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https://dx.doi.org/10.1109/CBMS.2017.164

PhytoCloud: A gamified Mobile Web Application to modulate diet and physical activity of women with breast cancer

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***Abstract*— Breast cancer incidence and mortality rates vary geographically reflecting factors including regional and cultural differences in diet and lifestyle. There are numerous successful commercial mobile apps to help people control their diet and manage weight. However, such products are not suitable for people with special medical conditions that may require targeted dietary as well as motivational support. The paper presents a user centered approach of developing a Mobile Web App that focuses on breast cancer patients looking at their specific dietary, physical and mental requirements depending on the stage of their medical treatment. The paper explores the effect of incorporating gamification and social media as motivational drive to engage and motivate people to achieve their goals of adopting healthier eating habits while increasing physical activity in order ensure lasting lifestyle behavioural change. The design of "PhytoCloud" is being described, a gamified Mobile Web App that enables users to record their dietary habits and physical activity and motivate their consumption of food with oestrogen-like properties (phytoestrogens) which are linked to the prevention of reappearance of breast cancer. The paper concludes with a discussion of future directions and adaptations to the current design to suite a Mobile Native Application design.**

Keywords—Diet Mobile Web App; gamification; breast cancer; phytoestrogens; lifestyle behavioural change.

I. INTRODUCTION

Breast cancer is a complex disease with diverse risk factors and many influences that may alter the individual's outcome after treatment. However, despite the complexity of the disease, observational and epidemiological studies with tens of thousands of individuals have shown the importance of environment in the development and progression of breast, colorectal and other cancers [1]. The adoption of a healthy lifestyle, making wise nutritional choices and undertaking physical activity have all been shown to improve quality of life and to reduce the risk of developing breast cancer, as well as minimising the risk of relapse[2][3][4].

The Cancer Research Group at the University of Westminster has extensive experience in the study of both breast cancer and patient behaviour. It undertakes pioneering research into the detection, treatment and prevention of solid and blood borne cancers and studies are undertaken at the genetic and epigenetic, transcriptomic and proteomic levels. DietCompLyf [3], an ongoing study where members of the Cancer Research Group at the University of Westminster undertook principle role as research investigation, was set up to see if diet, complementary therapies and lifestyle factors have an effect on breast cancer survival. Data from 3,159 patients from 56 UK-based hospitals have being studied in terms of their diet and lifestyle and their long term outcomes [5]. The DietCompLyf study has shown that approximately half of all patients with breast cancer make a dietary or lifestyle change within 12 ±3 months following diagnosis [6]. At recruitment 92.2% of patients on the DietCompLyf study completed the 130-item food frequency questionnaire and similarly 94.7% of patients completed the lifestyle questionnaire, highlighting the highly motivated nature of this group of individuals [5]. The completion of the lifestyle questionnaire is based on recording data of patients in monthly basis. One of the major challenges for Healthcare Professionals is accurately monitor patient diet and physical activity in daily basis to verify precision of those results.

Our own studies have shown that around half of all patients with breast cancer make dietary changes in the first year following a breast cancer diagnosis. However, another issue faced by the Healthcare Professional is to support women with breast cancer to make and sustain healthy lifestyle choices at a time when they receive difficult diagnoses and undergo aggressive treatments, severely impacting on quality of life. Whilst many factors are important when predicting the risk of breast cancer or the outcomes after treatment, there is also recognition that many people seek to do something for themselves. Patients diagnosed with breast cancer often report that they feel a lack of control over their own recovery and they sometimes express a desire to take a proactive role, for example by examining their own behaviour in terms of their dietary patterns or their lifestyle choices. Patients have also expressed that during or after receiving treatment they are provided with a list of food they should consume, but many times they fail to incorporate those into meals that suit them and their family plan. As a response to this request the Cancer Research Group at the University of Westminster created a recipes book specifically tailored to help combat breast cancer [7]

1063-7125/17 $31.00 © 2017 IEEE
DOI 10.1109/CBMS.2017.164

The m-health ecosystem provides great potential for the delivery of health behaviour interventions that could benefit breast cancer patients. This could be by encouraging them to adapt and maintain positive behavioural changes for a sustained period of time. Our motivation for the research reported in this paper is to develop mobile technology that supports patients and individuals who are concerned about breast cancer to make dietary and lifestyle choices based on the most up to date scientific findings.

II. RESEARCH BACKGROUND

A. Mobile applications to for diet control and exerciset

Thousands of applications have been developed to allow individuals to record and monitor their diet, often for the purposes of controlling calorific intake (e.g. MyFitnessPal, My Meal Mate, FoodSwitch, Change4Life - Sugar) and to assist individuals to achieve weight loss. However, there is little evidence of which precise factors contribute to user motivation and self-efficacy [8]. Understanding these factors can help mobile user experience designers understand how best to transfer the benefits of fitness tracking engagement to other consumer m-health applications.

Mobile phone technology is currently being assessed in a clinical setting to assess its ability to deliver tailored physical activity interventions to promote healthy lifestyle behaviours and improve quality of life, for example the International Centre For Sport Security (ICSS) "Directed Physical Activity Enhancement for Colon Cancer Survivors" trial www.clinicaltrial.gov. The widespread use of mobile phone technology means that this is an ideal platform for the confidential monitoring and modulation of patient behaviour [9][10]. In addition, serious games and social media are emerging genres which combine behavioural change interventions with entertainment to provide an engaging medium which can produce beneficial health behaviour changes [11].

B. Gamification for diet control and exercise

Gamification in healthcare applications has been an area of increased interest in recent years due to the potential for assisting users/patients to develop personalised lifestyle plans, connecting and competing with others, tracking progress towards goals, and earning rewards with the objective of adopting a healthier lifestyle [4][12]. Thus, research in this area is expected to have great impact to both society and business.

C. Aims and objectives and research questions

We have identified the use of mobile technology and gamification to monitor diet and motivate individuals maintain favourable dietary and exercise patterns as weight gain post diagnosis is recognised as poor prognostic indicator [6][13]. This project is targeting to further our understanding of breast cancer patients' dietary behaviour and will provide insight into how gamification can be incorporated in Mobile Web App design with the aim of ensuring sustained use of this technology to achieve the desirable results of the adaptation of a healthier life style.

The key research questions addressed in this project will be how mobile technology can be used to:

- accurately monitor diet and physical activity;
- motivate individuals to make positive health choices with the use of gamification and social media;
- help maintain positive behavioural changes for sustained period of time.

Below we present the development of a prototype Mobile Web App that aims to address the issues stated above.

III. PHYTOCLOUD

A. PhytoCloud Purpose

PhytoCloud is a prototype Mobile Web App, which has been developed to enable:

- monitoring and recording diet and physical activity in daily basis;
- suggesting, creating and recording recipes that comply to the users goals;
- incorporating social media and gamified elements to motivate the use of the application for a sustained period of time which can have an effect in positive behavioural change and the adaptation of a healthier lifestyle.

PhytoCloud is an on-line tool kit that allows women use technology to check their own diets and lifestyle and aims to help them, where appropriate, make sustained changes fitting with their own dietary and lifestyle preferences, in keeping with the best available advice and using Government Guidelines, informed by the scientific literature. PhytoCloud incorporates a dietary intervention (based on the consumption of food with plant hormone like chemicals, phytoestrogens) and takes into account existing dietary preferences. It includes a motivational toolkit that provides recommendations based on the analysis of user dietary input and capturing data on physical activity and supplement usage.

PhytoCloud is not intended to give medical advice, it is used to provide information that may enable women with breast cancer to better understand their diet and fitness levels based on information entered into the web-app. PhytoCloud is not intended to take the place of nutritional advice from a qualified dietician, or exercise guidance from physiotherapists. It is not intended to take the place of advice from a clinical team. PhytoCloud urges its users to consult with a qualified physician for answers to their personal and medical questions and to consult a qualified dietician if they have any concerns about their diet. PhytoCloud provides a tool to allow its users to record their own dietary and lifestyle information and compare those values to the relevant normative ranges.

B. PhytoCloud requirments

Focus groups with a multi-disciplinary team at the University of Westminster consisting of: biomedical scientists; dietitians; sport and exercise scientists; and computer scientists looked at ways of developing technology to assist current practices to support women with breast cancer to module their diet and lifestyle. This practice derived a list of requirements for the development of PhytoCloud as a Mobile Web App to serve this purpose. These requirements are divided to two sets of: functional and non-functional requirements. The functional requirements (FR) map the functional capability of the system and have been classified as requirements for: user

account; user profile; diary module; diet plan module; recipes module; exercise module; social media; and goals module.

The non-functional requirements highlight the platform technology and infrastructure in which the system will function. They split to requirements for: interface; hardware and software; communication interfaces; data conversion and security and privacy.

1) Functional Requirements[User Account]

FR1. Users shall be able to login using a pre-generated user ID and password.

FR2. Users shall be able to edit/modify/update their profile.

FR3. Users shall be able to provide personal information like gender, age, weight and height.

FR4. Users shall be able to request closing down of their profile/account and sign out from it.

2) Functional Requirements[User Profile]

FR5. Users shall be able to complete the DietCompLyf [5] food frequency questionnaire to create a health profile of their dietary habits.

FR6. Users shall be able to specify their medical condition.

FR7. System should provide personalized recommendations of diet and exercise based on user profile and goals.

3) Functional Requirements [Diary Module]

FR8. User shall be able to add their food intake per day.

FR9. User shall be able to search through existing database for known category of foods.

FR10. System should provide the means to offer a calendar based Diary for added food intake.

FR11. User shall be able to remove food intake records.

FR12. User shall be able to update added foods quantity.

FR13. User shall be able to view their diet historical records.

FR14. System should provide metric data presentation of foods intake such as calories, fat, carbohydrate and phytoestrogen.

FR15. User shall be able to add their fruits/vegetables and water intakes separately per day.

FR16. User shall be able to view food recipes. Recipes are provided as set of pre-selected data.

4) Functional Requirements [Diet Plan Module]

FR17. User shall be able to search through existing recipes database.

FR18. System shall present food and recipes based on their personal profile.

FR19. Users shall be able to add their diet from existing list.

FR20. Users shall be able to edit or remove food from their diet routines.

FR21. Users shall be able to enable or disable diet routine tracking in their profile.

5) Functional Requirements [Recipes Module]

FR22. Users shall be able to create and recipes.

FR23. User shall be able to search through existing recipes database.

FR24. System should provide metric data presentation of foods intake such as calories, fat, carbohydrate and phytoestrogen per recipe.

FR25. Users shall be able to edit and remove recipes.

6) Functional Requirements [Exercise Plan Module]

FR26. User shall be able to search through existing exercise database.

FR27. Users shall be able to add their exercise routines from existing list.

FR28. Users shall be able to edit and remove their added exercise routines.

FR29. Users shall be able to enable or disable exercise routine tracking in their profile.

7) Functional Requirements [Social Media]

FR30. User shall be able to search through a list of members with similar profile.

FR31. Users are able to share their profile and interests.

FR32. Users shall be able to share their recipes within their network.

FR33. Users shall be able to share their diet routine within their network.

FR34. Users shall be able to share their exercise routine within their network.

FR35. Users shall be able to rate recipes, diet routine, exercise routine of members within their network.

FR36. System should provide leaderboards of higher rated recipes and diet routines.

FR37. System should provide random tips for healthy habits.

8) Functional Requirements [Goals Module]

FR38. Users should be able to set their goals.

FR39. System shall be able to track user diet and exercise entries to provide insight on user goals achievements.

FR40. System should provide metric data presentation for user goals achievements.

FR41. System should allow users to share their goals achievements.

9) Interface Requirements (IR)

IR1. Angular.js shall be used to implement the user interface. Express.js is used for rapid back-end development.

IR2. Front-end/user interface must be rendered on multi-platforms such as desktop and mobile phones.

IR3. System interface must be supported by mainstream browser such as Chrome, IE and Safari.

10) Hardware Interfaces

The back-end (API), which is an MVC structured RESTful JSON API built with ExpressJS. The database driver is MongooseJS and it makes https requests to

connect to the Nutritics API (where applicable)[14]. Permissions are implemented as group policies with three groups setup as of now (admin, user and guest).

11) Communications Interfaces (CI)

CI1. The system shall be able to connect to Nutritics database [14] for additional food search capabilities. The Nutritics provides additional data about food types.

Nutritics [14] is cloud-based software that enables the analysis of food diaries for over 258 nutrients using an extensive food database of over 125,000 foods. It can be accessed from any Windows, Mac or Linux computer with an internet connection.

12) Data Conversion Requirements (DCR)

DCR1. System should provide connection to an extended version of the legacy data source known as McCance and Widdowson data source [15] that includes data analysis on phytoestrogens.

McCance and Widdowson's Chemical Composition of Foods integrated dataset on the nutrient content of the UK food supply. This offers a detailed set of information on the nutritionally important components of foods and provides values for energy and nutrients including protein, carbohydrates, fat, vitamins and minerals and for other important food components such as fiber.

13) Software Requirements (SR)

SR1. System will be implemented using the following technologies for rapid and agile development process: Node.js (v6.2.2) & npm; MongoDB (v3.2); Grunt; Bower.

14) Security and Privacy (SPR)

SPR1. System should encrypt data files and associated account details.

SPR2. Data must be stored in a secure location and in compliance with the requirements of Data protection act.

The requirements were discussed between a multi-disciplinary team and then catalogued and implemented accordingly as presented above. In addition to its data analysis capabilities, the system includes gamification features to better engage users. Below we discuss the system architecture.

C. PhytoCloud system architecture

Diagram 1, depicts the PhytoCloud system architecture. The back-end (API) is an MVC structured RESTful JSON API built with ExpressJS. The database driver is MongooseJS and it makes https requests to connect to the Nutritics API (where applicable). Permissions are implemented as group policies with three groups setup as of now (admin, user and guest).

The front-end is built as a templated HTML website that communicates with the API via Ajax calls. It is MVCS structured, with services mainly acting as configuration interfaces and HTTP connectivity gateways (all the calls to the back-end is being achieved via services). Controllers are used for bootstrapping services to the views, and the main logic is all implemented as part of the services. Models are Angular factories that provide object constructors (and crud methods) and are part of the Service layer too. Views are plain html templates with little or no logic at all (other than basic looping and conditional inclusions).

D. PhytoCloud design

The modular approach that has been employed for the development of PhytoCloud provides facilities to separate code and package reusable modules and it allows the development of parts of the application independently and connect them once required. This section presents the PhytoCloud design that addresses the above stated requirements.

1) User Account

User data shall not be shared nor identifiable while used in written report or publications. Therefore, the system is designed and implemented under the assumption that the data entry into the application will be made anonymously and that this will not impact the functionality of the system. To serve anonymity the application allows users to login using a pre-generated user ID and password which is known only to the user and the research team. In this way only the research team can identify individuals and follow up data related to them that can aid cancer research. However, for best utilization of the application and use of social network, such personal data is necessary. For example, recommendation of seasonal, local food and connecting people with similar medical conditions living in close proximity.

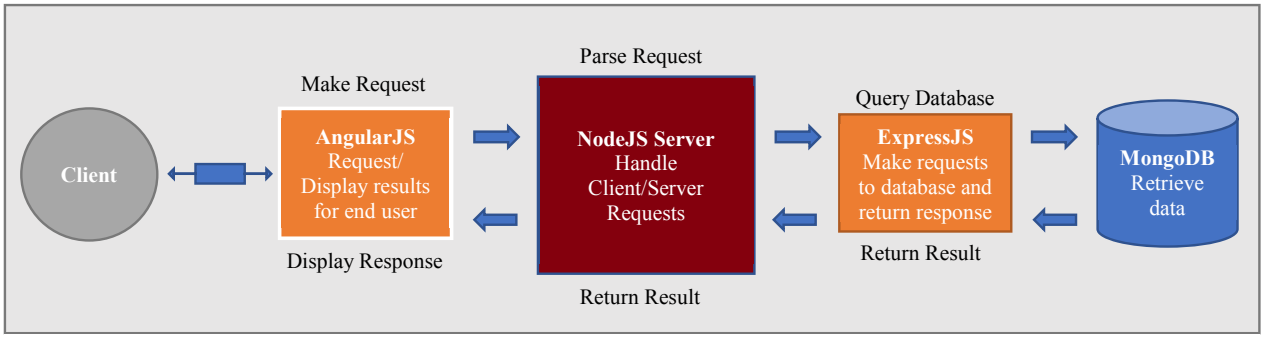

Diagram 1 PhytoCloud system architecture

2) User Profile

Users are able to edit and update their profile to allow personalized assistance of the application. Personal information which is required is gender, age, weight and height based on the users BMI is calculated. Users are also asked to enter information about their medical condition based on which the goals, food and exercise plan are adapted.

Users complete the DietCompLyf food frequency questionnaire that consists of 120 questions that helps in building accurate health profile of individuals' dietary habits based on which PhytoCloud provides customized food and recipes recommendations. Filling such a long questionnaire using a Mobile Web App is off-putting for users, thus the application has been designed to allow progressive completion of the questionnaire. The completion of each category of this questionnaire is followed by a video that provides advice about the effect of the consumption of the specific category of food. Users are rewarded based on the completion level of this questionnaire. In addition, a set of videos is included that provides information related to portions of food.

3) Diary Module

The Diary Module allows users to add their food intake per day separated in main meals breakfast, lunch, dinner and snack. Users are able to search through an existing database of foods. To assist better search results the application allows users to search food per category. The food categories comply with the DietCompLyf questionnaire and the Nutritics food categories. To accelerate data entry users can add frequently selected food in favourites. In addition, the app keeps recently selected food. An outline of food entry is included in a widget organized per meal. Information presented per food entry includes food title and calories per 100gr. The users can edit food quantity, favourite or delete each food entry.

The Diary Module presents also the consumption of five-a-day fruits and vegetables based on UK Government recommendations and 1250ml of water. The user is able to add and remove those items. This information is additional to the selected food that may contain fruits and vegetables or liquid. The Diary Module shows also daily exercise, that cannot be entered or edited in this mode, but it can be deleted.

The Diary Module includes also a graph that displays at a glance the user goals, the eaten calories and specifically the consumption of carbohydrates, fats and phytoestrogens and the consumed calories based on the exercise plan.

The Diary Module in includes also a widget that displays tips of the day targeting to motivate and positively encourage the users in adopting healthier life style.

The app displays automatically the current days Diary. However, the user is able to inspect and edit previous or next days' diaries.

4) Diet Plan Module

To accelerate data entry the application offers the Diet Plan Module that allows users to create a diet plan that they usually follow or that they want to follow to achieve their goals. This includes food entry per day organised in meals. The creation of a Diet Plan can be a tedious process. However, once a diet plan is created and enabled the user Diary Module is pre-populated with the data entered in the Diet Plan and the users only have to verify that they followed the plan, edit or delete an entry. In addition, a desktop device can be used to create a Diet Plan where the data entry is comparatively easier.

Users are able to share their Diet Plan within their network, which is another way that can aid acceleration of data entry.

5) Recipes Module

The Recipes Module allows users to create and save a recipe in a database which is then added to searchable food. To create a recipe the search module is used. Once a recipe is created the system provides metric data presentation of foods' intake such as calories, fat, carbohydrate and phytoestrogen per recipe. Recipes can be added to the diary, edited, deleted and shared within the users' social network.

6) Exercise Plan Module

The Exercise Plan Module is planned to support users to meet the NHS requirements for adults aged 19-64 [16]. The exercises that are recommended are organized in light intensity, moderate intensity and vigorous intensity activities. Users can select a weekly plan or create the exercise plan they want to follow and they can edit the duration of exercises. Activation of the Exercise Plan Module pre-populates the Diary Module with the selected plan and the users only have to verify that they have followed the plan, edit or delete an entry. Users are able to share their Exercise Plan Module within their network.

7) Social Media Module

The Social Media Module allows users to look for PhytoCloud members with similar profile and connect with them. Once members are connected they can share: their recipes, diet and exercise plans and information related to achieving their goals following that plan. The application allows the users to rate and comments on other members' recipes and/or plans. The application provides leaderboards of higher rated recipes and diet routines.

8) Goals Module

The Goals Module allows users to set goals which are:

- *be healthier*, eat and train for optimum health (eat within permitted level of calories, carbohydrates, fat, sugar and phytoestrogens, and exercise 150 minutes per week), eat 5 a day, drink 1250ml a day and reduce sugar and salt;
- *get fit*, specify a fitness plan suitable for a specified personal profile, age, weight, health;
- *module weight* (lose/gain) within acceptable ranges and period of time.

The app tracks user diet and exercise entries and the Goals Module presents an insight of user goals achievements. The app allows users to share their goals achievements and it presents a leaderboard to users achieving their goals.

IV. FUTURE WORK AND CONCLUSIONS

Currently the application is in the stage of functional testing to ensure that it conforms with all the requirements.

Once this stage is completed two sets of testing and evaluation needs to be conducted:

- to verify the validity of the collected data; and
- to gather user experience information related to the ease of use of the application, its effectiveness to record daily dietary and exercise routines and its success in motivating users to adhere with it for a long period of time.

Several user testing trials will be conducted with patients recruited from self-help breast cancer groups to further knowledge of the software development - driven by breast cancer patients' needs and requirements. This project paves the way for a larger scale dietary intervention study aimed at reducing breast cancer recurrence rates.

Data collected in this project will be subject to data protection act and will be treated anonymously. The research questions will be addressed by:

- collecting data for patients diet and physical activity in daily basis for 4 weeks using the proposed Mobile Web App, compare data accuracy with data collected with conventional methods currently used to monitor patients diet and physical activity and indicate the effect this could have in our understanding of breast cancer research;
- identifying specific gamified elements that could lead to increasing patients motivation to make positive behavioural change over sustained period of time by comparing a purpose build Mobile Web App with a widely used "off-the-self" mobile application (e.g. MyFitnessPal) to monitor diet and physical activity.

User testing will determine the further development of PhytoCloud. Features and further functionality will be related to accelerating data entry by scanning barcodes and recognizing packed food or food on a plate. Other functionality will be related to personalising care by making individuals healthstyle data available to clinicians and enabling them to contact patients and offer targeted advice. In addition, to effectively use of notifications to engage and motivate users we are focusing in the development of a native version of PhytoCloud.

ACKNOWLEDGMENT

PhytoCloud is being developed by a Steering Committee of academics and students at the University of Westminster. The project has been sponsored by the University of Westminster Strategic Development Fund 2015/16 and the generous donations from the University's Alumni.

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