Towards evidence based m-health application design in cancer patient healthy lifestyle interventions.

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Abstract— **Cancer is one of the most prevalent diseases in Europe and the world. Significant correlations between dietary habits and cancer incidence and mortality have been confirmed by the literature. Physical activity habits are also directly implicated in the incidence of cancer. Lifestyle behaviour change may be benefited by using mobile technology to deliver health behaviour interventions. M-Health offers a promising cost-efficient approach to deliver en-masse interventions. Smartphone apps with constructs such as gamification and personalized have shown potential for helping individuals lose weight and maintain healthy lifestyle habits. However, evidence-based content and theory-based strategies have not been incorporated by those apps systematically yet. The aim of the current work is to put the foundations for a methodologically rigorous exploration of wellness/health intervention literature/app landscape towards detailed design specifications for connected health m-apps. In this context, both the overall work plan is described as well as the details for the significant steps of application space and literature space review. Both strategies for research and initial outcomes of it are presented. The expected evidence based design process for patient centered health and wellness interventions is going to be the primary input in the implementation process of upcoming patient centered health/wellness m-health interventions.**

Keywords:m-health; cancer; health apps; application design; evidence centered design

I. INTRODUCTION

In Europe in 2012, 3.45 million new cases of cancer and 1.75 million deaths from cancer were estimated [1]. Breast cancer (464,000 cases), colorectal (447,000), prostate (417,000) and lung (410,000) were the most common types of cancer, representing half of the overall burden of cancer in Europe. Significant correlations between dietary habits and cancer incidence and mortality have been confirmed by ecological studies [2][3]. Physical activity habits are directly implicated in the incidence of cancer [4].

Eherman et al. 2013 reported cancers associated with excess weight and lack of sufficient physical activity. An increased risk of adenocarcinoma of esophagus, colon and rectal cancer, pancreas cancer, kidney cancer, and endometrial and postmenopausal breast cancer has been associated with excess weight [5], [6], [7], [8]. Also, there are evidences suggesting an association between an increased risk of gallbladder, liver, thyroid, and hematopoietic cancers and excess weight [5]. On the other hand, an increased risk of colon, endometrial, and breast cancers may be associated with lack of physical activity [5], [9], [10], [11], [12]

Andersson et al. [13] conducted a review of the current evidence related to excess body fat and cancer. The incident cancer burden attributable to excess body mass in 30 Europe countries was estimated by Renehan et al. [14] finding a risk of 3.2% in men and 8.6% in women. Evidences from prospective studies have confirmed associations between excess weight and thyroid, liver, leukaemia, malignant melanoma, multiple myeloma, and non- Hodgkin lymphoma [15], gastric cardia cancer [16], and advanced prostate cancer [17], [18].

Healthy lifestyle recommendations are not only suggested for cancer prevention but also for patients and survivors. Cancer prognosis and quality of life among cancer survivors may be negatively affected by excess weight and lack of physical activity. There are studies reporting excess weight is associated with poorer survival among patients with breast cancer [19], [20], [21] and colorectal cancer [22], [23], [24], [25]. Obesity is associated with mortality and incidence of late-stage disease but not with incidence of early-stage disease among prostate cancer patients [25]. Physical activity after diagnosis of breast or colon cancer may have reduced cancer-specific mortality. Physical activity and physical exercise interventions may reduce

disease and treatment-related symptoms of prostate cancer patients during and after treatments, improving their quality of life [26], [27], [28], [29], [30].

Co-morbid chronic diseases are common among cancer patients/survivors. Cancer and its treatment are associated with an increased risk for co-morbid conditions including heart disease, diabetes, and stroke [31]. Type 2 diabetes has been associated with colon, breast, and pancreas cancer [1]. Patients with type 2 diabetes are at increased risk of liver, pancreas, endometrium, colorectal, breast, and bladder cancers [32], [33], [34]. Risk reduction of type 2 diabetes and cardiovascular disease may be achieved by body weight reduction [1]. Lifestyle modification programmes involving diet, exercise, and behavioural techniques has been effective to reduce weight and to avoid weight gain [1].

Finally, cancer patients and survivors' mental wellbeing, psychological and psychosocial factors are also affected by diet and physical activity. Depression is common among cancer patients/survivors [35], [36], [37], [38], (Honda & Goodwin 2004) affecting negatively the physical and psychological health of cancer survivors. Depression is also associated with obesity, diabetes, and cardiovascular disease [39], [40], [41]. Exercise has been identified as a treatment to mitigate depression symptoms in cancer survivors [42], [43].

Lifestyle behaviour change may be benefited by using mobile technology to deliver health behaviour interventions [44], [45], [46]. mHealth offers a promising cost-efficient approach to deliver them enabling in masse interventions [47], [48], [49]. Smartphone apps have shown potential for helping some individuals lose weight and maintain healthy lifestyle habits [44], [47]. Behavior change techniques, gamification and personalization features should be included in apps to promote healthy lifestyle. However, evidence-based content [48], [49], [50] and theory-based strategies [46], [51] could not be incorporated by those apps as was revealed in Breton et al. 2011 [50].

Cowan et al. performed a content analysis of apps primarily aimed at increasing exercise [51]. They found that overall the apps contained few features based on behavioral change theory.

Azar et al. conducted a comparative, descriptive assessment of the top-rated free apps to assist with weight management in iTunes App Store [52]. The objective of this review was to evaluate diet/nutrition and anthropometric tracking apps based on incorporation of features consistent with behaviour change theories. 23 apps were analysed. They found low overall scores for inclusion of behavioural theory-based strategies.

Helf & Hlavacs performed a critical review of motivational tools (gamification) to increase user engagement included in health-related apps [53]. They found low scores in dimensions requiring interdisciplinary work, such as designing interventions based on scientific theories or content personalization based on personality types or traits. From the previous discourse it is clear that there is a significant body of literature that explores health and wellness mobile applications. With this fact in mind this work aims to put the foundations for exploring this literature towards evidence based m-health application design for prevalent chronic diseases such as breast and prostate cancer.

II. METHODS

Towards the aforementioned goal, a survey of publications was conducted. This survey assess the efficacy of mobile/wearables applications for maintaining healthy lifestyles or affecting healthy behavioral change. In this context, an initial tentative research question was formulated:

What are the most effective app features in the whole wearables/mobiles ecosystem (including gamified and AR/VR apps) for maintaining healthy lifestyles or affecting health behavioral change?

From answering this research question it would be possible to refine a list of effective application features that would be used as the pool from which to draw when designing applications for specific topics, diseases and comorbidities. For that, a literature and application review was organized for mobile, tablet, and wearables features for maintaining healthy lifestyle and affecting healthy behavioral change. Initial constraints were:

- A Focus on multilingual applications
- A Focus on features that are relevant to exercise motivation and nutritional improvement
- Inclusion of applications that are available to both mobile devices and wearables.

Within these constraints a detailed work plan was devised consisting of the following specific tasks:

- Definition of the conceptual review field.
  - Definition of the application review field.
  - Definition of Search engines.
  - Definition of keywords subcategories
    - Behavioral change theories, behavioral change constructs
    - Specific diseases and demographics
    - mobile/wearables app ecosystem features
    - Exclusion criteria
    - Focus on excluding publications that are not providing evidence based direct or indirect links between relevant topics
    - Focus on app exclusion criteria based on non-international market reach, language barrier, popularity threshold, non-proper feature documentation.
- Conducting the Literature Survey.
  - Initial Keyword search in the literature; archiving of results.
  - Application of exclusion criteria.
  - Between observer consistency check
- Conducting the app stores' keyword search
  - Application of exclusion criteria
  - Archiving of final results.
- Analysis of discovered data.
  - Aggregation of reported efficacy links between behavioral change theories and specific diseases and target groups. Distilling of most impactful behavioral change theories within the scope of the selected diseases and target groups

- Aggregation of reported links between behavioral theory constructs and behavioral change theories. Distilling of behavioral change constructs in scope with previously determined theories
- Aggregation of literature reported links between behavioral change constructs or theories and mobile/wearable applications' features. Distilling of application features relevant to previously determined constructs and theories.
- Aggregation of literature reported efficacy of application features in motivating behavioral change for healthy exercise and nutrition habits (from strand 1 described above)
- Aggregation of feature proliferation in the existing mobiles/wearables application ecosystem.

- Conceptual, evidence supported, design guidelines formulation
  - Critical revision of aggregated material.
  - Hierarchical classification of shortlisted app features based on implicit impact to specific demographic and disease
  - Hierarchical classification of shortlisted app features based on proliferation in the overall application ecosystem.
  - Formulation of feature guidelines regarding application design for the specific demographics and diseases.
- Presentation and finalization of the work.
  - Drafting and publication of a research paper with the outcomes of this work.

For the review part of this endeavor it was determined that the research would follow a scoping review method. This is an appropriate method to systematically scan and evaluate which studies are within or out of the scope of the research area that is explored for evidence [54]. Different types of literature review methods where considered, but a scoping review study best fit our research purpose with the emphasis placed on the scoping technique to "map" relevant literature in the field of interest rather than collecting similar evidence for a highly focused research question. The method is effective in identifying gaps in the evidence base where no research has been conducted and identifying emerging results in new fields of research; The methodological framework of Arksey and O'Malley [55] is adhered to as it aligns with the proposed work plan. This consists of five stages of scoping and review:

- Identify the research question,
- Identify relevant studies,
- Select studies,
- Chart the data, and
- Collate, summarize, and report the results.

III. Results - Outcomes

Having established the previous methodologic foundation the final research questions for this work were formulated:

- *What are the literature validated behavioral change constructs that support the efficacy of the various mobile and tablet application features in healthy lifestyle change and maintenance apps?*
- *What is the minimum specific set of behavioral change theories that are the literature validated to be effective in motivating breast cancer patients for healthy lifestyle?*
- *What is the minimal ideal feature set for maximum impact of mobile apps for healthy lifestyle maintenance/change on breast cancer patients based on existing behavioral theory research?*

To move into the process of identifying relevant studies the keywords that were considered based on BCT experience and topical research (cf. introduction) are summarized in Table I.

TABLE I Keywords (per broad subject)

Behavioral change theories	Behavioral change techniques	Mobile application Topis and features
Theory of reasoned action/planned behavior (TPB)	Stress management, General communication skills training, Model/demonstrate the behavior, Relapse prevention/coping planning, Facilitate social comparison, Goal setting (behavior), Action planning, Provide feedback on performance, Barrier identification/problem solving, Provide instruction, Teach to use prompts/cues, Provide normative information about others' behavior, Plan social support/social change, Provide rewards for behavior, Prompt self-monitoring of behavior, Provide information on the consequences in general, Provide information on the consequences for individual, Use of follow up prompts, Prompt self-monitoring of behavioral outcome, Reinforcing effort toward behavior, Emotional control training, Provide information about others' approval, Goal setting (outcome), Prompt review of behavioral goals, Shaping, Environmental restructuring, Prompt practice, Agree behavioral, contract, Fear Arousal, Prompt self-talk, Motivational interviewing, Set graded tasks, Prompt review of outcome goals, Prompting generalization of behavior, Prompting focus on past success, Prompt identification as role model, Prompt anticipated regret, Prompt use of imagery, Time management, Provide non-specific social support, habituation, spontaneous recovery, dishabituation, conditioning, reinforcement, stimulus/ response generalization, extinction, overlearning, shaping, successive	Mobile OR Ubiquitous OR Tablet
Transtheoretical model (TTM)		
Social cognitive theory (SCT)		
Elaboration likelihood model (ELM)		Phone
Extended parallel process model (EPPM)		Physical activity
Self-regulation theory (SRT)		Exercise
Precaution adoption process model (PAPM)		Health OR Healthy
Diffusion of innovations model (DIM)		Diet
Health belief model (HBM)		Food
Social		

norms theory (SNT)	approximation, response differentiation, avoidance, sensitization, desensitization, flooding, aversive conditioning/punishment, contingency management, convert control, Contingency management for behavior elimination : time-out, response differentiation, token economy, response cost, negative practice, flooding- response prevention	

TABLE II Search engines to include in the keyword search.

Literature search engines included for the scoping review keyword search.
PubMed
IEEE xplore
ACM digital library
Web of Science
Cochrane Library
ERIC
Embase
SCOPUS
Google scholar
BASE

Practically these keywords were organized in formal queries in several search engines (Table 2). An example query for each research question is presented for PubMed in Table 3 but shall be implemented to all the aforementioned search engines where there is capacity for advanced searches. It must be noted that the behavioral change techniques were deemed too numerous to include explicitly, thus only the theories behind them were used in the queries.

TABLE III Search engines to include in the keyword search.

PubMed search argument:	
Q1) Cancer and physical activity mobile apps.	(“Mobile” [TIAB] OR“Ubiquitous” [TIAB] OR ”Tablet” [TIAB] OR ”Phone” [TIAB]) AND (“Physical activity” [TIAB] OR “Exercise” [TIAB] OR ”Diet” [TIAB] OR “Dietary” [TIAB] OR “Food” [TIAB] OR “Healthy Lifestyle”[TIAB]) AND (“Cancer”[All Fields] OR “ Oncology”[All Fields] OR “Neoplasm” [All Fields] OR “Neoplastic” [All Fields])
Q2) Behavioral change theories and mobile apps.	(“Mobile” [TIAB] OR“Ubiquitous” [TIAB] OR ”Tablet” [TIAB] OR ”Phone” [TIAB]) AND (“Behavioral Change Theory”[All Fields] OR “Theory of reasoned action/planned behavior” [All Fields] OR “Transtheoretical model” [All Fields] OR ”Social cognitive theory” [All Fields] OR ”Elaboration likelihood model” [All Fields] OR “Extended parallel process model” [All Fields] OR “Self-regulation theory” [All Fields] OR “Precaution adoption process model” [All Fields] OR “Diffusion of innovations model” OR “Health belief model” [All Fields] OR “Social norms theory” [All Fields] OR “Learning Theory” [All Fields])

Regarding the search strategy in the app stores (Google Play & App store), due to the fact that a manual search in the Google play store as well as the Apple App store would be an encyclopedic task it was decided for the 42matters (https://42matters.com/app-market-data) search API to be utilized in order to perform this endeavor.

IV. Discussion

The overall aim of this work is to create a conceptual, evidence based design recommendation towards developing mobile and wearables applications to support patients suffering from the specific chronic diseases and belonging in the specific demographic. A mapping of the conceptual framework behind this strand is presented in Figure 1.

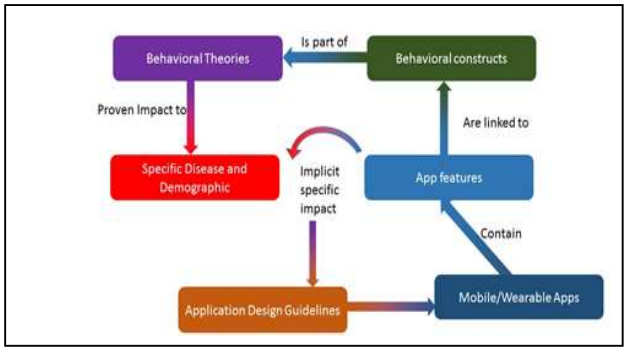

Figure 1 Conceptual framework of implicit link between specific app features and specific disease and demographics.

To proceed towards this endeavor we aim to

- Critically explore research linking app features with behavioral constructs
- Critically explore research linking specific behavioral constructs with overall behavioral change theories.
- Critically explore research about the efficacy of the aforementioned theories and constructs on our joint endeavor’s specific diseases and comorbidities (Breast and Prostate cancer and their comorbidities especially in the elderly) so that
- A literature based, evidence supported, efficacy link can be formulated between specific mobile/wearable application features and the specific diseases and comorbidities of interest to the joint research group.

Previous work from members of this research team in this strand has a demonstrated experience in gamified engagement endeavors for the elderly. It has developed and piloted its own elderly exergaming platform with published results [60],[61]. Furthermore it has experience in ecologic validity of living lab environments having established in its premises a prototype Living Lab. This living lab consists of an environment equipped with monitoring sensors and analytics software for performing technology assessment in

ecologically valid environments and stealth assessment of cognitive and physical capacities of the elderly [62]. Furthermore, this research team has extensive experience in integrating mobile and wearable devices in elderly ambient assisted living environments, with EU funded research providing published results in these endeavors [63]. These expected outcomes of this work are the necessary refinement effort that focuses on describing the conceptual basis and initial methodological findings that align behavioral change theories and the means to apply them. The expected evidence based design process for patient centered health and wellness interventions is going to be the primary input in the implementation process of upcoming patient centered health/wellness m-health interventions.

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