important bit of information everyday which could be useful in managing their disease.

For example, the use of sensors was a prominent feature in most of the applications found in the research. However, most of the respondents to the questionnaire indicated that they used the Blackberry Smartphone. The use of Blackberry Smartphones may be influenced by cell phone plans in the geographic location. Notably, most Blackberry models do not have built in sensors and the use of sensors in this application would have required possibly outfitting users with sensors (potentially adding a high cost to the users' outlay for the technology and hence limiting). These facts must be considered for future research.

VI. THE HYPOTHESIS AND ASSOCIATED RESULTS

The findings of our study do not reflect our expected outcome as identified in the hypothesis above. The findings have not shown an improvement in regimen compliance for *all* persons in the population, and this is specifically so for those who are generally noncompliant even without a mobile application. This may seem obvious, however we found that persons who are already compliant could be influenced to maintain and possibly improve their regimen. Specifically, persons who are living healthily and complying with the positive behaviours for someone with diabetes used the application frequently. However, persons who had low compliance had low rates of MHCA use. There are several possible reasons for this and correlation analysis is necessary in future studies ensure that we analyse the behaviour of those who are specifically noncompliant.

The evaluation of the MHCA was done by evaluating the information collected by the application over the two-week testing process and from the feedback provided by the users who put forward their suggestions and comments.

There were sixteen persons from the questionnaire who indicated they wished to participate further in the study. However, of those sixteen, only eleven persons actually signed up and used the application. There was one person who indicated they wanted to participate in the study but did not sign up, citing the reason that they did not believe the application was taking enough information to be useful to her. This is of note for future research, however, the number of questions asked and the usability of the MHCAS must be balanced.

We analysed the data collected from the application throughout the two-week study and acknowledged that, based on the number of respondents, we are presented with a small data set, from which we are unable to generalise. That is, there were eleven persons testing and using the MHCA. The results of this case study cannot be said to be fully representative of diabetes patients' behaviours in the population. However, there are few studies in information technology for healthcare in the populations of the Caribbean [9]. Further, the use of information technology and mobile technologies is also sparse in the given context. Hence the knowledge gained in this work is a step in the right direction given the use of such healthcare enablers in more developed countries.

In addition there was a positive implication that the MHCA can influence behaviour in this population, but only for those who already have a tendency to comply. This is borne out in the following findings.

Various trends were identified while analysing the data accumulated by the application. Twenty-seven per cent (27%) of the total persons testing the application, signed up at the beginning of the trial period. Those persons were the most active among all the users, typically using the application every day and according to their answers, and were the ones best managing their disease. In contrast, those persons who signed up halfway through the trial or close to the end did not use the application as much. These persons would interact with the MHCA once every couple of days and some persons created an account and did not complete even one mobile consult.

Another trend noticed was that the persons who interacted most frequently with the application were between the ages of twenty-one and thirty. In the case of the persons who used the application less frequently, only one person was below the age of thirty (30). The days of the week most common for infrequent users' interactions with the application were on Fridays and Saturdays. The frequency and way the users interacted with the application were not the only aspects of the analysis performed on their usage. Their answers to the questions in the mobile consults were also evaluated to assess their behaviours.

Sixty-six per cent (66%) of the persons who took the mobile consults claimed they had exercised on the days which they used the application. The other three indicated that they had not exercised. It is also quite encouraging that almost all of the persons who had taken the mobile consult checked their feet on a regular basis. Only one person indicated that they had not checked their feet.

The user's diet was the next part of their daily activities to be evaluated. When prompted with the question about consuming 25 grams of fibre, one hundred per cent (100%) of the persons who answered the question said they had not consumed that amount of fibre. The use of mayonnaise was another one the questions posed in the mobile consult. Contrary to the dietary guidelines for diabetics, 80% of the persons responded that they do still use mayonnaise in their daily meals, with only twenty per cent (20%) saying they do not. The most frequent type of beverage chosen by the user was also asked, with the options being: water, juice, soft drinks and tea. The most common choices were juice and water. Soft drinks and tea had one person each consuming them frequently. It is noted juices are normally very high in sugar which could cause blood sugar spikes and was not a very good trait to discover from the responses.

Healthy snacking habits are very important to a diabetic and a question about those habits was included in the consult. Alarmingly, the majority of persons who answered the question stated they never incorporated healthy snacks into their daily diet, with one person saying occasionally they would. A large number of persons also indicated that they had consumed food from a fast food restaurant recently. This indicates that the daily eating habits of these persons were not in line with how a diabetic person should be eating.

As was stated earlier, only three persons of the eleven actually used the application frequently and had healthy behaviours, according to their answers to the consults. The other participants did not use the application frequently and according to their answers, did not have healthy daily regimes. This result was different to results found in the background research. The applications found in the background research had success, having numerous participants and also very high participation rates and gradual change of “incorrect behaviour” over time. It lends to a future correlation of incidences of the negative impacts of diabetes in the populations studied for the background research, versus the prevalent negative impacts seen in the Caribbean studies. There may be population specific (and likely cultural) attitudes that lead to conformance.

Through analysis, we see a number of possible reasons for the differences in results. For example, the Adaptive Persuasive System that used tailored text messages to try to curb the snacking habits of users; was supported by doctors. The doctors forwarded the application to their patients. Their scope was not only vast but the participants were under instruction from their physician to use the application. The Move2Play application was supported by a local diabetes association and also had a large scope. These are all possible reasons for the differences in the results obtained in this study compared to the results in the background research. The reasons will influence future approaches in deploying our solutions. For example, we will engage the users via physician’s recommendation.

VII. CONTRIBUTIONS

Diabetes is a threat to human life and more so to members of the African diaspora. Recent studies have suggested that the implementation of various mobile health technologies could help combat diabetes and other non-communicable diseases. However, these studies have generalised the situation among several ethnic groups, when studies show that African-origin populations have a far higher rate of contraction and are much more likely to develop related complications [2][9]. Despite these facts, the use of technology to specifically manage the behaviours of individuals in the African-origin populations has been low. As a result, we have quantified important trends for the African Diaspora in the Caribbean and identified possible means of further engaging the populations to effectively use the targeted technology. The findings of our study do not reflect our expected outcome as identified in the hypothesis section above. Persons who are living healthily and complying with the positive behaviours for someone with diabetes used the application frequently. Persons with low compliance had low rates of MHCA use.

VIII. FUTURE DEVELOPMENTS

Participation in the study and getting the volunteers to use the application daily was one of the major limitations of the study. Collaborating with a healthcare professional (e.g. a doctor) is known to boost participation and usage levels. A healthcare professional has access to patients and even commands their trust and respect, which is needed to get persons using the application. The next step therefore is collaboration with healthcare professionals and/or diabetes organisations. We are aware that study was short, and usability needs to be studied. The length of the study was guided by the fact that it was done

at the end of the semester which may also explain the decline in participation. We will continue the study for a longer period in the general population and with a control group with people in another region with more diverse ethnic backgrounds.

According to the World Health Organisation, there is evidence to support that diabetes cases and their related complications can be averted by having a healthy diet, engaging in regular physical activity, maintaining a normal body weight and abstaining from the use of tobacco. Although the public knows these facts, diabetes persists in many populations. Therefore, it can be noted that just the availability of this knowledge, is not enough to change behaviours of the general public. Another improvement on this research is to implement a motivation model or theory into the technology to influence behaviour such as the Health Belief Model [10].

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