Design And Evaluation Of A Culturally-Tailored Persuasive Application For Promoting Physical Activity

by

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DEDICATION

I dedicate this dissertation to God Almighty (Allah), my creator, my source of inspiration, wisdom, knowledge and understanding. I also dedicate this work to my beloved parents.

In the Arabic language, I would say " اللهم اجعل هذا العمل خالصاً لوجهك الكريم وتقبله مني "

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ABSTRACT

This dissertation presents the design, development, and evaluation of a culturally-tailored persuasive app to motivate physical activity. The app titled StepsBooster-S is tailored to be culturally appropriate for Saudi adults using the user-centered design approach. First, prior to designing the app, we conducted a large-scale study (N= 430) and developed several models to determine and compare factors influencing physical activity among Canadian (individualists) and Saudi (collectivists) populations using the Health Belief Model. Furthermore, we investigate possible moderating effects of age and gender both within and between the cultural groups. Second, based on the results from the analysis, we mapped the determinants of physical activity to their corresponding persuasive strategies and app design features through several consultations and discussions with experts in the area of Persuasive Technology. Third, we designed the StepsBooster-S app tailored to be appropriate for the Saudi audience using the iterative design process employing the appropriate persuasive strategies and features. Finally, we conducted a 10-day in the wild evaluation of the app to establish its usability and effectiveness using the mix-method approach.

The results of the field evaluation of Canadian and Saudi adults (N=30) showed that StepsBooster-S is generally effective, however, it led to a highly significant increase in physical activity among the Saudis audience compared to the Canadians. This confirms our hypothesis that Saudi-tailored apps (according to the results from our model) will be more effective for the Saudi audience. Our results also show that the Saudi audience engaged more with the app in general, reported more positive experience from using the app, and enjoyed the collectivists-oriented features such as cooperation more than the Canadian audience. Therefore, we conclude that persuasive health apps, especially those targeted at physical activity are more effective if they are tailored to be culturally appropriate for the target audience. The findings reinforce the need to take culture into account as an important factor in technology design decisions. Finally, this dissertation also demonstrated how behaviour change theories can be employed to inform persuasive technological intervention design and how the behavioural determinants from the theory can be translated into technology design components in the persuasive systems, hence bridging the gap between the behaviour theory and persuasive systems design.

LIST OF ABBREVIATIONS USED

PA	Physical Activity
PSD	Persuasive Systems Design
BCTs	Behaviour Change Techniques
PT	Persuasive Technology
HBM	Health Belief Model
SUS	Perceived Susceptibility
SEV	Perceived Severity
BAR	Perceived Barrier
BEN	Perceived Benefit
CUA	Cue to Action
SI	Social Influence
R1	Research Question 1
R2	Research Question 2
R3	Research Question 3
R4	Research Question 4
CFA	Confirmatory Factor Analysis
PLS-SEM	Partial Least Square Structural Equation Modeling

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CHAPTER 1 INTRODUCTION

1.1 The Problem

Physical inactivity is a significant risk factor for many non-communicable diseases such as heart disease, diabetes and evidence shows that physical inactivity is one of the highest risk factors for death globally [36]. The number of inactive adults (18 years or older) is reported to be 1 in 4 or 1.4 billion adults globally [36]. This high number of inactive adults continues to rise, as it is driven by economic development and urbanization. Therefore, physical activity promotion remains both an important and difficult task due to the interactions and interdependencies of various factors including demographic, psychological, social, biological, and behavioural factors.

Most research and documented work on the factors that contribute to physical inactivity and how it could be addressed were conducted in Western countries, leaving a huge gap in research regarding how these factors apply to the non-Western countries and how they can be addressed. Cultural differences between Western countries and non-Western countries is an important factor to consider in the design of an effective physical activity motivational tool. Hence, there is a need for research towards understanding the factors influencing physical activity behaviour in non-Western countries. This will aid the design of physical activity intervention that will effectively motivate behaviour among non-Western adults.

Therefore, the overarching question for this research is:
How can persuasive applications be culturally tailored to promote physical activity and how effective is a tailored persuasive application with respect to promoting physical activity?

1.2 Motivation

Most existing physical activity motivating technological interventions target people from Western cultures. Thus, these interventions may not be suitable for individuals from non-Western cultures due to differences in culture, religion, and other beliefs. Although, researches have acknowledged the cultural differences between the Western and Non-Western countries,

whether these differences apply to their physical activity behaviours and what motivates them is unknown. However, it has been suggested that persuasive technologies tailored to be culturally appropriate for the target audience will be more effective than a generic design [70],[82].

To minimize the scope of our research we focus on Canada as a representative of Western cultures and Saudi Arabia represents non-Western cultures. According to Hofstede's model, Canada scored 80 (out of 100) in the individualist dimension; therefore, it can be characterized as an individualist culture. On the other hand, Saudi Arabia scored 25 (out of 100) in the individualist dimension and hence is considered collectivistic culture [17] [18] [70]. The contrast between the two nations makes them of interest for this study as representative of collectivist (Saudi Arabia) and individualist (Canada) country.

Further, the high penetration mobile phone across the globe offer unprecedented opportunities for developing persuasive interventions that will integrate into users' daily lives. Saudi Arabia has one of the highest mobile phone penetration rates in the world [96]. Saudi Arabia also had 21 million mobile phone users in 2017, and 84% of this total were adults; this is expected to increase to approximately 24 million in 2022 [92].

Persuasive mobile apps that focus on health and wellness have gained popularity worldwide; it is estimated that there are over 40,000 mobile apps aimed at changing behaviours in different health domains such as smoking, diet, and physical activity [46]. Despite the growing body of research in the area of persuasive technology [38], systematic analysis of existing apps shows that the current apps are designed with limited integration of behaviour theories on behavioural change or persuasive technology and include minimal evidence-based content [19],[60]. Consequently, there have been multiple calls for designing apps intended to promote behavioural changes to be designed based on theory and evidence [1], [91]. Therefore, we can leverage the ubiquity of mobile phones in Saudi Arabia to design a theory-based persuasive app to motivate physical activity behaviour among Saudi adults.

1.3 Solution

To answer the overarching question, this research introduces the design process, development, and field evaluation of a culturally-tailored persuasive app aimed at motivating physical activity behaviour among Saudi adults titled StepsBooster-S. This work is comprised of six steps as follows:

Step 1: Comprehensive Literature Review

This step provides an empirical review of 19 years (54 papers) of research on persuasive technology for physical activity promotion and presents all the predominant persuasive strategies employed by studies to motivate physical activity behaviour.

Step 2: Identifying the Determinants of Physical Activity Behaviour

In this step, we conducted a comparative analysis of factors effecting physical activity behaviours among Saudi Arabian population and Canadian audience using the extended Health Belief Model (HBM) [29]. We applied the extended HBM to the two culturally different countries (Saudi Arabia and Canada) to uncover the determinants influencing physical activity behaviour in both countries. Canada and Saudi Arabia are used in this work because they represent two distinct cultures and to show how important it is to tailor persuasive apps to accommodate the cultural differences in the target audience of the persuasive intervention. We developed two models show the relationships between the determinants identified by the extended HBM and the physical activity for Canadian and Saudi audience. Further, we developed eight additional models to explore for moderating effect of age and gender both within and across the Canadian and Saudi audience.

Step 3: Mapping the Determinants with the Persuasive Strategies

In this step, we mapped the result from Step 2 to the appropriate persuasive strategies. Since our main objective is to design physical activity motivating app tailored to the Saudi population, we focused mainly on mapping the top three determinants from the Saudi model to their appropriate design strategies. The mapping process involved several iterative processes, starting with some suggested mapping from the literature and ending with consultation several persuasive technology researchers to discuss, validate, and refine the mapping.

Step 4: Mapping Persuasive Strategies to App Features

In this step, we were inspired by some successful examples of previous works that translated persuasive strategies into tangible design components that can be implemented in an app.

Step 5: Designing and Implementing StepsBooster-S

This step involves multiple prototyping and pilot testing of StepsBooster-S to ensure usability and feasibility of the employed persuasive strategies to successfully promote physical activity behaviour.

Step 6: Evaluating StepsBooster-S

This step presents the evaluation of StepsBooster-S on 30 participants (15 Canadian, 15 Saudi) and measures the app's effectiveness and persuasiveness for motivating physical activity behaviour through a post-study interview and questionnaire.

CHAPTER 2 RESEARCH BACKGROUND

2.1 Persuasive Technology

Designing technology to motivate behavioural change has been of interest to both researchers and industrial professionals. Persuasive technology (PT) is an interactive system intended to help people adopt healthy behaviours and avoid harmful ones [70]. It has been argued that technology is never neutral, and it has always influenced people in one way or another [69]. Nevertheless, these influences are usually a side effect of technology use as opposed to a planned effect of its design [25]. Contrarily, the design of PTs is intended to change the user's attitude and/or behaviour in a particular way, i.e., to achieve a planned effect. The mindful application of different persuasive techniques in PT design to influence human behaviour in an intended way distinguishes PT from other technologies that may influence people as a side effect of its use. Various domains, including marketing, health, safety and security, and environmental sustainability [8],[32],[33],[50],[78], have used PT interventions to promote user behaviours. Health is a significant and important domain, as many health challenges are lifestyle related. Thus, these challenges can be addressed by motivating people to make lifestyle changes [97] and adjust certain behaviours. For instance, alcoholism, smoking, and drug addiction obesity are issues that can be controlled through lifestyle choices and lifting these risky behaviours without any treatments poses serious health risks. The use of PT to motivate desirable changes by shaping and reinforcing behaviours and/or attitudes is widely increasing in all areas of health and wellness. PT can be classified into two categories: PT for disease management and PT for health promotion [70][71]. In health promotion, PT targets behaviours initiated by individuals to prevent illness, detect early disease symptoms, and maintain general wellbeing [79]. PT for disease management helps patients enhance their health-related self-management skills such as assisting them in complying and adhering to treatment directives and teaching them how to manage certain diseases [80]. Physical activity (PA) is a domain that has benefited from the application of persuasive technology. Digitalization has made the idea that physical activity can be promoted by the use of technology a reality [42]. This has led to increased interest in the potential of technological devices and applications to motivate physical activity. These PT interventions use a broad range of technologies (e.g., web-based applications and smartphones).

Technological developments in smartphones and their ubiquitous nature offer infinite opportunities for designing mobile interventions to promote PA. For example, mobile PTs can leverage inbuilt smartphone sensors to track PA, provide just-in-time suggestions, and motivate people to be more physically active [5]. As improving the physical and mental well-being of individuals is becoming an area of frequent research, this review concentrates mostly on PT for behaviour change with an emphasis on promoting physical activity.

2.2 Comprehensive Literature Review

The use of behaviour change systems and persuasive technologies to promote desirable behaviour is increasingly gaining attention. Studies on this topic are fragmented and use many different approaches and concepts. Thus, it is necessary to conduct a systematic review to re-evaluate and reveal important trends, best practices, research gaps, and opportunities for improvement. This section provides an empirical review of 19 years (54 papers) of research on persuasive technology for physical activity promotion. The review aims to (1) identify the predominant persuasive strategies used to motivate PA, (2) evaluate the effectiveness of PTs used to motivate PA, (3) evaluate the effectiveness of PTs employing social influence strategies to promote PA, (4) summarize and highlight trends in the outcomes and employed technological platforms, (5) reveal some weaknesses of existing PTs that promote PA, and (6) offer suggestions for improvements and opportunities for future research in this area. This review serves as a reference for future research in this area, providing a comprehensive overview that will be a useful starting point for anyone interested in using persuasive technology for physical activity promotion.

2.2.1 Background

Advances in technology may offer solutions to many health issues caused by physical inactivity. The field of mobile health provides an opportunity to enhance disease prevention and management through the use of mobile technology [23]. The growing prevalence of smartphones and increasing ease of Internet accessibility suggest that mobile technology could play an

important role in health in the future. There is significant potential for healthcare and clinical interventions to be transformed by mobile technologies [10].

The framework for the Persuasive Systems Design (PSD) model has been developed for those who are interested in designing and evaluating systems intended to influence the attitudes or behaviours of users [69]. The model defines seven postulates that need to be considered when designing or evaluating persuasive systems. These postulates relate to system features, the users of persuasive systems, and persuasion strategies. Persuasive strategies are techniques that can be used in PT design to motivate change in behaviours and/or attitudes. The strategies developed by Oinas-Kukkonen [69] have been widely employed in PT design.

The PSD classifies 28 strategies into four main categories: primary task support, dialogue support, system credibility, and social support, as shown in Figure 2.1.

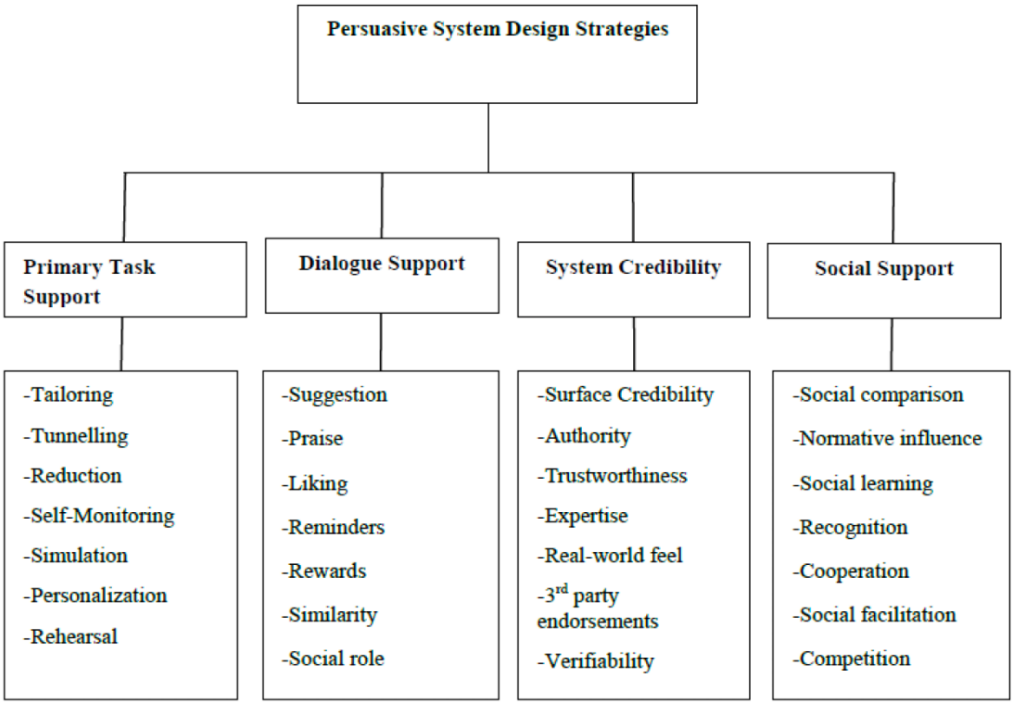


Figure 2.1- Persuasive Systems Design Strategies [81]

Primary Task: The strategies in this category are used to direct the target behaviours. They deal with users' real-world tasks (target behaviour change) the system is purposely designed to support. Seven strategies have been identified in this category: reduction, tunnelling, tailoring, personalization, self-monitoring, simulation, and rehearsal (see Figure 2.1).

Dialogue Support: The strategies in this category facilitate interaction between the user and the system (similar to face-to-face interaction) that moves users toward their goals or target behaviour. The persuasive strategies in this category include praise, rewards, reminders, suggestions, similarity, liking, and social roles.

System Credibility: The perceived system credibility design strategies describe how to design a system to be more trustworthy and thus more persuasive. The strategies in the credibility category include trustworthiness, expertise, surface credibility, real-world feel, authority, third-party endorsements, and verifiability.

Social Support: Social influence employs the power of others to move one towards adopting a target behaviour. This is because most of our behaviours are built on observations of what others do in similar situations. Likewise, considering the computer as a persuasive social tool can persuade people to change their behaviours by providing social support or by leveraging social rules [26]. The strategies in this category include social learning, social comparison, normative influence, social facilitation, cooperation, competition, and recognition.

Persuasive technologies in promoting physical activity are becoming more prevalent as access to smartphone technology increases. Mobile applications are being developed that incorporate various persuasive design strategies that are being used to change the behaviour of users. These applications are continually evolving, and people are increasingly using them in their daily lives. Individuals are being inspired and motivated to achieve their physical activity goals and improve their wellbeing. Although many applications such as those designed by Nike [69] have been developed, there is a lack of comprehensive reviews on the persuasive system design strategies

employed in PA promotion applications. By utilizing the PSD framework, this review will evaluate the persuasive strategies employed by PA applications throughout the years.

The results from this systematic review will identify the emphases, gaps and commonly used design strategies in applications that motivate physical activity. The inbuilt persuasive strategies of these applications will be mainly determined using the PSD model and a small part of the Behaviour Change Technique (BCT) [101].

2.2.2 Materials and Methods

As our aim is to systematically analyze and evaluate applications employing persuasive strategies to motivate PA, we applied quantitative content analysis, a technique that uses the contrast, comparison, and classification of data according to various concepts and themes [88]. The technique requires collecting data rigorously and paying special attention to the objectivity of the research.

In searching the literature, we used multiple databases (e.g., Elsevier Scopus, PubMed, EBSCOHost, Springer, the ACM Digital Library, and Google Scholar). We searched for the terms "Persuasive Technology and Physical Activity", "Behaviour Change Technology and Physical Activity", "Technology and Physical Activity Interventions", and "Persuasive Technology and Exercise". This ensures sufficient coverage of technology-driven physical activity interventions across disciplines including medical and health informatics, health information systems, human-computer interaction (HCI), and other related research disciplines.

The search result revealed 345 unique titles, of which 229 articles were considered relevant following a title examination. After reviewing the abstracts of each article, a total of 54 articles (out of the remaining 229) published between 2000 and 2019 were included in this analysis. We only included articles that discussed the design and evaluation of a new PT for promoting physical activity or the evaluation of existing PTs for promoting physical activity that were published in English. Studies describing the design and development of PT for physical activity without an evaluation were excluded. The search and exclusion processes are summarized in Figure 2.2.

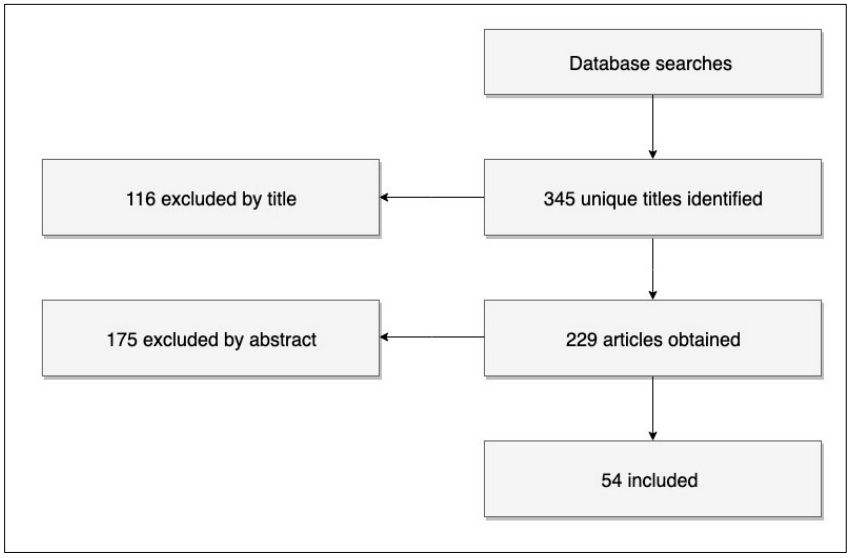


Figure 2.2- Included study identification process

2.2.3 Analysis and Coding Scheme

In the next stage of the review, we coded the articles. To achieve this, we adapted a coding scheme that was developed and evaluated by Orji and Moffatt [72]. The coding sheet includes the following parts: the study author(s), study title, year of publication, the technology platform used (e.g., web, mobile, games, desktop applications), duration of evaluation (e.g., hours, days, weeks, months, and years), behaviour theories employed in the PT design or evaluation, motivational strategies (motivational affordance employed in PT design), Age range of participants involved in the evaluation, country where the study was conducted, targeted behavioural or psychological outcome (e.g., behaviour, attitude, adherence), findings/results (whether positive, partially positive or negative. Subsequently, we classified the data of 54 articles using the coding sheet (see APPENDIX A for the studies included in this review).

2.2.4 Results

Our analysis of existing persuasive technology for PA promotion showed some interesting outcomes and trends. In this section, we present our findings under different categories including the target demographic, employed technological platform, and effectiveness of persuasive strategies for motivating PA.

2.2.4.1 Study Participants and Sample Size

The sample size, which is the number of participants in the evaluation of the persuasive technology for promoting PA, varies significantly across the studies. The sample size ranges from 2 to 684 participants for the reviewed studies. However, one study did not state the total number of participants in their evaluation [84], and some evaluations were conducted in multiple stages with the sample size and composition varying at each stage. In such studies, we report a combined sample size from all stages. As shown in Figure 2.3, 74% of all the studies were targeted at adults, 15% focused on children and teens, 9% were explicitly targeted at elderly, and 2% of all studies did not specify their target audience.

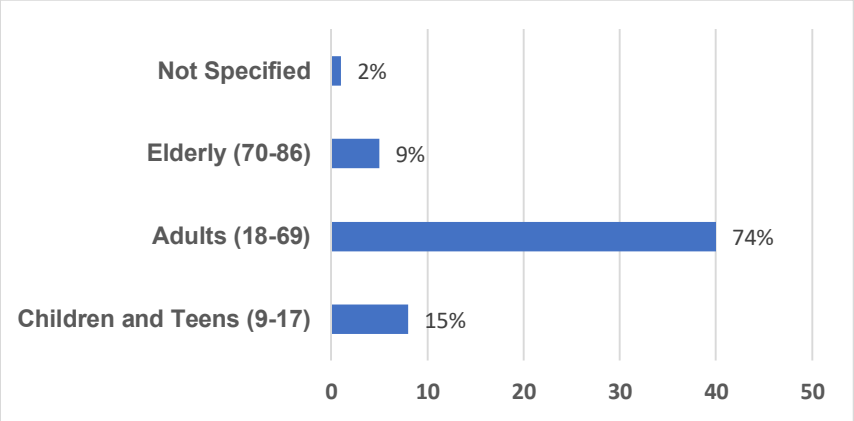


Figure 2.3- Targeted age demographic

2.2.4.2 Persuasive Technology in the Physical Activity Domain by Year and Country

Figure 2.4 shows that a considerable number of empirical studies on persuasive technology for PA promotion emerged in 2006. After 2006, there were some year-to-year fluctuations, and the

number of studies peaked in 2014. There were some declines in the following years until 2018. It is important to note that although the year 2019 seems to have the fewest number of studies since 2008, that is probably because the study was completed in the first quarter of 2019, with many of the publications for the year still pending.

As shown in Figure 2.5, the studies were conducted in 16 different countries, with the USA leading the list with a total of 35% of all the studies. The USA is followed by the Netherlands with 20%. Japan is in third place with a total of 7%, and Australia, Germany and the UK are in fourth place, having 6% each of all the studies.

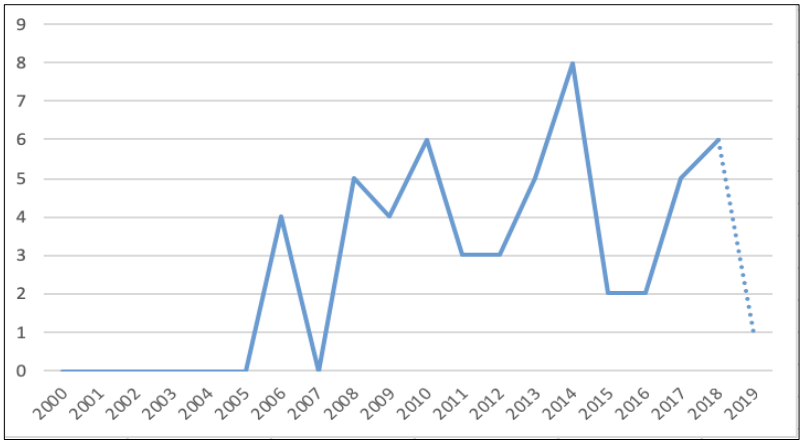


Figure 2.4- Persuasive technology for physical activity promotion trend by year

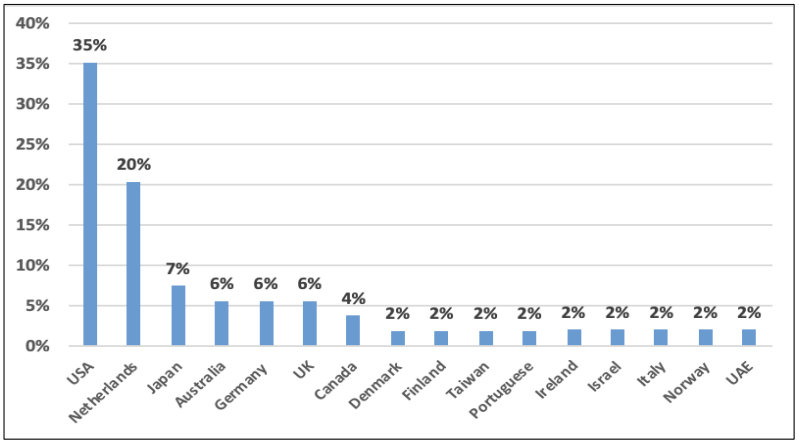


Figure 2.5- Persuasive technology for physical activity trend by study country

2.2.4.3 Technology Platforms for Physical Activity Promotion

Figure 2.6 presents the major technology platforms employed by designers for PA promotion. The most frequently used technology platforms were shown to be mobile and handheld devices with a total of 27 (38%). This is understandable considering the pervasive nature of mobile and handheld devices, which makes them appropriate for physical activity tracking anywhere and at any time. Mobile devices are followed by sensors and wearable devices with 18 (25%). Games is in the third place with 9 (13%). This category included any form of games, whether the game is mobile-based, web-based, or runs on a stand-alone desktop. In addition, PT applications for promoting PA implemented as web and social networking tools were popular among the studies reviewed. Desktops are the least employed platform with only (1%) of PA-promoting applications belonging to this category.

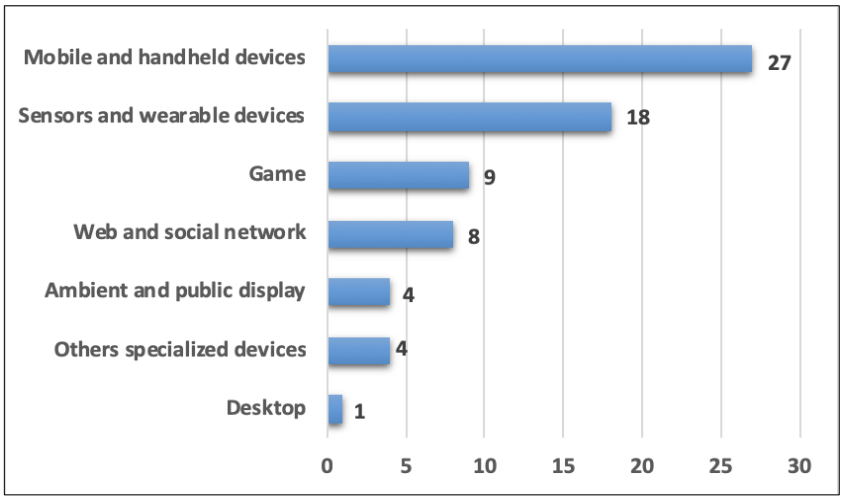


Figure 2.6- Persuasive technology for physical activity promotion platforms

2.2.4.4 Technology Platforms for Physical Activity Promotion by Target Age Group

As shown in Figure 2.7, the most persuasive applications for promoting PA targeted at adults are delivered in the form of mobile applications (with 19 studies). This is followed by sensors and wearable devices (13 studies). For children and teens, however, most of the persuasive apps for PA promotion are delivered using sensors and wearable devices (4 studies). This is closely

followed by apps delivered in the form of games and mobile apps (with 3 studies each). With respect to elderly people, most of the persuasive applications for promoting PA are delivered using other specialized devices (2 studies). In general, ambient and public display seem to be dedicated to apps targeted at adults only (4 studies), while desktop apps are used only by children and teens (1 study).

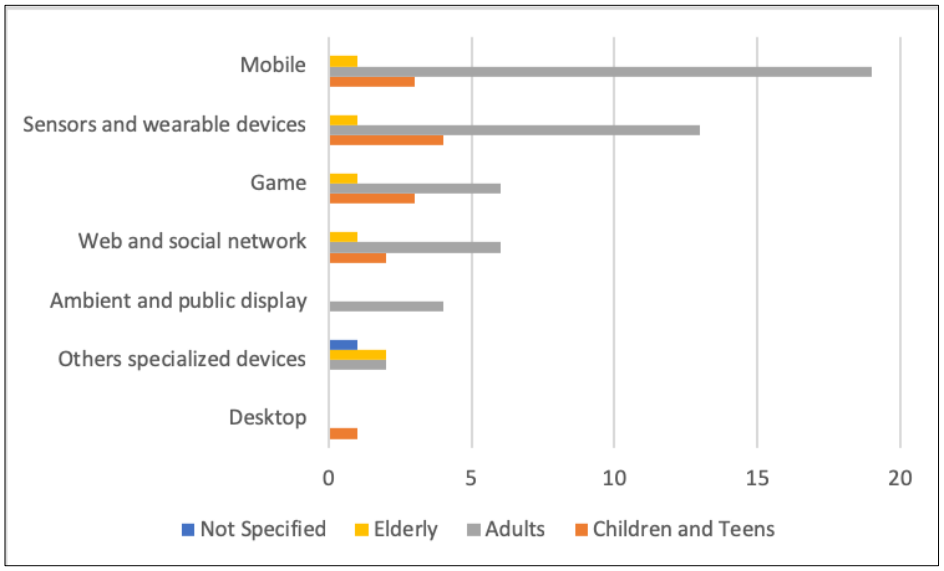


Figure 2.7- Technology platforms for physical activity promotion by target age group

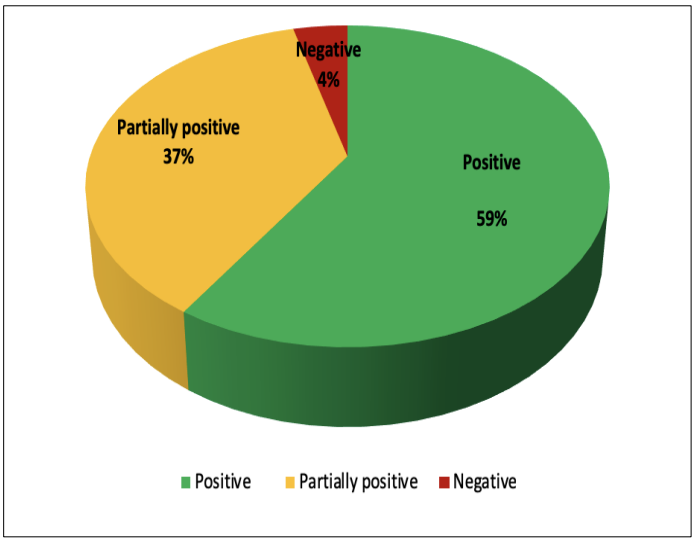


Figure 2.8- Summary results of the effectiveness of persuasive strategies in the physical activity domain

2.2.4.5 The Effectiveness of Persuasive Strategies in the Physical Activity Domain

Figure 2.8 summarizes the results from the evaluation of all the persuasive strategies for promoting PA reviewed for this systematic review. Of the 54 reviewed studies that matched our inclusion criteria, 32 (59%) reported fully positive results from applying persuasive strategies to motivate PA. Twenty studies (37%) reported partially positive results. Only two (4%) of all the studies were unsuccessful at achieving their intended persuasion goal.

The categories (fully positive, partially positive, and negative) are based on whether the objectives of the study are fully fulfilled, partially fulfilled, and not fulfilled). If the objectives are fully satisfied then it is fully positive, while if some of the objectives are met but not all of them then it is partially positive. However, if none of the objectives met then it is negative.

2.2.4.6 Predominant persuasive strategies in the physical activity domain

As shown in Figure 2.9, tracking and monitoring are the top strategies used for promoting physical activity and were employed 36 times in the reviewed studies. They are followed by competition, as a considerable number of studies used this strategy (27 studies). A reward strategy is in third place and was employed by 19 studies. This is closely followed by studies that applied a social comparison strategy (18 studies). A feedback strategy was employed 12 times in the reviewed studies, followed by cooperation, which was used in 10 studies. Both personalization and praise strategies were applied in 6 studies. On a general note, goal setting, recognition, reminders, and suggestions, tailoring and reduction, and authority, commitment, liking, and tunnelling (listed in the decreasing order of frequency) emerged as the strategies employed the least by PT interventions in the physical activity domain.

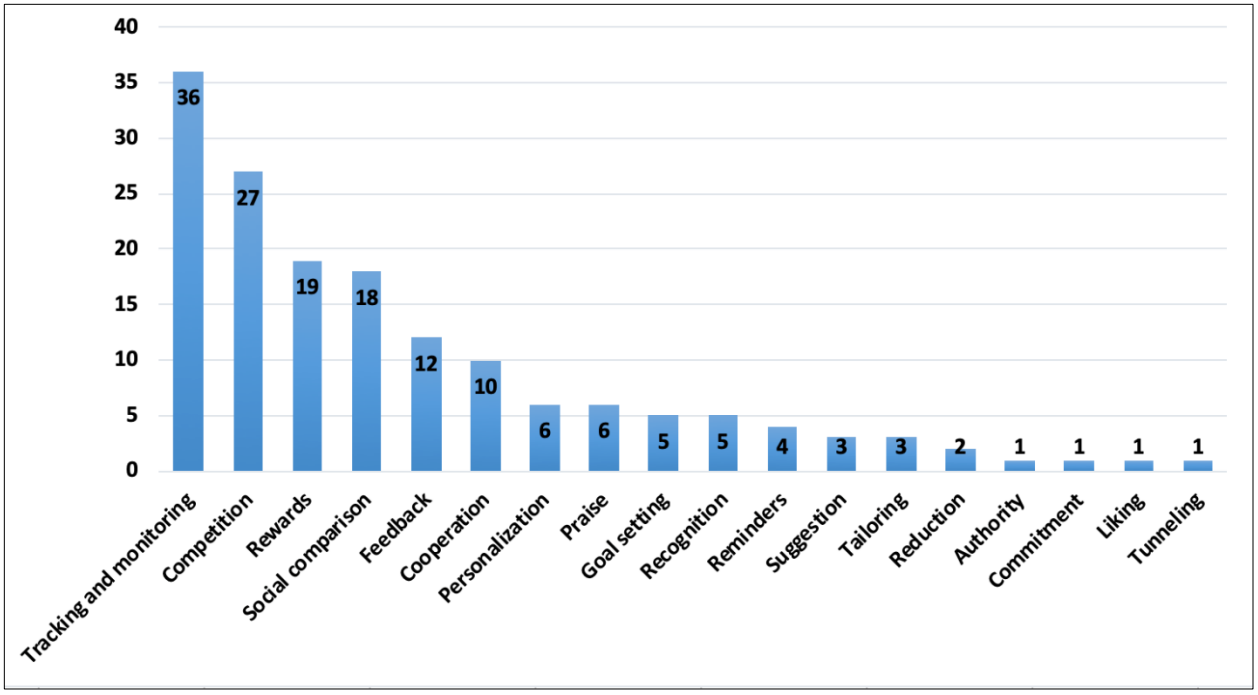


Figure 2.9- Predominant persuasive strategies employed in the physical activity applications

2.3 Socially Oriented Strategies Systematic Study

The second part of this systematic review specifically investigates the effectiveness of three social influence strategies (competition, social comparison, cooperation) employed in persuasive apps for promoting physical activity. This work was published at the UMAP'19 conference [3].

According to a recent review [72], social influence strategies are among the most widely used strategies in health application design, specifically in PA promotion apps. Social influence strategies employ social oriented strategies such as competition, social comparison, and cooperation as described by Oinas-Kukkonen and Fogg [26] [68] to motivate behaviour change. These strategies have been shown to be effective at motivating behaviour change in the PA domain [30][93]. Although studies have shown the effectiveness of social influence strategies, there is still a need to conduct an empirical and systematic review to evaluate the effectiveness of existing applications that used social influence strategies to promote PA.

One way that PTs can be personalized is to tailor the strategies to be appropriate to the domain of interest. The effectiveness of persuasive strategies can be domain dependent. Hence, our findings

can guide designers in choosing the appropriate socially oriented strategies to employ to motivate PA while considering many factors, including their effectiveness and target audience.

2.3.1 Socially Oriented Strategies Background

The importance of socially oriented strategies lies in their ability to leverage the influence of other people (social influence) to motivate behaviour change [68].

Oinas-Kukkone [69] describes (competition, social comparison, and cooperation) as the following:

- **Competition strategies** allow users to compete with each other during the performance of the behaviour as a way of motivating users to engage in the desired behaviour.
- **Social comparison strategies** allow people to compare their behaviour performance with other user(s). As opposed to competition, comparison strategies do not involve winning or losing, and they may not involve direct interaction with others.
- **Cooperation strategies** allow people to work together to accomplish a shared behaviour goal and reward them for their achievement.

In the area of physical activity (PA), a mobile application developed by Toscos et al. [98] employs the power of social influence to motivate teenage girls to exercise by comparing their activity levels. On the contrary, Fish 'n' Step [59] used a self-monitoring strategy to promote physical activity by giving users the ability to track their own behaviours.

We investigate the three most frequently used socially oriented strategies in this part of the review (competition, social comparison, and cooperation).

2.3.2 Socially Oriented Strategies' Materials and Methods

We used the same approach in searching our literature and databases as described in section 2.2.2.

2.3.2.1 Socially Oriented Strategies Analysis and Coding Scheme

We also used the same methods in coding the articles and classifying the data as described in section 2.2.3.

As the aim of this part of the review is to evaluate the PA apps that implemented social influence strategies, out of the 54 studies that determined the inclusion criteria, 32 of them used social influence strategies as shown in Figure 2.10 (see APPENDIX B for the studies included in this review).

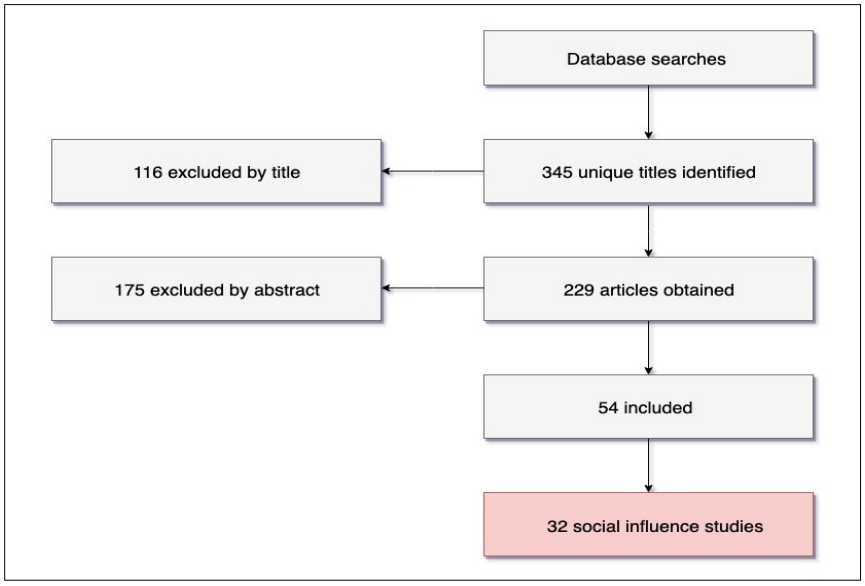


Figure 2.10 - The inclusion of social influence strategies studies

2.3.2.2 Socially Oriented Strategies Implementation

This section describes the implementation of the socially oriented strategies – competition, social comparison, and cooperation in sample PA promotion applications and presents brief examples of studies showing how these strategies encourage behaviour change in such applications.

Fish 'n' Step [59] and Chick Clique [98] are classic examples of apps using a socially-driven strategy to motivate PA. Fish 'n' Step uses competition and cooperation to encourage physical

activity. A daily step count of the user is linked with the growth of a virtual fish in a tank. This tank includes other users' fish, which encourages both cooperation and competition. Users can compete individually with one another (competition) or as part of a group (cooperation) and are provided with feedback on their personal progress, ranking, and calories burned. Similarly, Chick Clique employs competition and comparison strategies to motivate teenage girls to exercise. Chick Clique allows up to four girls to see their own progress and that of three close friends. They engage in a friendly competition where the group's walking step count is tracked, ranked (competition), and compared with those of the other members (comparison). Chick Clique proved effective at promoting physical activity; the girls in the study felt supported and motivated by the social presence of their close friends [75]. ClimbTheWorld [15] is a mobile game aimed at motivating people to take stairs instead of escalators to increase their physical activity. The user has to climb real-world buildings, e.g., the Eiffel Tower or the Empire State Building by climbing stairs during his/her everyday life. Once started, the game tracks and records data from the accelerometer and counts the number of stairsteps climbed. The game has four different game modes, three of which use social influence strategies, and the modes can or cannot involve the user's friends. The modes are Social Climb, Social Challenge, and Team vs. Team. The first mode asks the user to climb a building individually. As some buildings may have a large number of stairsteps, the user can also invite his/her Facebook friends to help climb to the top of the building (cooperation). In the second mode, Social Challenge, the users do not collaborate but instead compete. The winner is the first user who reaches the top of the building (competition). The Team vs. Team mode implements a challenge between teams of an equal number of players (competition and cooperation). The study results highlighted that the Team vs. Team game mode is capable of achieving more persistent results; that is, cooperation and competition together tend to motivate users to continue their activity.

2.3.3 Socially Oriented Strategies Results

The analysis of the existing socially oriented strategies for physical activity promotion revealed some interesting outcomes and trends. In this section, we present our findings with an emphasis on the effectiveness of the social influence strategies for motivating physical activity.

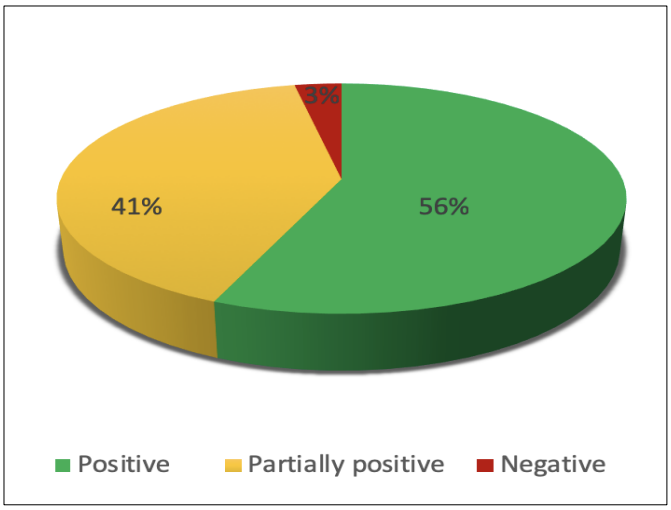


Figure 2.11- Summary results of the effectiveness of social influence strategies in the physical activity domain

2.3.3.1 The Effectiveness of Social Influence Strategies in the Physical Activity Domain

Figure 2.11 summarizes the results from the evaluation of the social influence strategies for promoting PA reviewed in this study. Of the 32 reviewed studies that matched our inclusion criteria, 18 (56%) reported fully positive results from applying a social influence strategy to motivate PA. Thirteen studies (41%) reported partially positive results and only one (3%) of all the studies was unsuccessful at achieving its intended persuasion goal. It is important to consider that most of the reviewed studies employed more than one motivational strategy such as tracking and monitoring, rewards, personalization, and praise along with socially oriented strategies. The categories (fully positive, partially positive, and negative) are as described in section 2.2.4.5.

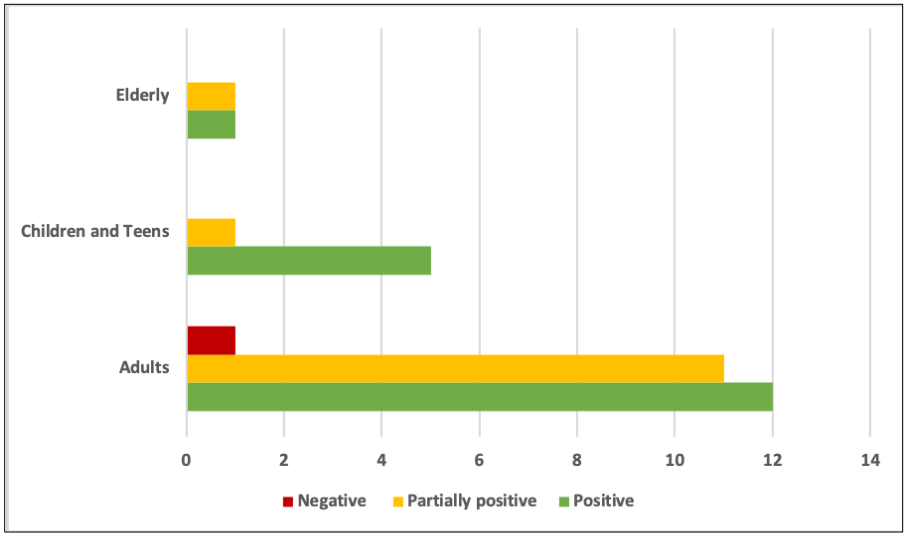


Figure 2.12- Comparative effectiveness of social influence strategies by target audience

2.3.3.2 Effectiveness of Social Influence Strategies by Target Audience

Based on the results from the analyzed studies, social influence strategies targeting the elderly appeared to be the least successful with respect to the effectiveness of social influence strategies at promoting desirable changes in PA with one study having fully positive results and another study adding partially positive results. For studies targeting children and teens, (5 studies) reported fully positive results and (1 study) reported partially positive results. Social influence strategies targeting adults seem to be the most successful with respect to their effectiveness at promoting desirable change in PA with (12 studies) showing fully positive results and (11 studies) showing partially positive results as shown in Figure 2.12. We acknowledge that it may not be possible to compare the effectiveness of the interventions across the target audience considering the significant variations in the number of apps targeting each group of users considered in this review.

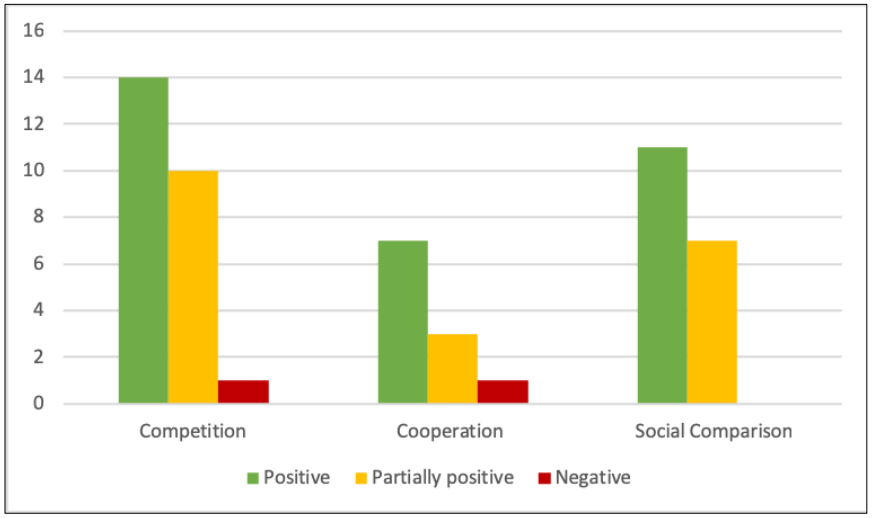


Figure 2.13- The effectiveness of employed social influence strategies

2.3.3.3 Effectiveness Based on Employed Social Influence Strategy

Figure 2.13 compares the effectiveness of the employed social influence strategies (competition, social comparison, cooperation). Interestingly, competition appears to be the most effective strategy with (14 studies) of the reviewed studies reporting fully positive results, followed by social comparison with (11 studies) reporting fully positive results. Cooperation seems to be the least effective with (7 studies) reporting fully positive results, and (3 studies) reporting partially positive results.

2.4 Discussion:

Based on the reviewed literature and our results, it can be concluded that persuasive strategies are effective at promoting physical activity and specifically social influence strategies (competition, social comparison, cooperation) are effective at promoting physical activity, with 97% of all the reviewed studies reporting some positive outcome (fully and partially positive) from the use of persuasive strategies.

Despite this seemingly positive outcome, the majority of the reviewed studies are targeted at behaviour and/or attitude changes along with the original principles of PT by Fogg [3] (technology aimed at changing attitudes and/or behaviours). Generally, the studies targeted and measured other behaviour-related or psychological outcomes beyond the common outcome of

promoting physical activity, such as socializing [17]. Likewise, most PA technologies are aimed at reinforcing and strengthening existing behaviours such as increasing a daily step count. This confirms that persuasive technology for PA promotion has developed over the years to comprise various practices that were not established in the initial conceptualization.

Due to the ubiquitous nature of mobile and other handheld devices, most of the reviewed studies were implemented as mobile applications. Adults comprise the majority of mobile users, which explains why mobile is the dominant platform for implementing apps targeting this group. In general, persuasive applications targeted at promoting PA among adults appear to be more effective than those targeting elderly people and children/teens. One reason for this is that most available applications are targeted at adults because it is easier to design and evaluate applications targeting adults compared to those targeting children and the elderly. Another possible reason is that adults generally tend to be more physically active than children and elderly people, hence making it more likely that persuasive apps targeting them would succeed, since they would most likely be enhancing/reinforcing already existing behaviours.

Regarding the predominant persuasive strategies for PA motivation, tracking and monitoring was found to be the most common persuasive strategy discussed in the reviewed articles. This strategy was implemented in the form of the automatic tracking of physical activity [56] either in terms of step count [62], distance travelled [63] or other tracking and monitoring criteria. A qualitative study of users' attitudes towards mobile applications promoting physical activity indicated that tracking and monitoring is considered an important strategy in behaviour modification [21]. Applications included the inbuilt motion sensors of the mobile device or manual logging tools such as Fitbit to record the user's physical activity. The data could then be used by the application to provide feedback to the user. In general, capturing cycles of user data and giving feedback is a powerful tool for effectively persuading the user to change their behaviour.

Competition was implemented by displaying the user's results against the results of other users [6] [27]. One study reported that users believed competition through sharing progress with other users would be useful [98]. Also, competition strategies can be combined with cooperation

strategies by assigning users to groups that then compete against each other [98]. Generally, users that received social feedback became more competitive and engaged in higher levels of physical activity [6].

Rewards were usually implemented in the form of symbolic visual rewards displayed to the user upon completion of a goal or a task. Users were rewarded with symbols displayed on the application dashboard each time the user completed a physical activity [39]. Reward systems were implemented that encouraged users to complete physical exercise goals with visually appealing ribbons and trophies being shown in the rewards menu of the application [65].
Cooperation strategies motivate people to change together and achieve their goals together by offering opportunities for mutual support, collaboration, and group reinforcement. As previously discussed in regard to competition, the group of users work together in competition against other groups of participants to achieve their shared activity goal [15] [22].

Social comparison strategies were typically implemented by comparing the physical activity levels of different users; for instance, through a feature that recorded the step count of the user and then compared the results to those of other users [102] [103]. Social comparison is implemented, which allows users to compare their activity data individually [6] or with a group [102].

Feedback strategies are commonly implemented strategies in health and wellness applications [72]. The implementation of the feedback varies in the reviewed literature, as it is often represented in different forms, including audio, visual, or text-based feedback. Also, the variation in activity levels between users may affect the effectiveness of the feedback strategy, as shown in a study of a context-aware coaching system [20]. For inactive users, reaching a daily step target and general coaching messages might be sufficient to increase their activity level, whereas a more targeted intervention is needed for users who are already somewhat active. For highly active users, coaching did not lead to an additional increase in their physical activity level.

2.5 General Limitations and Recommendations for Future Work

Analysis of the existing academic research on persuasive strategies used in motivating physical activity has revealed some interesting trends. Most of the reviewed studies employed more than one persuasive strategy, including the social influence strategy. Thus, evaluating the effectiveness of persuasive strategies can be complicated, and it is difficult to determine which strategy contributed the most to the observed behavioural outcome. The number of articles relating to persuasive applications for physical activity promotion has been increasing, and papers that have not yet become available for review or are in the process of publication would also have been useful to our review. However, the time needed to finish a study and publish the findings means there is a gap between the apps currently being developed and the apps evaluated in academic papers. This systematic review is limited to articles written in English. Hence, articles describing persuasive strategies used in physical activity promotion applications that were published in other languages were excluded during the article selecting process. Another limitation is that the evaluation period of the effectiveness of persuasive strategies is often short and with a limited audience [61] [98]. Therefore, future work should focus on the long-term evaluation of persuasive applications for promoting physical activity on a larger audience. Regarding the demographics of the target audience, most existing persuasive strategies for promoting PA are targeted at adults, making it difficult to establish their effectiveness in other demographic groups. Thus, future research should expand on or focus entirely on other demographic groups such as older adults and children.

CHAPTER 3 TAILORING PERSUASIVE STRATEGIES TO THE TARGET AUDIENCE

3.1 Behaviour Change Theories

Health behaviour theories aid in understanding health behaviour problems, contribute to designing interventions based on important determinants that affect behaviours, and are used to evaluate the effectiveness of developed health interventions[80]. "The most effective persuasive interventions for behaviour change usually occur when the intervention is behaviorally focused, and theory driven" [71]. Through the years, various health behaviour theories have been used to support persuasive intervention designs [71], such as Social Cognitive Theory [7], Transtheoretical Model [85], Theory of Planned Behavior [2], and the Health Belief Model [90]. However, the Health Belief Model (HBM) is one of the most widely applied health behaviour theories [90],[71],[70],[77],[74]. Therefore, this thesis employed the Health Belief Model (HBM), which is shown in Figure 3.1, to understand factors affecting physical activity behaviour across culturally different countries. This model was developed to provide an interpretation of why some people take actions aimed at preventing diseases or activities that can lead to ill health while others care less. Simply stated, the HBM assumes that the likelihood of performing a particular health behaviour is related to people's belief that their actions can lead to ill health, their evaluation of the severity of diseases that could contribute to ill health, and to the belief that the target health behaviour can prevent the risk of developing health behaviour-related diseases. The model establishes that the likelihood of an individual to engage in a health-related behaviour is influenced by his/her perception of the following six determinants:

Perceived susceptibility: "perceived risk for contracting the health condition of concern"

Perceived severity: "perception of the consequence of contracting the health condition of concern"

Perceived benefit: "perception of the good things that could happen from undertaking specific behaviours"

Perceived barrier: "perception of the difficulties and cost of performing behaviours"

Cue to action: "exposure to factors that prompt action"

Self-efficacy: "confidence in one's ability to perform the new health behavior" [80]

Social Influence: "is a term used to explain the effect that other people have on us – our behaviours, beliefs, and attitudes. Social influence occurs when an individual's behaviour or attitude is affected by others. Almost all our behaviours can be shaped by the power of social influence" [75].

These six health determinants identified by the HBM together provide a valuable framework for designing behaviour change interventions. The HBM concentrates mainly on health motivators; therefore, it is most suitable for addressing problem behaviours that have health consequences such as physical inactivity [77]. It can be argued that the HBM is outdated and may not be effective for addressing more modern physical activity health challenges such as coronary heart disease, hypertension and diabetes. However, the HBM has been proven effective and has been successfully applied in the design of many interventions for motivating physical activity [34],[43],[53]. As an example, Hoseini et al. [40] investigated the effect of an education plan based on the Health Belief Model on the physical activity of females at risk for hypertension. The physical activity of both the experimental and control female group were evaluated before and two months after the intervention. The intervention plan was comprised of three education sessions that were conducted in four weeks. The results successfully showed that physical activity levels increased significantly in the intervention group two months after the intervention.

Researchers have designed mobile applications that applied some of the health belief model (HBM) determinants to promote physical activity behaviour. For example, Fish'n'Steps is a game designed to promote physical activity by mapping the growth of a fish with the user step count [59]. It employed some HBM determinants in their design. If the total number of steps exceeded a predefined target, the fish's appearance improved to the next growth level. The growth of the fish once the steps target is achieved can be likened to a *perceived benefit*. The user's success in achieving the daily step goal also affected the facial expression of the fish, happy when the goal is reached, angry when the goal is partially reached, and sad if the goal is not reached. The different facial expressions can be associated with *perceived susceptibility and severity*. Similarly, in the second version of Fish'n'Steps, each fish-tank contained four fishes. Each user has one fish and the growth of each fish impact the whole fish tank. If any of the team members does not achieve the step goal, the tank's coloration was gradually removed, and the

water got darker. The consequences of not achieving the step goal of each member can be associated with *perceived severity* [59].

Another example is Time for Break [58] implemented *cue to action* through periodic notifications adjustable via personalized settings to allow people to set up their preferred work and break duration. These notifications encourage moving and standing.

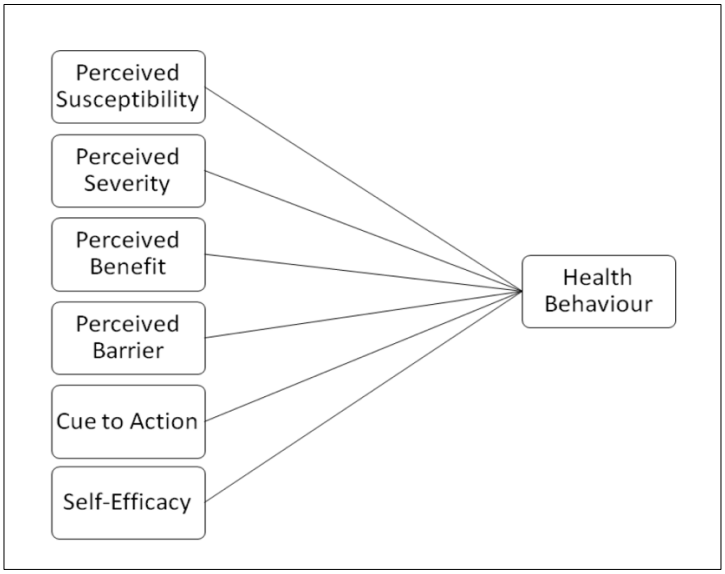


Figure 3.1- The Health Belief Model [80].

Besides the six original HBM determinants, we extended it by including the social influence determinant, as it is identified as an important factor affecting physical activity behaviour in the literature [15],[59],[98],[95]. This factor is added to determine the influence of others on exercise or physical activity behaviour. While several studies have shown the major role that others play in motivating physical activity behaviour, the effects of HBM determinants and social influence together and their impacts on culturally different users are still unclear. Research has shown that the HBM can be extended and adapted to increase its predictive power and suit various health behavioural context. For example, Orji et al. extended the HBM variable with additional new variables that were not in the original model [77]. Hence, we use the HBM extended to include the social influence in this study to examine and compare factors influencing Physical activity behaviours among Saudi and Canadian population.

3.2 Research Questions

The main research questions that guide this particular study are:

R1: How do the extended HBM determinants impact Saudis' and Canadians' physical activity behaviour?

R2: Are there some gender and age differences in the determinants of physical activity among the Saudi Arabian and Canadian Population?

R3: How effective is a culturally tailored physical activity app at motivating physical activity among Saudis and Canadians audience?

R4: How do Saudis and Canadians use the culturally tailored app to support their physical activity?

3.3 Extended Health Belief Model Study

Most existing studies on the determinants of physical activity behaviours focused on people from the Western countries. To further understand how these determinants of physical activity behaviour as identified by the HBM apply to people from non-Western cultures, this study examines possible cultural differences in the determinants of physical activity using the extented HBM. Cultural and contextual factors should be taken into consideration in designing interventions aimed at motivating healthy behaviour change to ensure the success of these interventions. One of the crucial cultural dimensions is collectivism and individualism, as many studies have shown that these two dimensions make up most of the variation in global differences [100],[41].

There are some differences between individualist cultures and collectivist cultures that distinguish each from the other. In an individualist culture, there are loose ties between individuals, and individuals are expected to take care of themselves and their immediate family members [100]. People in individualist cultures tend to be more independent in making decisions, more competitive, less cooperative, and less concerned with in-group goals [51],[94]. In a collectivist culture on the other hand, people get united into solid cohesive groups from

birth. The collectivist expects other in-group members to take care of them and to protect them in return for unquestioning loyalty [51], [94],[41].

Therefore, this study will focus on individualism and collectivism to identify cultural difference on how the determinants influence people's physical activity behaviour. This will inform the design of culturally-tailored persuasive intervention and increase their suitability for the target group as well as their effectiveness at motivating physical activity. As stated by Hofstede [100], most Western nations scored high on the individualist index, while non-Western nations scored low. The individualist index is consisting of a 16-item scale designed to measure four dimensions of collectivism and individualism [99]. The scores of this index are presented as a spectrum from 0 to 100. The higher the score obtained, the more individualists and the lower scores obtained are collectivists.

Researchers generally categorize North America, Western Europe, and Australia as individualist nations, whereas Africa, Asia, and South America are characterized as collectivist societies [100]. Therefore, in this research, we use a similar classification to allocate participants into cultural groups – Canada represents individualistic cultures, while Saudi Arabia represents collectivistic cultures. Canada scores 80 on the individualist index and therefore, can be characterized as an individualist culture whereas Saudi Arabia scores 25 on the individualist index and thus considered a collectivistic culture [17],[18],[70].

3.3.1 Measurement Instrument

In an attempt to answer our research questions presented in a previous section, we developed an online survey hosted on Dalopinio. The survey was developed after a comprehensive review of HBM determinants, their application for promoting physical activity and their effectiveness. The survey instrument (APPENDIX C) consists of questions assessing (1) participant demographics, (2) perceived benefits of physical activity, (3) perceived barriers to physical activity, (4) perceived susceptibility, (5) perceived severity, (6) cue to action, (7) self-efficacy, (8) social influence, and (9) intention to be physically active. The questions used in measuring the HBM variables are questions (2) to (7) listed above,while question eight is added to extend the HBM. All the survey questions were adapted and validated by [77],[70],[53],[34],[4],[48] and were measured using a 7-point Likert scale ranging from "1 = Strongly disagree" to "7 = Strongly

agree". Before the main study, we pilot tested the survey questionnaire on 15 participants for refinement.

To enable us to accommodate Saudi participants, the survey was translated from English to Arabic by the lead researcher, as she is fluent in both languages, and the translation was validated by two Saudi graduate students at Dalhousie University and Mount Saint Vincent University. Therefore, the Arabic version of the survey was distributed to the Saudi audience (collectivist audience), and the English version was shared with the Canadian audience (individualist audience). Participants in this survey are 18 or over.

3.3.2 Survey Recruitment

The target population for the study is Canadian and Saudi adults. We aimed to recruit a minimum of 400 participants in total. Our participants were recruited through email groups for graduate and undergraduate students in Canada. For the Saudi audience, participants were recruited through Saudi Arabian University email lists. In order to recruit public participants, the recruitment script was posted on local classified websites such as Kijiji. We also recruited participants through posting announcements on social media groups (e.g. Facebook and Twitter). Some official organizations in Canada and Saudi Arabia took part in our study by posting the survey on their dedicated social media accounts such as the Kinesiology Association of Nova Scotia, Canadian Kinesiology Alliance, Dalhousie Kinesiology Society, and National Center for Social Studies (NCSS) in Saudi Arabia.

3.3.3 Extended HBM Study Participants

The survey data were collected (between December 2018 and February 2019). A total of 217 Canadian responses were received, of which 4 were removed as they were incomplete. Similarly, the total received Saudi responses were 225 of which 8 were removed as they were incomplete. Table 3.1 summarizes the participants' demographic information. The total complete responses from both countries are 430 responses.

Table 3.1- Summary of Participants' Demography in the HBM Survey

Variables		Canada (N = 213)	Saudi (N = 217)	Total (N = 430)
Gender	Male	109	55	164
	Female	102	162	264
	Non-Binary	2	-	2
Age Group	Younger Adults (18-35)	118	144	262
	Older Adults (36-45 and over 46)	95	73	168

3.3.4 Data Analysis

One of the main objectives of our study is to examine the similarities and the differences between Saudi (Collectivists) and Canadian (individualist) audience with respect to the determinants of physical activity and whether gender and age also moderate the influence of these determinants on their physical activity behaviour.

Analyzing the collected data from the extended HBM survey is done in the following steps:

1- A Confirmatory Factor Analysis (CFA) is conducted to test whether the survey data fit our hypothesized model, that is if the survey data replicate the seven determinants (from extended HBM) in physical activity behaviour [16].

We used the software SmartPLS 3 to perform a component-based confirmatory factor analysis CFA for each group of data. Each question/ indicator loaded onto their corresponding factors and kept only indicators that had factor loadings of at least 0.5 in all the groups while removing indicators with factor loadings less than 0.5 from all the groups [37].

2- Next, we used Partial Least Squares (PLS) Structural Equation Modeling (SEM) to establish the relationship between the extended HBM determinants and the physical activity behaviour. The relationship is obtained by developing two models of physical activity determinants; one for Saudi and one for Canadian audience. Again, we developed additional eight models to investigate and compare the gender and age differences within and between the cultural groups (4 for the Saudi and 4 for the Canadians). The structural models determine the relationship

between the determinants (severity, susceptibility, benefit, barrier, self-efficacy, cue to action, and social influence) and physical activity behaviour. The (PLS-SEM) is a powerful statistical technique that allows a researcher to explore relationships between a set of variables [49], it also recommended to analyze behavioural science data as this type of data includes many variables to be observed [89].

To explore the differences and similarities between individualists and collectivists in their physical activity determinants, we developed ten different models. To test if differences exist between collectivists and individualists, we split the sample and built a model for each group. Then, we examined the influences of the seven determinants (severity, susceptibility, benefit, barrier, self-efficacy, cue to action, and social influence) on physical activity behaviour in the two models. Again, before comparing the models for the collectivists and individualists culture, we established measurement invariance between Saudi and Canadian samples. The psychometric properties from our two groups shows that they have the same structure; therefore, our data is suitable to conduct group comparison. Measurement invariance was assessed using component-based CFA via SmartPLS 3 [86]. Examining variations both within the same culture and between cultures plays a significant role in the validity and generalizability of the findings. Failure to consider variations within the same culture could lead to overgeneralization of the findings [31]. Therefore, acknowledging within-cultural variations is fundamental in cross-cultural comparisons.

In our study, we consider variations both within the same culture and between cultures by examining the moderating effects of age and gender groups on collectivists and individualists. The Saudi and Canadian samples were further divided by gender and age to create models of individualist males and females, collectivist males and females, individualist younger and older adults, and collectivist younger and older adults. Hence, we developed eight additional models of physical activity behaviour: four for the culture/age groups and four for the culture/gender groups. Please note that Canada represents individualist cultures, while Saudi Arabia represents collectivist cultures. We combined two age categories from the extended HBM survey to allow creating two distinct age groups for comparison. For example, we combined the category (18-25) and (26-35) to create the category Younger Adults (18-35) and similar procedure done on the Older Adults category. (see Table 3.1).

In SmartPLS 3, we used some recommended measures for model reliability and validity. The reliability is measured using the Cronbach's alpha and composite reliability as both examine how every indicator strongly correlates with its variable [70]. In our model, Cronbach's alpha and composite reliability scores are higher than the threshold of 0.7 [14] [28]. The validity is measured using both convergent and discriminate validity [73] [76]. All variables have an Average Variance Extracted (AVE), "*which represents the variance extracted by the variables from its indicator items*" [70] higher than the recommended threshold of 0.5 and higher than the variance shared with other variables [14]. The heterotrait-monotrait ratio of correlations (HTMT) were all below the recommended limit of 0.9.

We follow the same approaches performed by Orji et al. [70] in examining the model reliability and validity. The scale reliability and validity for Canadian and Saudi yielded acceptable results for all indices for PLS-SEM model validity and reliability as presented in Table 3.2 and Table 3.3.

Table 3.2 - Canadian scale validity/reliability.

Variables	AVE	Composite reliability	Cronbach's alpha
Threshold values	**≥ 0.5**	**≥ 0.7**	**≥ 0.7**
BAR	0.513	0.893	0.871
BEN	0.544	0.953	0.947
CUA	0.504	0.909	0.888
EFF	0.598	0.899	0.867
SEV	0.625	0.832	0.717
SUS	1.000	1.000	1.000
SI	0.625	0.869	0.625
BEH	0.555	0.833	0.733
BAR = perceived barrier, BEN = perceived benefit, CUA = cue to action, EFF = self-efficacy SEV = perceived severity, SUS = perceived susceptibility, SI= social influence, BEH= physical activity behaviour			

Table 3.3 - Saudi scale validity/reliability.

Variables	AVE	Composite reliability	Cronbach's alpha
Threshold values	**≥ 0.5**	**≥ 0.7**	**≥ 0.7**
BAR	0.686	0.813	0.742
BEN	0.526	0.943	0.935
CUA	0.514	0.880	0.842
EFF	0.651	0.880	0.815
SEV	0.707	0.827	0.725
SUS	1.000	1.000	1.000
SI	0.649	0.880	0.823
BEH	0.549	0.827	0.719
BAR = perceived barrier, BEN = perceived benefit, CUA = cue to action, EFF = self-efficacy SEV = perceived severity, SUS = perceived susceptibility, SI= social influence, BEH= physical activity behaviour			

3.3.5 Extended HBM Study Results

The results from our models reveal some interesting similarities and differences between participants from Saudi Arabia and Canada, males and females, and younger and older adults concerning the influence of the six HBM determinants and social influence (SI) on their physical activity behaviour as shown in Tables 3.4, 3.5, and 3.6 In this section, we summarize and compare the results for various groups as well as explain the results.

3.3.5.1 Collectivists Vs. Individualists

Table 3.4: Standardized path coefficients and Significance of the models for individualist and collectivist cultures. The numbers represent coefficients that are significant at least at p< .05, and '-'represents non-significant coefficients

	BAR	BEN	CUA	EFF	SEV	SUS	SI
Saudi Arabia	-.26	-	.15	-	.11	-	.24
Canada	-	.12	.35	.22	.13	-	.18
BAR = perceived barrier, BEN = perceived benefit, CUA = cue to action, EFF = self-efficacy SEV = perceived severity, SUS = perceived susceptibility, SI= social influence							

To answer our research question R1:"*How do the extended HBM determinants impact Saudis' and Canadians' physical activity behaviou*r?" The results in Table 3.4 shows that among the six HBM determinants and social influence (SI) hypothesized to influence physical activity behaviour, social influence, cue to action, and severity emerged as significant motivators of physical activity for Saudis. Perceived barrier is the only determinant that influences physical activity behaviour negatively for the Saudi audience. However, for Canadians, cue to action, self-efficacy, social influence, and perceived benefit significantly influenced physical activity behaviour and barrier does not have significant effect on Canadians.
Social influence emerged as the factor that affects the Saudi physical activity behaviour the most, while for Canadians, social influence emerged as the third-highest determinant that influences their physical activity.

Possible interpretations of these results can be obtained from the characteristics of collectivist and individualist cultures. Individualist cultures promote individual identity and encourage the achievement of individual objectives, whereas in collectivist cultures, the focus is on group identities, and individuals are encouraged to cooperate to achieve group objectives [24]. That explains why social influence is more effective for the Saudi audience. Moreover, the HBM emphasizes individual perceptions and actions and their effects on individuals' health with little or no emphasis on collectivist people. Therefore, such a model is mostly developed for Western audiences, which makes it more applicable to Canadians, while for Saudis there could be other factors that affect their physical activity behaviour more such as religious and cultural factors. Our results are related to previous research [52], which suggested that most of the determinants from HBM are more suitable for individualist cultures and not for collectivist cultures [70].

3.3.5.2 Moderating Effect of Gender and Age

To further examine potential differences and the generalizability of our cultural models, we explored the moderating effect of gender and age within the individualist (Canada) and collectivist (Saudi Arabia) cultures. Sections 3.3.5.2.1 and 3.3.5.2.2 answer our research question R2: "*Are there some gender and age differences in the determinants of physical activity among the Saudi Arabian and Canadian Population*?" The model's results are summarized in Tables 3.5 and 3.6.

3.3.5.2.1 The Interaction of Culture and Gender

	BAR	BEN	CUA	EFF	SEV	SUS	SI
Saudi Females	-.25	-	.26	.32	.25	-.12	-
Saudi Males	-.23	-	.37	.11	-	.13	.25
Canadian Females	-.26	-	.10	-	.13	-	.26
Canadian Males	-.33	.15	.21	-	-	-	.15

BAR = perceived barrier, BEN = perceived benefit, CUA = cue to action, EFF = self-efficacy
SEV = perceived severity, SUS = perceived susceptibility, SI= social influence

Table 3.5 - Standardized path coefficients and significance of the models for males and females within the individualist and collectivist cultures. The numbers represent coefficients that are significant at least at p< .05, and '-' represents non-significant coefficients

Saudi Males and Females

Saudi males and females differ significantly in how the seven determinants influence them. Self-efficacy, cue to action, and severity (in decreasing order) are the significant motivators of physical activity for the Saudi female group. However, for Saudi males, cue to action, social influence and susceptibility emerged as the top three significant motivators of physical activity followed by self-efficacy. However, barrier and susceptibility influence the physical activity behaviour negatively for Saudi females, whereas benefit and severity are non-significant motivators for the Saudi male group and barrier associated negatively with the physical activity. Perceived severity and social influence emerged as the main differentiators of Saudi males and females.

Canadian Males and Females

Canadian males and females share some significant similarities and differences in the effect of the determinants on their physical activity. The determinants cue to action and social influence significantly influence behaviour for Canadian males and females (although at different degrees). Barrier impacts physical activity behaviour negatively for both Canadian males and females, whereas self-efficacy and susceptibility are not significant for both groups. Benefit is positively associated with physical activity behaviour for Canadian males, whereas is not significant for Canadian females. Perceived benefit and severity emerged as the main differentiator of Canadian males from Canadian females.

3.3.5.2.2 The Interaction of Culture and Age

	BAR	BEN	CUA	EFF	SEV	SUS	SI
Saudi Younger Adults	-.33	-	.15	-	.19	-	.16
Saudi Older Adults	-.40	-	.12	-.16	-	.13	.50
Canadian Younger Adults	-.32	.26	.28	-	-	-	-
Canadian Older Adults	-.12	-	.41	.23	.32	-.13	.17

BAR = perceived barrier, BEN = perceived benefit, CUA = cue to action, EFF = self-efficacy
SEV = perceived severity, SUS = perceived susceptibility, SI= social influence

Table 3.6 - Standardized path coefficients and significance of the models for younger and older adults within the individualist and collectivist cultures. The numbers represent coefficients that are significant at least at p< .05, and '-' represents non-significant coefficients

Saudi Younger and Older Adults

The results for younger and older Saudi adults show some interesting similarities and differences as well. Social influence and cue to action positively influence both younger and older Saudis' physical activity while benefit is not significant in both age groups. However, barrier is perceived negatively in both younger and older Saudi adults. Younger and older Saudi adults differ in their perception of self-efficacy, severity, and susceptibility. Older Saudi adults perceive susceptibility as positive, while the same determinant is not significant for younger Saudis. Self-efficacy is not significant for younger Saudi adults, whereas it negatively affects behaviour for older Saudi adults. Finally, severity is positively associated with younger Saudi adults, whereas it is not significant for older Saudi adults.

Canadian Younger and Older Adults

Similar to the Saudi model, the results for younger and older Canadian adults show some interesting similarities and differences as well. Both younger and older Canadian adults are motivated by cue to action to be physically active, whereas barrier discourages them from increasing their physical activity. On the other hand, younger and older Canadian adults differ in their perception of benefit, social influence, susceptibility, severity, and self-efficacy. Older Canadian adults perceive social influence, severity, and self-efficacy as positive, while these determinants are not significantly associated with physical activity behaviour for younger

Canadian adults. In contrast, older Canadian adults perceive susceptibility as negative, while susceptibility is not significant for younger Canadian adults in motivating physical activity behaviour. Finally, benefit is positively motivating younger Canadian adults and not significant for Canadian older adults.

3.4 Extended HBM Study Discussion

This section provides further interpretation and discussion of the previous findings.

Perceived Susceptibility: Considering the result of perceived susceptibility presented in Table 3.4, both Saudi and Canadian participants do not care about the risk associated with physical inactivity behaviour as the models show that the relationship between perceived susceptible and likelihood of physical activity is not significant. However, this situation changed when we examined the moderating effect of age and gender in Tables 3.5 and 3.6. Saudi males and Saudi older adults emerged as the only group that are motivated by perceived susceptibility. The risk associated with low physical activity level is mostly an increase in the risk factor associated with many diseases, and in the worst case scenario, death [70]. Researches prove that cultural backgrounds can affect the person's perceptions about a disease, including (its causes, symptoms, and treatment) and health, which reflect on the person's health beliefs [70] [57] [83].This can explain the variance in our results between Canadian gender/ age groups and Saudi gender/ age groups with respect to how the perceived susceptibility affect their physical activity behaviour.

Perceived Severity is known as "the seriousness of the consequences of developing a health condition" [70]. The results of perceived severity vary among the different groups. It is positively associated with Canadians and Saudis in general, including both Canadian and Saudi females, Saudi younger adults, and Canadian older adults. This implies these groups are motivated to be physically active by their perceptions of the seriousness of the consequences of being physically inactive [47]. On the other hand, perceived severity is not significant in Saudi older adults, Canadian younger adults, and both Canadian and Saudi males. An interpretation of this is similar to the explanation in perceived susceptibility where not only cultural backgrounds can affect the person's perceptions about diseases and the causes and cures, but also age and

gender. This implies that individuals who associate the causes and cures for disease to external factors (such as religious beliefs) will have adverse beliefs of the relationship between diseases and physical inactivity. Our results show that Saudi older adults, Canadian younger adults, and both Canadian and Saudi males belong to such group. Therefore, they underrate the consequences resulted from physical inactivity related diseases [70].

Perceived Barrier is significantly negatively associated with the following groups: Saudi general model, both Canadian and Saudi females and males, Saudi younger and older adults, Canadian younger and older adults. In contrast, it is non-significant for the Canadian general model. For behaviour change to occur, perceived benefits must outweigh the perceived barriers [44].This can clarify that perceived barrier is non-significant in Canadian general audience, while they are significantly motivated by perceived benefits. Also, individualists (Canadians) consider self-benefit and personal achievement more than difficulties and the cost associated with performing the behaviours (barriers) compared to the collectivists (Saudis) [70].

Perceived Benefit significantly motivates Canadians in general, Canadian males, and Canadian younger adults, whereas it is not significant for all of the Saudi groups and Canadian older adults. This implies that individualists (Canadians) are more motivated to perform physical activity because of the benefit associated with physical activity [70]. Hence, an application that help them to see the benefit associated with physical activity is more likely to motivate them. They are more likely to perform the behaviour if the benefits outweigh the barriers. A possible explanation for Saudi results is that Saudis view the benefits associated with performing physical activity as a shared benefit meaning that the benefit of physical activity should be reflected in terms of how they affect their community or the group they are associated with. Most of the benefits as operationalized in HBM are focused on personal benefits (benefits to self), not group/community related benefits of performing physical activity. This is in line with argue that most existing theories are designed to be more appropriate for people from the Western cultures [70] [74].

Cue to Action "can be thought of as any event or stimuli that triggers the performance of a target behaviour" [70]. Cue to action emerged to be the only factor that is significant among all

Canadian and Saudi groups. This highlights the importance of implementing various cue to action orientated-strategies such as reminders, prompts, and alerts in physical activity promotion interventions targeting Canadian or Saudi population to promote desired behaviours. People may know the benefit of the behaviour but may still need some nudge to take action towards performing the desired behaviours.

Self-efficacy can be described as "confidence in one's ability to perform the new health behaviour" [80]. Self-efficacy is positively associated with the Canadian general group, Canadian older adults, and Saudi females and males. Th significant association with self-efficacy implies that these groups are more likely to perform physical activity if the intervention is implemented to boost their self-efficacy with respect to promoting their ability to be physically active. Strategies such as incremental goal setting and feedbacks can be used to build self-efficacy [70].

Social Influence refers to the influence that other people have on us and our behaviour**.** The results show that social influence is significant for most of the groups. It's significantly positively associated with Saudi and Canadian general audience, Saudi males, Saudi younger and older adults, Canadian males and females, and Canadian older adults. Although these groups are positively associated with social influence, they vary in the magnitude of the social influence impact. Most Saudi groups are more strongly associated with social influence than the Canadian audience. An interpretation can be derived from the characteristics of collectivists. Most of their behaviours are regulated by group norms and community expectations. Therefore, they are more affected by social influence. Surprisingly, the results indicate that social influence is not significant for Saudi female and Canadian younger adult groups. This is in contrast with the results of the study that found that females are more influenced by social influence than males [12].

CHAPTER 4 THE DESIGN IMPLEMENTATION OF A CULTURALLY TAILORED APP TO PROMOTE PHYSICAL ACTIVITY

In this chapter, we discuss the process we followed before and during the design of StepsBooster-S application for promoting physical activity.

4.1 StepsBooster-S Development Process

Step1: Identifying the Top Three Determinants

To develop an effective persuasive system for promoting physical activity, we selected the top three determinants influenced the physical activity behaviour of Canadian and Saudi audiences based on the results from our general model in Chapter 3. As shown in Table 4.1, some common determinants influenced both Saudi and Canadian populations. In the Saudi model, social influence (SI) is at the top determinant that motivates Saudis, which is expected for a collectivist culture, followed by cue to action (CUA) and severity (SEV). In the Canadian model, cue to action (CUA) leads the list, followed by self-efficacy (EFF) and, finally, social influence (SI). Please note that we developed and evaluated only one version of StepsBooster due to our limited time and resources for this dissertation. We designed and evaluated the Saudi version of our persuasive app (StepsBooster-S), and our work will contribute to close the gap in the area of persuasive technology for promoting physical activity in collectivist cultures.

Table 4.1- The top three determinants of the extended HBM that influenced the physical activity behaviour of Canadian and Saudi audiences.

Saudi Arabia	Canada
SI = 0.24	CUA = 0.35
CUA = 0.15	EFF = 0.22
SEV = 0.11	SI = 0.18

Step 2: Mapping the Determinants with Persuasive Strategies

We mapped the top three determinants obtained from the extended HBM survey with suitable persuasive strategies. To manage the scope of this work, we decided to design app targeting only Saudi audience. As our app StepsBooster-S is tailored to the Saudi population, we only focused on mapping the top three determinants from the Saudi model. Social influence (SI) is mapped to the cooperation strategy, and the selection of this persuasive strategy was made based on the major characteristic of collective culture (cooperation) [70]. We mapped cue to action (CUA) to the reminder and suggestion strategies. As they are suggested by previous research by Orji et al. [77], cue to action can be related to the reminder and suggestion strategies [77]. Lastly, the severity (SEV) determinant is mapped to punishment strategy, based on previous research [71] [101], as severity reflects the seriousness of the health problem that may be associated with physical inactivity and its potential consequences. Hence, punishment is operationalized in our app by losing rewards as a consequence of not performing physical activity behaviour. We validated the suitability of this mapping through several consultation with groups of persuasive technology and HCI researchers in the department.

Step 3: Mapping Persuasive Strategies to App Features

The process of mapping the persuasive strategies to app features can help bridge the gap between physical activity motivation app designers and persuasive technology designers. Based on our comprehensive literature review (presented in Chapter 2), we were inspired by some successful studies that translated persuasive strategies (cooperation, reminder and suggestions, and punishment) into tangible design components that can be implemented in an app. For example, from the section 2.3.2.2 "Socially Oriented Strategies Implementation" in Chapter 2, a cooperation strategy in ClimbTheWorld [15] is implemented in which a team with an equal number of players cooperates together to achieve a goal. The reminder strategy proved to be more effective when attached to activity goals [65]; hence, we mapped this strategy to a tangible reminder that is attached to user's activity goal. Punishment is implemented as a form of losing rewards if the user does not achieve the intended behaviour [76].

We took some insights from the various persuasive physical activity app papers we reviewed. Then, we created our first prototype of StepsBooster-S (see APPENDIX E). This prototype was created using Proto.io [87], and was presented on the Persuasive Computing Lab consisting of 15 persuasive technology researchers to get feedback and insights on our proposed design.

We considered all the suggestions from the group members and improved our design by adding some features to increase the overall persuasiveness (gaining rewards and leaderboard) and applied them to develop the final design. These features were considered important to adding enjoyment and increasing user engagement with StepsBooster-S. We presented a second prototype to the Persuasive Computing Lab members and added minor changes before the final implementation. The following section illustrates the final design process.

4.2 Deconstructing Persuasive Features Employed in StepsBooster-S

StepsBooster-S is a persuasive mobile application that motivates users to be more physically active. In our app, a step count represents physical activity behaviour, as walking is safe, easy, and, most importantly, results in positive health outcomes [45][64]. The app's name is inspired by its objective, as it focuses mainly on increasing the walking period as a form of promoting physical activity. Several persuasive and design strategies, as identified from the HBM survey and the prototype presentation insights, were employed in the development of StepsBooster-S.

4.2.1 StepsBooster-S Overview

The user can choose from one of the two types of steps challenges: 1) an individual challenge and 2) a team challenge (team challenge is the implementation of cooperation strategy – social influence (SI)). Once the challenge is created with a specific number of steps to complete (challenge goal is based on the user preference and customizable), the user has to complete the challenge goal within a certain amount of time (before the challenge end date – as determined by users). If the user completed the challenge goal, he/she is rewarded with points, or a reward will be removed if the goal is not achieved (removing rewards is an implementation of the

punishment strategy which represents perceived severity (SEV)). The user could set a reminder to be reminded to create challenges and complete them (challenge reminder is the implementation of reminder strategy – Cue to action (CUA) from the extended HBM). The App periodically sends suggestions as a form of tips in the notifications to motivate the users to be physically activity (suggestions are also an implementation of suggestion strategy – Cue to action (CUA) from the extended HBM).

4.2.2 StepsBooster-S Implementation

StepsBooster-S uses the Google Fit application programming interface (API), which interacts with the sensors on Android devices to track steps taken by a user. Thus, each user will grant the app the necessary permission directly after the installation to collect their step counts. After permission has been successfully granted, the number of steps taken by each user is used to determine if the challenge's goal is achieved or not as well as to produce other required elements (e.g., a leaderboard, rewarding with points, or punishing if the goal is not reached).

StepsBooster-S was developed using Android Studio. The reason for choosing Android Studio was due to our familiarity with it and with Java language. We searched for StepsBooster-S icons using generic open access websites. The data the app collects, such as individual challenges, team challenges, rewards, and total steps, are stored securely through a cloud database called Firebase, which can flexibly integrate with Android.

4.2.3 StepsBooster-S Persuasive Features

Challenges Feature

Individual challenge: On the main screen of StepsBooster-S, there are four main icons, as shown in Figure 4.1. In the Create Challenge icon, users can select the challenge type, which in this case is individual. Users need to input some challenge information such as the challenge name, challenge steps goal, and the start and end date of the challenge. The minimum steps goal is 50 steps, and the maximum is left open based on the user's ability. The user has the freedom to create more challenges if the active challenge is completed.

Team Challenge: We implemented the cooperation strategy which represents social influence as a team challenge where a user can invite another user to cooperate equally to achieve the challenge goal. The process of creating a team challenge is similar to creating an individual challenge; however, the only difference is with the challenge code. This code consists of four unique digit numbers produced randomly by StepsBooster-S every time a team challenge is created (Figure 4.2) The user can invite someone using the SHARE CODE button via email. When the other end receives the email with the team challenge code, the challenge code can be added in the Join Challenge icon located on the main screen of the app. The user has the choice to accept the challenge or reject it after entering the challenge code and clicking the CHECK button, which allows them to view the challenge information (Figure 4.3).

Figure 4.1: The Main Screen of StepsBooster-S.

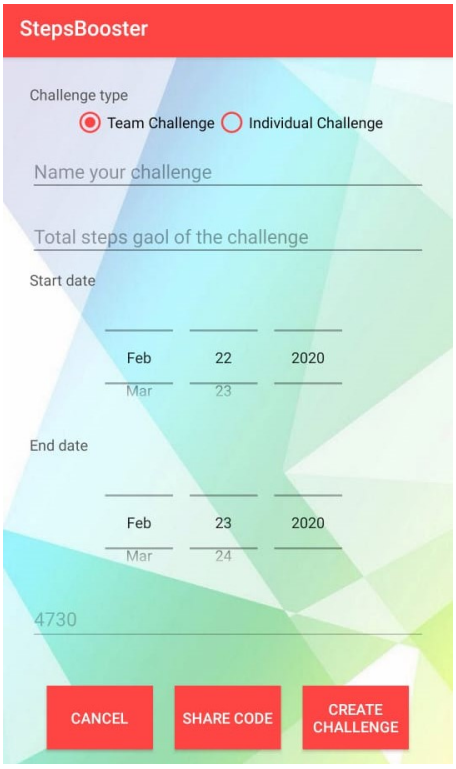


Figure 4.2: The Team Challenge with the Challenge Code

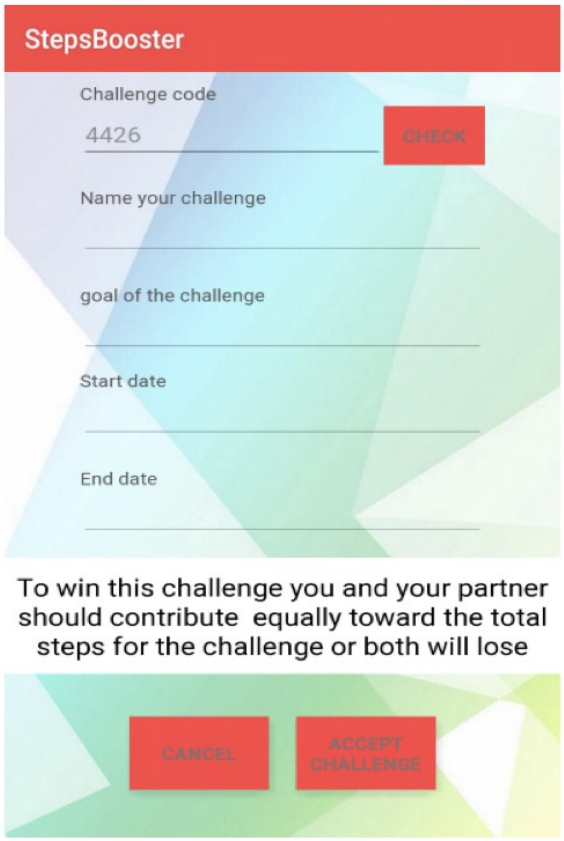


Figure 4.3: Join a Team Challenge in StepsBooster-S

Gaining Rewards Feature

The reward strategy is implemented as a gaining reward feature. There are three types of rewards used to reward users when they achieve their steps goal.

Hearts: As shown in Figure 4.4, each time a step goal is reached, whether it is in the individual challenge or the team challenge, user will be rewarded with one heart, and the heart's colour will turn from an empty heart to a lively red. The heart represents the improvement made in the user's health in general and, more specifically, in their heart health, as physical inactivity is associated with heart disease [55].

Badges: Badges in StepsBooster-S are earned when the user successfully wins four challenges, whether individual or team challenges, in a row, as shown in Figure 4.5.

Health Score: This is the third type of rewards in StepsBooster-S, and it is developed as a circular progress bar with percentages. It represents the user's health at the beginning when they are less active with a red shade and their health score starting at 0%, and it increases and turns into a green shade as they become more physically active (Figure 4.4). With each challenge win, the user receives an increase in their health score by 5% until it reaches 100%; after this, the progress bar returns to zero again. These three types of rewards are found under the Achievements icon in the app's main screen.

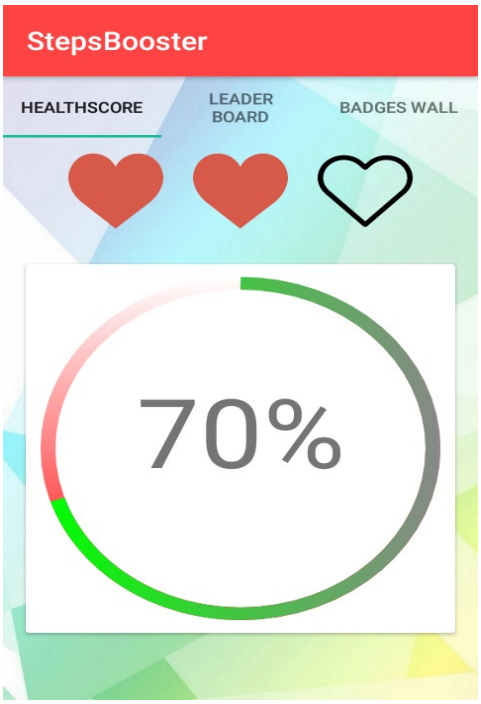


Figure 4.4: Hearts and the Health Score of StepsBooster-S

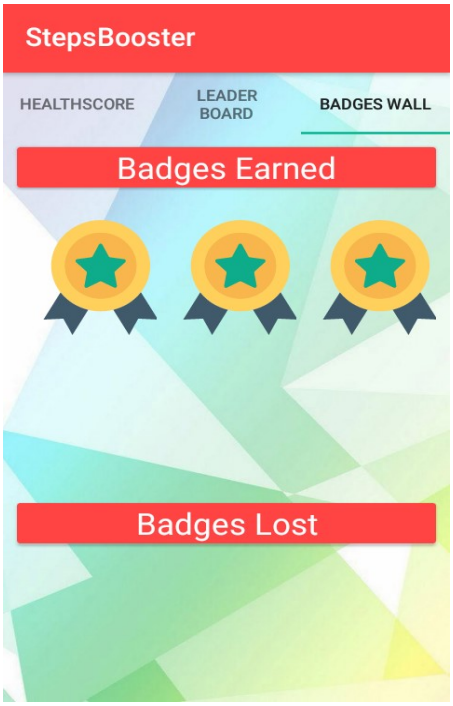


Figure 4.5: Badges in StepsBooster-S

Removing Rewards Feature

The punishment strategy is implemented as removing rewards if the user does not reach the steps goal. The only counted steps are those in the achieved step goals that are intentionally created by the user. If the user doesn't achieve his/her step goals, the user will be punished by losing hearts and health scores. This applies to both individual and team challenges. In the event of losing a challenge, one heart and 5% of the health score will be deducted from the total hearts and health scores. If the user loses four challenges in a row, one badge will be subtracted from the total badges earned and appear in the Lost Badge section. In the team challenge, both users have to contribute equally to achieve the challenge goal; for example, if the challenge goal is 4000 steps, each should complete 2000 steps before the end date of the challenge. If one of them or both of them did not achieve the goal, one heart and 5% of the health score will be subtracted from the total hearts and health scores of both users because they fail to cooperate to succeed in reaching the team goal.

Reminder Feature

The implementation of a reminder strategy is developed as a flexible reminder feature that helps users remember their challenges. The reminder feature is intuitive and easy and can be reached by clicking on the bell icon on the main screen of StepsBooster-S. The reminder is linked with Google Calendar on the user's phone. The reminder in StepsBooster-S needs the user's permission to connect with Google Calendar. Once permission is granted, a daily or weekly reminder can be set as well as the date and the time to be reminded (Figure 4.6).

Suggestion Feature

The suggestion strategy is implemented in form of tips that appear in the notifications of StepsBooster-S. These tips can be used to motivate users to achieve more challenges, and they suggest ways to collect more steps. Figure 4.7 shows an example of the tips suggested to the user "Take the stairs to get more steps".

Leaderboard Feature

This feature employs two persuasive strategies: social comparison and competition. The unique design of our leaderboard differentiates it from other common leaderboards. In our design, the leaderboard is divided into three categories Canadian, Saudi, and All. The Saudi and Canadian categories Figure 4.8 and Figure 4.9 respectively show only users belonging to each group, while the All category ranks user from both countries based on their high scores. The nationality of the user is determined at the login screen of StepsBooster-S. The step count on the leaderboard is the cumulative of the achieved step goals. The social comparison and competition can be perceived through the rank of these achieved step goals of users in the leaderboard, where each user can compare their scores with other users and be motivated to complete more challenges. The leaderboard also creates a place for a competition where the users are motivated to perform more challenges to attain the highest rank in the leaderboard and beat other users.

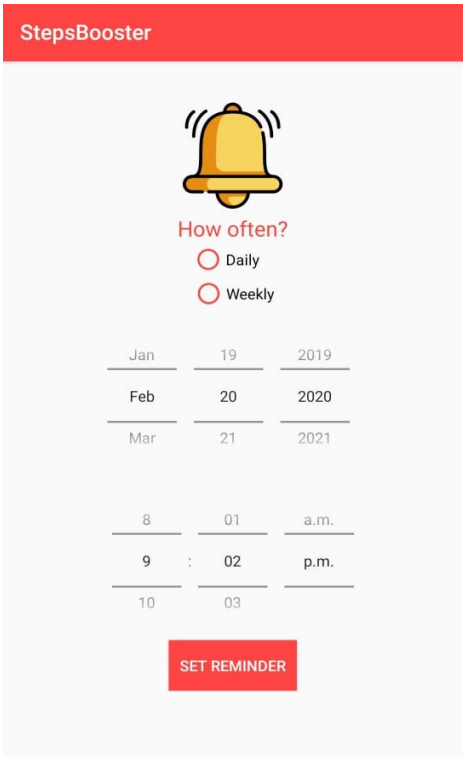


Figure 4.6: Reminder in StepsBooster-S.

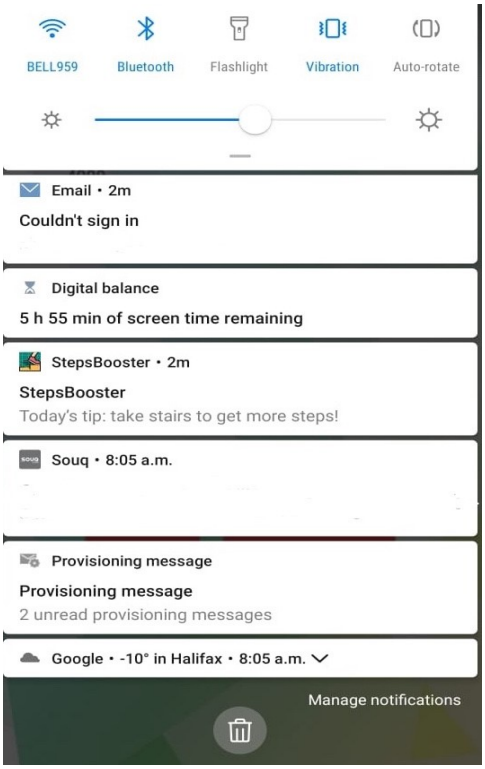


Figure 4.7: The Suggestions from StepsBooster-S in Notification

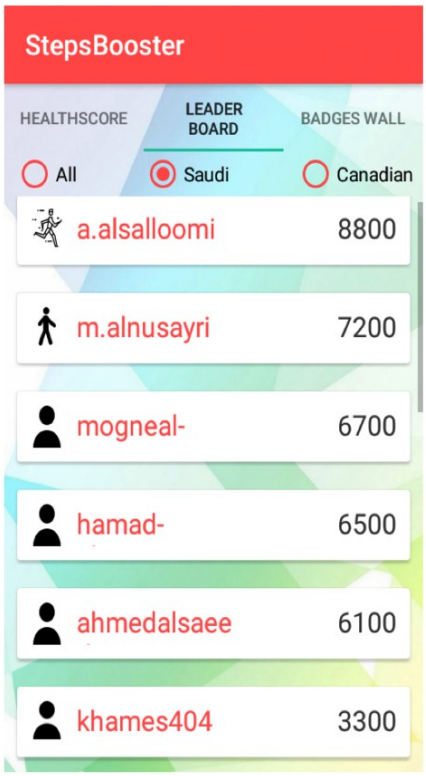


Figure 4.8: The Saudi Category in the Leaderboard

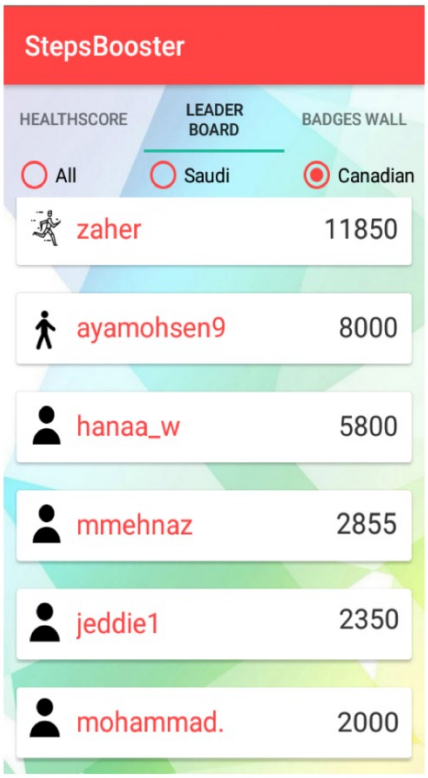


Figure 4.9: The Canadian Category in the Leaderboard

CHAPTER 5 STEPSBOOSTER-S PERSUASIVE APP EVALUATION

To ensure that the implemented persuasive features in StepsBooster-S are effective in promoting physical activity in its users, we evaluated our app with both Saudi and Canadian participants. StepsBooster-S was developed to persuade users to increase their physical activity level by taking more steps every day. The steps count was implemented in our app, as walking is safe, easy, inexpensive, and common among different populations, and, most importantly, it contributes to positive health outcomes [45] [64]. In this chapter, we show the results from the evaluation study of StepsBooster-S and the implications of these results. In the following sections, we present the results of a post-study survey and a semi-structured interview conducted after using StepsBooster- S for ten days. Lastly, we discuss the implications of all these results.

5.1 StepsBooster-S Pilot Study

Before conducting the main evaluation of StepsBooster-S in the wild, we ran pilot studies to identify bugs or any technical issues and to test the overall usability of the app. The pilot study was conducted on six random participants, three from Saudis and three Canadians. The participants were given paper sheets to report any issues they experienced during the three-day pilot use of StepsBooster-S. All the comments were addressed and included in the primary study. APPENDIX G shows some examples of feedback from the participants.

5.2 StepsBooster-S Evaluation Recruitment

The target population for our app's evaluation study is Canadian and Saudi adults. We recruited 30 participants in total (15 Saudi and 15 Canadian) using different recruiting methods. These methods involve email groups for graduate and undergraduate students in Canada and Saudi Arabia, local classified websites such as Kijiji, announcements on social media (e.g. Facebook and Twitter) and posting hard copies of the recruitment script in public places in Halifax such as (libraries, gyms, and community centres). Although StepsBooter-S is mainly tailored to be appropriate for the Saudi audience using the results from our model. We also evaluated the app on Canadians as a control group to compare the results.

5.3 StepsBooster-S Evaluation Study Design

The evaluation consists of (1) using StepsBooster-S for 10 days, (2) completing a semi-structured interview and (3) a post-study survey. All 30 participants signed a consent form (APPENDIX H). Then, participants were instructed to install and use StepsBooster-S for 10 days. After completing the evaluation period, participants were contacted to complete a semi-structured interview (APPENDIX I) and a post-study questionnaire (APPENDIX J). The post-study questionnaire assessed (1) participants' demographics, (2) the app's persuasiveness adapted from Orji [76], (3) the app's effectiveness with respect to ability to promote physical activity, and (4) the user's preference for the implemented features. The questions were measured using participant agreement with a 7-point Likert scale ranging from "1 = Strongly disagree" to "7 = Strongly agree".

5.4 StepsBooster-S Evaluation Quantitative Results

5.4.1 Participants' Demographics

Table 5.1- Summary of Participant Demographics

	Canada N=15	**Saudi N=15**
Gender	Males = 7, Females = 8	Males = 7, Females = 8
Age	(18-25) = 1, (26-35) = 7, (36-45) = 2, (Over 46) = 5	(18-25) = 3, (26-35) = 8, (36-45) = 3, (Over 46) =1
Education	Less than high school = 0 High school or equivalent = 2 College diploma = 0 Bachelor's degree =10 Master's degree = 2 Doctoral degree =1	Less than high school = 0 High school or equivalent = 2 College diploma = 1 Bachelor's degree = 9 Master's degree = 3 Doctoral degree =0

5.4.2 Overall Persuasiveness and Effectiveness of StepsBooster-S

First, we measured the overall persuasiveness of StepsBooster-S in addition to the effectiveness of the app in general in promoting physical activity behaviour. This was done using a combined dataset (of Saudi and Canadian participant) to obtain the overall persuasiveness and effectiveness of StepsBooster-S without considering cultural variations (as a one-size-fits-all approach).

Overall Persuasiveness

We measured the persuasiveness of StepsBooster-S using four questions on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree) after the participants used the app. To analyse the overall persuasiveness, we conducted a one-sample t-test with an optimistic neutral point/mid-point of 4. This was performed to determine if the persuasiveness score of participants was higher or lower than the optimistic neutral rating of 4.

Table 5.2 and Table 5.3 present the details of the overall persuasiveness of StepsBooster-S. The mean score for the overall persuasiveness of StepsBooster-S (5.90 ± 1.04) is significantly higher than the neutral persuasiveness score of 4.0, t (29) = 10.039, $p < .0001$. The results revealed a high overall persuasiveness of StepsBooster-S; therefore, the app has the ability to motivate people to be more physically active.

Table 5.2- Descriptive Statistics for Overall Persuasiveness

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Overall_Persuasiveness	30	5.9083	1.04114	.19009

Table 5.3- One Sample t-test for Overall Persuasiveness

One-Sample Test

	Test Value = 4					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Overall_Persuasiveness	10.039	29	.000	1.90833	1.5196	2.2971

Overall Effectiveness

We measured the effectiveness of StepsBooster-S using three questions on a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree) after the participants used the app.

To analyze the overall effectiveness, we conducted a one-sample t-test on a combined dataset with an optimistic neutral point/mid-point of 4. This was performed to determine if the overall effectiveness score of participants was higher or lower than the optimistic neutral rating of 4.

Table 5.4 and Table 5.5 present the details of the overall effectiveness of StepsBooster-S. The mean score for the overall effectiveness of StepsBooster-S (5.81 ± .89) is significantly higher than the normal effectiveness score of 4.0, t (29) = 11.161, p < .0001. The results revealed the high overall effectiveness of StepsBooster-S with respect to promoting behaviour change.; therefore, the app is effective overall at promoting physically activity among users.

Table 5.4- Descriptive Statistics for Overall Effectiveness

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Overall_Effectiveness	30	5.8150	.89069	.16262

Table 5.5- One Sample t-test for Overall Effectiveness

One-Sample Test

	Test Value = 4					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Overall_Effectiveness	11.161	29	.000	1.81500	1.4824	2.1476

5.4.3 Examining Persuasiveness and Effectiveness by Cultural Group

Based on the above results, StepsBooster-S is effective and persuasive in increasing the physical activity behaviour of Saudi and Canadian population overall. However, it is not clear whether there is a significant difference between the two groups independently. To achieve this, we conducted an independent sample t-test on the two groups to examine for possible differences.

Table 5.6 - Descriptive Statistics for Persuasiveness and Effectiveness by Cultural Group

Group Statistics

	Country	N	Mean	Std. Deviation	Std. Error Mean
Persuasiveness	Canada	15	5.4000	1.25285	.32349
	Saudi	15	6.4167	.34932	.09019
Effectiveness	Canada	15	5.3481	.88975	.22973
	Saudi	15	6.2815	.62130	.16042

Table 5.7- Independent Samples t-test for Persuasiveness and Effectiveness by Cultural Group

	Independent Samples Test					95% Confidence Interval of the Difference	
	t	df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Persuasiveness	-3.027	16.164	.008	-1.01667	.33582	-1.72800	-.30534
Effectiveness	-3.331	28	.002	-.93333	.28020	-1.50729	-.35937

The means of persuasiveness and effectiveness of both the Canadians and Saudis are compared in the analysis. The results of the independent sample t-test revealed that there is a significant difference in the scores for the persuasiveness of StepsBooster-S between Canadian audience (M= 5.40, SD = 1.25) and Saudi audience (M = 6.41, SD = 0.34); *t (16.164) = -3.027, p= 0.008.* The Saudi population found their culturally tailored app to be more persuasive than Canadian. Similarly, for the effectiveness of StepsBooster-S, there is a significant difference in the rating scores between Canadian people (M= 5.34, SD = 0.889) and Saudi people (M = 6.28, SD = 0.62); *t (28) = -3.331, p = 0.002* (See Table 5.6 and Table 5.7). Similarly, the Saudi population found their culturally tailored app to be more effective than Canadian.

5.4.4 Actual Effectiveness of StepsBooster-S at Promoting Physical Activity Overall

First, we begin our analysis by investigating the actual effectiveness StepsBooster-S with respect to promoting physical activity in the general audience without considering their cultures.

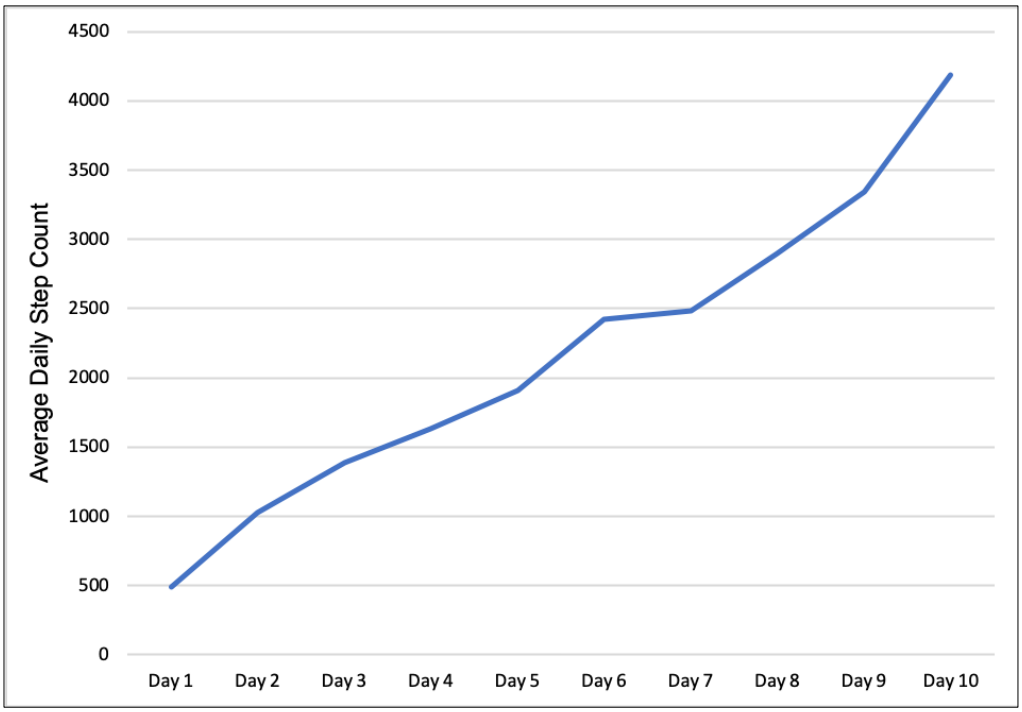


Figure 5.1 - Overall Average step count per day for all participants

Figure 5.1 presents the average step count per day overall without considering the cultural groups. At the beginning of the experiment, the app extracted and recorded the step counts for the first three days, which serves as the baseline and also accounts for possible novelty effect and time used in understanding how the app works. The first three days represent the baseline, which shows the normal average step counts of users before the intervention (StepsBooster-S) came into effect. We present the result from this period as a baseline for the rest of this thesis. The intervention phase of (StepsBooster-S) is between Day 4 and Day 10. Participants show a fairly steady increase in their average step counts during the intervention phase, which is spiked on day 10. This proves that StepsBooster-S is successful and effective at increasing physical activity overall.

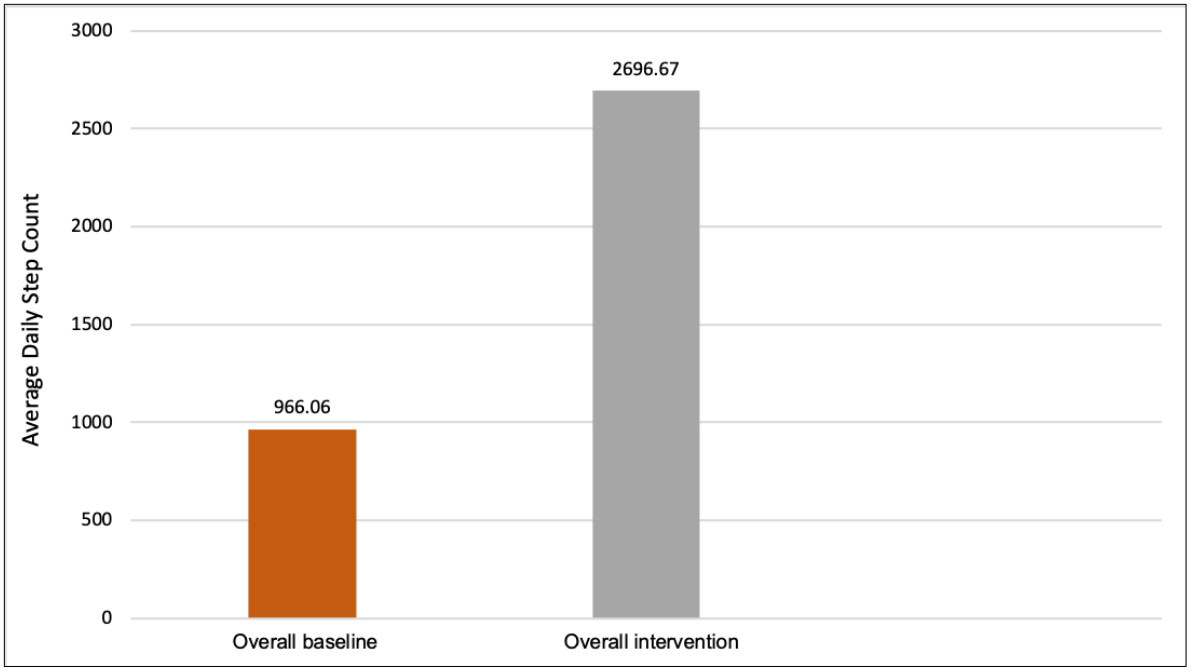


Figure 5.2- Comparison of the average daily step counts of baseline and intervention in all participants

As presented in Figure 5.2, the overall average step count increased significantly from 966.06 baseline to 2696.67 intervention stage after consistently using StepsBooster-S. We conducted a paired-samples t-test (Table 5.8 and Table 5.9) to determine if the mean of the overall step count in baseline and intervention are significantly different. The result is as follows: $t\ (29) = -6.380$, $p < 0.0001$. Due to the means of the overall baseline and the overall intervention, we can conclude that there was a statistically significant improvement in the average of steps count of all participants after using StepsBooster-S from 966.06 ± 1059.24 to 2696.67 ± 1692.63 ($p < 0.0001$). Therefore, StepsBooster-S is effective to increase the step count of all groups and hence improve their physical activity level.

Table 5.8 - Descriptive Statistics for Overall Step Count Improvement

Paired Samples Statistics				
	Mean	N	Std. Deviation	Std. Error Mean
Overall baseline	966.06	30	1059.24	193.39
Overall intervention	2696.67	30	1692.63	309.03

Table 5.9 - Paired Samples t-test for Overall Step Count Improvement

Paired Samples Test								
	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig.(2-tailed)
Overall baseline - Overall intervention	-1730.60	1485.77	271.26	-2285.40	-1175.81	-6.380	29	.000

5.4.5 Comparative Effectiveness of StepsBoosteer-S at Promoting Physical Activity

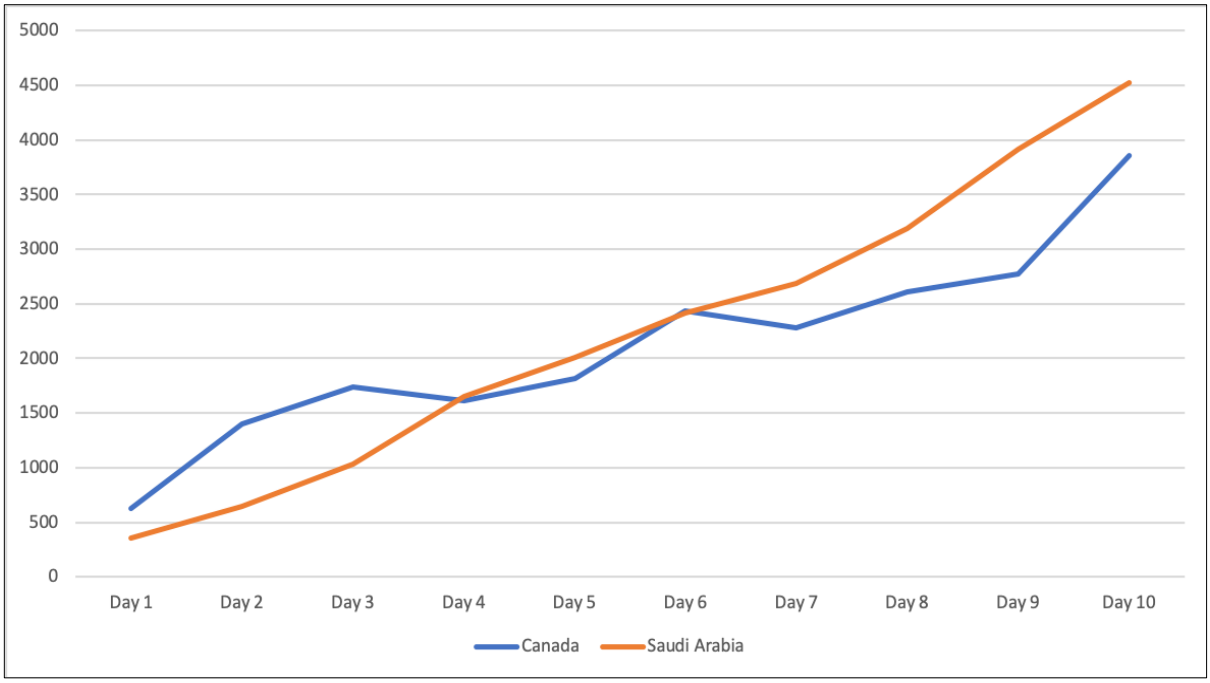


Figure 5.3 - Average step count per day for Canadian and Saudi populations

Figure 5.3 presents the comparative daily average step count of Saudi and Canadian population. Both Saudi and Canadian audience showed fairly similar with respect to pattern of increase in physical activity. Although the Saudi audience generally recorded lower step counts at the onset, the average daily step count of the two groups evened up on the day 4 – the start of intervention stage. Hence these groups were balanced during the intervention stage. During the intervention stage, the physical activity levels of Saudi participants increased more than the that of the Canadian. As shown in Figure 5.3, the Saudi's showed a more steady increase in physical

activity level for the entire experimental period which resulted in a significantly higher average daily physical activity (step count) at the end of the 10th day compared to the Canadians. This shows that StepsBooster-S is more effective for the Saudi audience (than the Canadians) with respect to its ability to promote physical activity. This validates our hypothesis that tailoring persuasive apps for promoting physical activity to be culturally-appropriate will increase their effectiveness. StepsBooster-S was intentionally tailored to be more culturally-appropriate for the Saudi audience.

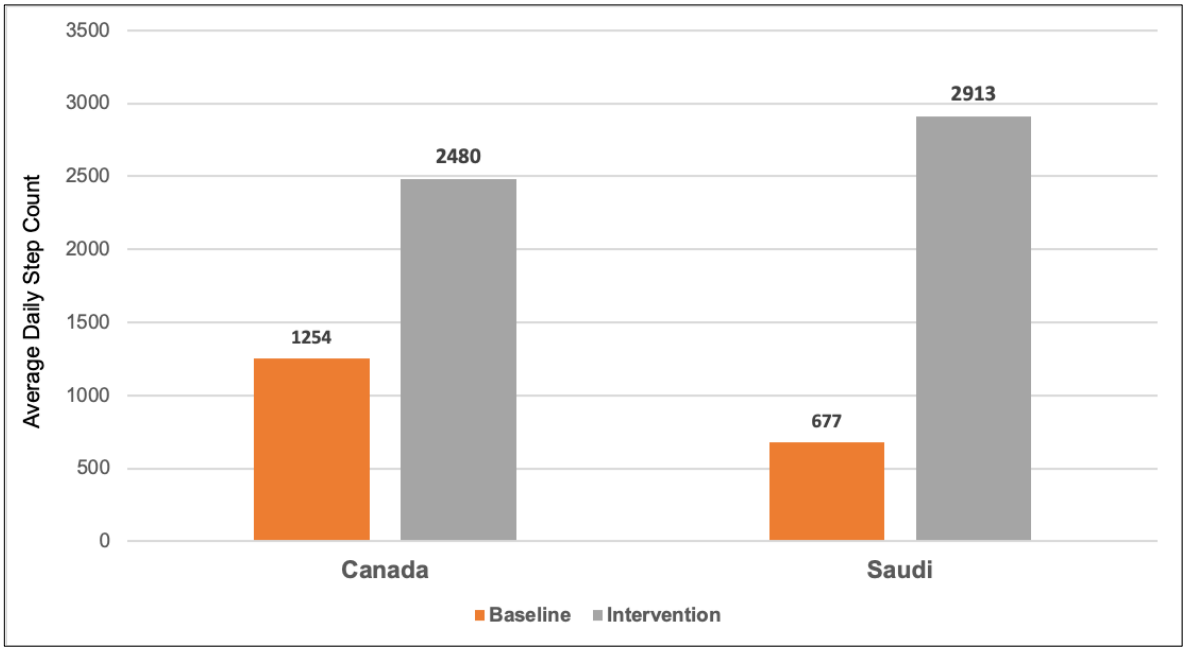


Figure 5.4- Comparison of the average daily step counts of baseline and intervention in Canadians and Saudis

To recap the results, as shown in Figure 5.4, although the Saudi audience recorded a significantly higher increase in physical activity (from 677 baseline to 2913 intervention stage), a statistically significant improvement in the average of steps count from baseline 677.77 ± 507.00 to intervention 2913.33 ± 1817.46; $t\ (14) = -5.35,\ p < 0.0001$.The average daily step count of Canadian users also increased significantly from 1254 to 2480, from baseline 1254.44 ± 1374.47 to intervention 2480.88 ± 1591.28; $t\ (14) = -3.99,\ p = 0.001$. The results of paired-samples t-test are shown in Table 5.10 and Table 5.11. This shows that in general, StepsBooster-S is effective for promoting physical activity. However, comparing the average changes in overall step counts from baseline to the intervention stage for the two groups shows that StepBooster-S is more effective when tailored to be culturally appropriate since Saudi's recorded more increase in

average daily step count from baseline to intervention compared to the Canadians (an average step count difference of 1009.12).

Table 5.10 - Descriptive Statistics for Step Count Improvement in Canadians and Saudis

Paired Samples Statistics				
	Mean	N	Std. Deviation	Std. Error Mean
Canadain_baseline	1254.44	15	1374.476	354.888
Canadain_intervention	2480.88	15	1591.281	410.867
Saudi_ baseline	677.77	15	507.001	130.906
Saudi_intervention	2913.33	15	1817.466	469.267

Table 5.11 - Paired Samples t-test for Step Count Improvement in Canadians and Saudis

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Canadian_baseline - Canadian_intervention	-1226.4400	1188.22511	306.79841	-1884.4571	-568.42286	-3.998	14	.001
Saudi_ baseline - Saudi_intervention	-2235.5553	1617.16193	417.54942	-3131.1098	-1340.0009	-5.354	14	.000

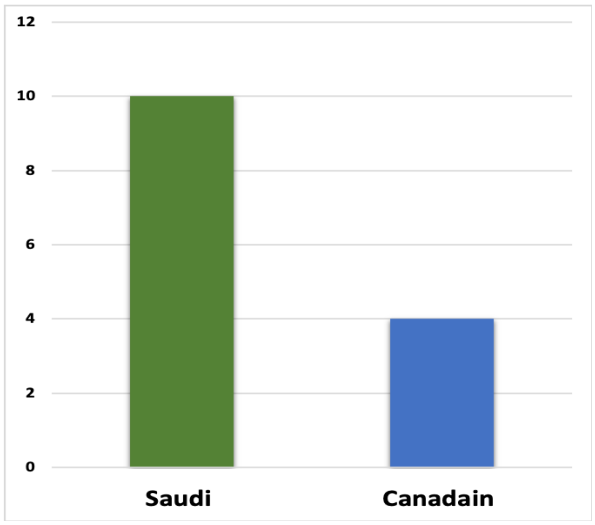


Figure 5.5 - Team challenges completed by Saudi and Canadian

As expected, the Saudi participants successfully completed more team challenges than the Canadian participants (See Figure 5.5). The number of completed team challenges by Saudis is almost double the number of Canadians (10 completed team challenges by Saudi and only 4 completed ones in Canadians). This result confirmed our extended HBM results in Chapter 3, which proves that the Saudi population is more influenced by social influence than the Canadian population. This is also in line with the inherent characteristics of the collectivists culture,as they more influenced by peer pressure [100] [70].

Considering the means of persuasiveness, effectiveness, and the corresponding t-value in addition to the step count results, we can conclude that there is a statistically significant difference in persuasiveness and effectiveness between Saudi and Canadian participants. This implies that although both groups benefit from StepsBooster-S, it appears that Saudi audience are more persuaded and motivated to increase their physical activity level using the StepsBooster-S than Canadian individuals. This result is in line with our hypothesis that culturally-tailored persuasive apps will be more effective at promoting intended behaviour, than a generic or random design. StepsBooster-S was tailored to be more appropriate for the Saudi audience using the results from our models that show the determinants of physical activity for both Canadian and Saudi audience, see Chapter 3. Therefore, we can conclude that StepsBooster-S was more appropriate for the Saudi audience, and hence they found it significantly more persuasive and

effective at promoting physical activity than Canadians, as it is intentionally tailored for the Saudi population.

5.4.6 Examining the Preference of StepsBooster-S Features

Overall Preference for the Features

We are interested in examining the differences in the preference for the implemented features in StepsBooster-S between Saudis and Canadians beside the participants' overall features preference. To achieve this, we conducted one-sample t-tests separately on the data obtained from features preference questions in the post-study questionnaire (APPENDIX J) for each group and on the combined data to get an overall preference of StepsBooster-S features.

The preference for the features was measured using participants agreement with a 7-point Likert scale ranging from "1 = Strongly disagree" to "7 = Strongly agree". Sample questions are below: " *The leaderboard helped me to be physically active because I want to be on top*", "*Rewarding me with hearts and health scores /badges motivated me to finish my challenges*".

	N=30				
	Mean	SD	MD	t	P
Overall Reward	6.27	1.143	2.267	10.865	.000
Overall Leaderboard	6.20	1.215	2.200	9.919	.000
Overall Team Challenge	5.77	1.695	1.767	5.707	.000
Overall Punishment	5.23	1.995	1.233	3.387	.002
Overall Reminder	5.20	1.648	1.200	3.987	.000
Overall Suggestions	5.20	1.648	1.200	3.987	.000

Table 5.12 - Means and standard deviations (SD), mean difference (MD), t-values (t), and significance levels (p) for overall preference of reward, leaderboard, team challenge, punishment, reminder, and suggestions on a scale from 1 (strongly disagree) to 7 (strongly agree) for the post-study questionnaire.

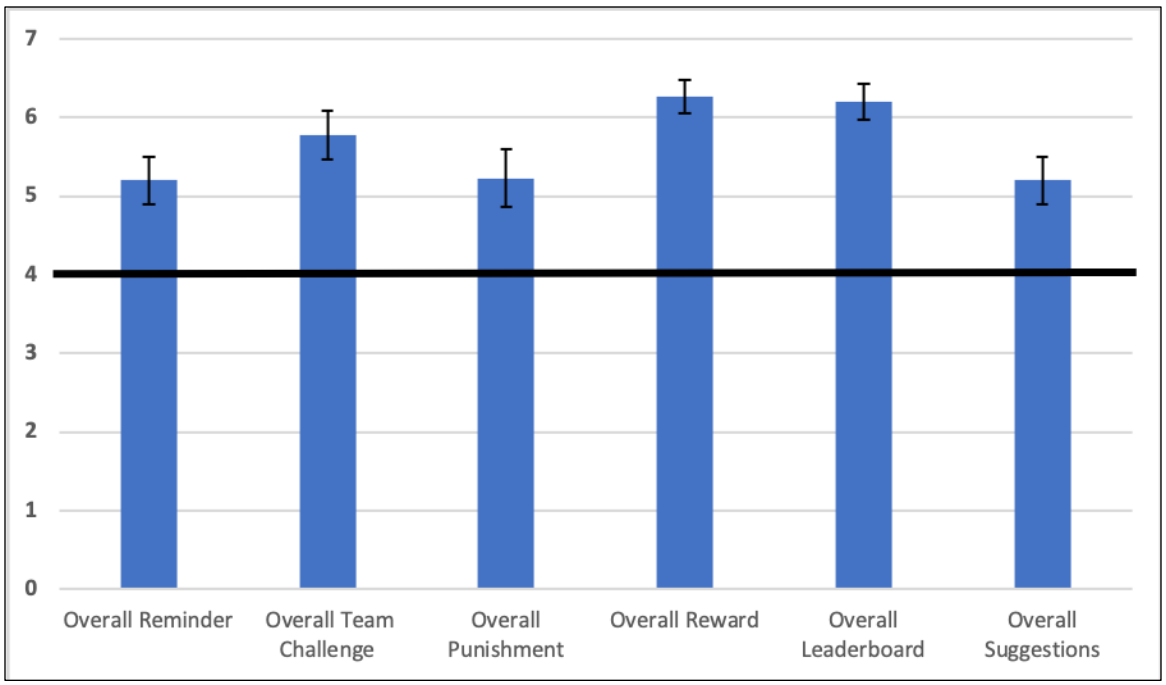


Figure 5.6 - The means of overall preference of StepsBooster-S features. Error bars represent a 95% confidence interval.

We compared this data against an optimistic neutral point/mid-point of 4 for our questionnaire's 7-point Likert scale. Figure 5.6 and Table 5.12 show the details of the overall preference of the StepsBooster-S features. In general, participants experienced high preference regarding the features: reward, leaderboard, team challenge, punishment, reminder and suggestions. As presented in Figure 5.6 and Table 5.12, the means of the individual features and the corresponding t-value are over the neutral point/mid-point of 4. Hence, StepsBooster-S was successful at encouraging physical activity behaviour overall. Overall, our participants preferred reward the most, it is followed by leaderboard, team challenge and punishment in decreasing order of preference. Reminder and suggestions emerged as the least preferred features overall.

Individual Preference of the Features

Similarly, Canadian and Saudi participants individually showed high preference for the features implemented in StepsBooster-S. Table 5.13 presents the p-values and the corresponding mean of the features preferred by each cultural group, all of which were over the neutral point/mid-point of 4. This was done by running one sample t-test on each group individually. As shown in Figure 5.7, Canadian and Saudi participants, therefore, highly rated StepsBooster-S features, though the

Saudi participants seemed to prefer the features more. Since all participants had positive experiences with StepsBooster-S features, we next examine whether there is any significant difference in the level of preference between Canadians and Saudis using the independent sample t-test.

Table 5.13 - Means and standard deviations (SD), mean difference (MD), t-values (t), and significance levels (p) for individual preference of reminder, team challenge, punishment, reward, leaderboard and suggestions on a scale from 1 (strongly disagree) to 7 (strongly agree) for the post-study questionnaire

	N=15 Canada					N=15 Saudi				
	Mean	SD	MD	t	P	Mean	SD	MD	t	P
Reminder	4.87	1.727	.867	1.944	.072	5.53	1.552	1.533	3.826	.002
Team Challenge	5.27	1.981	1.267	2.477	.027	6.27	1.223	2.267	7.179	.000
Punishment	4.33	1.915	.333	.674	.511	6.13	1.685	2.133	4.904	.000
Reward	6.13	1.302	2.133	6.346	.000	6.40	.986	2.400	9.431	.000
Leaderboard	5.80	1.474	1.800	4.731	.000	6.60	.737	2.600	13.667	.000
Suggestions	4.53	1.807	.533	1.143	.272	5.87	1.187	1.867	6.089	.000

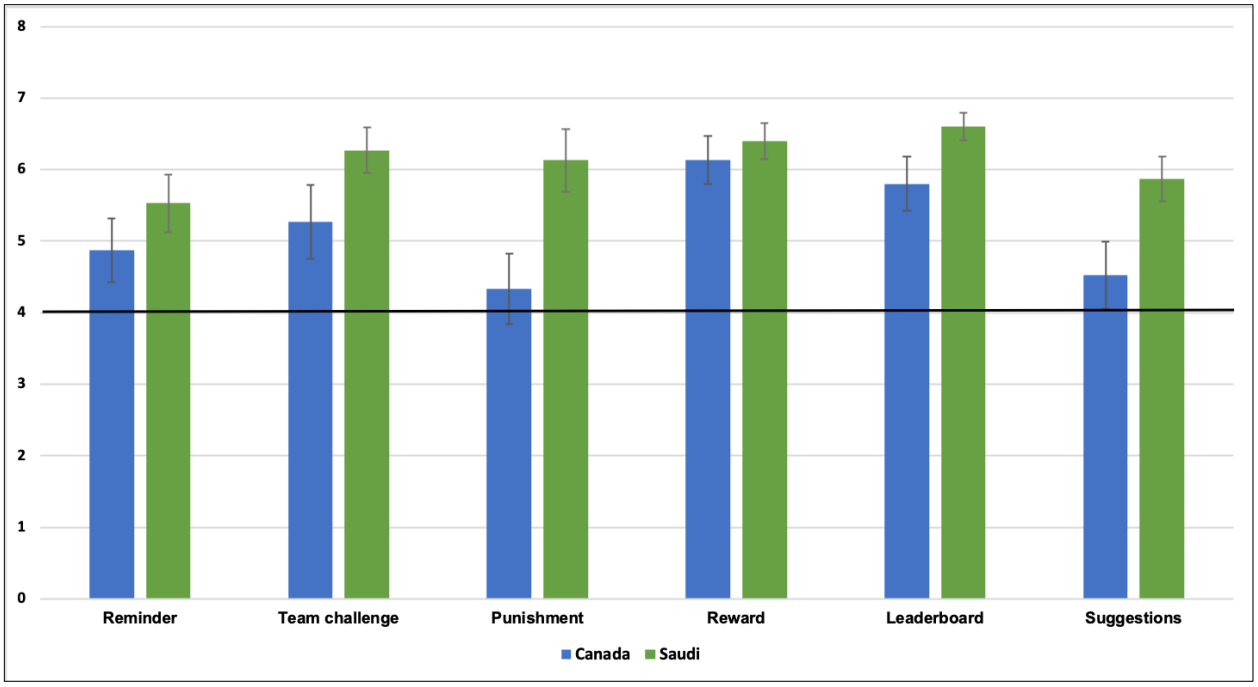


Figure 5.7 - A bar graph of the mean of individual preference of StepsBooster-S features for Canadians and Saudis. Error bars represent a 95% confidence interval.

5.4.7 Examining Preference of the Features by Cultural Group

We conducted an independent sample t-test to examine for possible significant difference in the level of preference for StepsBooster-S features between the Canadian and Saudi groups (See Table 5.14 and Table 5.15). Figure 5.8 shows the mean of feature preferences by cultural group, with error bars representing a 95% confidence interval.

Table 5.14 - Descriptive Statistics for StepsBooster-S Features Preference by Cultural Group

Group Statistics

	Country	N	Mean	Std. Deviation	Std. Error Mean
Reminder	Canada	15	4.87	1.727	.446
	Saudi	15	5.53	1.552	.401
Team Challenge	Canada	15	5.27	1.981	.511
	Saudi	15	6.27	1.223	.316
Punishment	Canada	15	4.33	1.915	.494
	Saudi	15	6.13	1.685	.435
Reward	Canada	15	6.13	1.302	.336
	Saudi	15	6.40	.986	.254
Leaderboard	Canada	15	5.80	1.474	.380
	Saudi	15	6.60	.737	.190
Suggestions	Canada	15	4.53	1.807	.467
	Saudi	15	5.87	1.187	.307

Table 5.15 - Independent Samples t-test for StepsBooster-S Feature Preference by Cultural Group

	Independent Samples Test					95% Confidence Interval of the Difference	
	t	df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Reminder	-1.112	28	.276	-.667	.599	-1.895	.561
Team Challenge	-1.664	23.317	.110	-1.000	.601	-2.242	.242
Punishment	-2.733	28	.011	-1.800	.659	-3.149	-.451
Reward	-.632	28	.532	-.267	.422	-1.130	.597
Leaderboard	-1.881	20.588	.074	-.800	.425	-1.686	.086
Suggestions	-2.388	28	.024	-1.333	.558	-2.477	-.190

Reminder: The results show no significant difference in the scores for the reminder feature between Canadian people (M = 4.87, SD =1.72) and Saudi people (M = 5.53, SD =1.55); t (28) = -1.112, p = 0.276. This result is in line with the results of our extended HBM model, that show that the cues to action (CUA) determinant scored in the top three HBM determinants for both the Canadian and Saudi groups.

Team challenge: Similar to reminder, the results show no significant difference between the Canadian and Saudi groups with respect to their preference for the team challenge (M = 5.27, SD =1.98), (M = 6.27, SD = 1.22); t (22.317) = -1.664, p = 0.110, respectively, although Saudi showed higher preference for the team challenge, but the difference is not statistically significant. This result is in line with the results from extended HBM model, that show the social influence (SI) determinant scored in the top three HBM determinants for both Canadian and Saudi audiences. However, Saudis are more affected by social influence than Canadians which clearly can be seen from the number of team challenges completed in each group.

Punishment: The results reveal a significant difference in the scores for the punishment feature between Canadian people (M = 4.33, SD =1.91) and Saudi audience (M = 6.13, SD =1.68); t (28) = -2.733, p = 0.01. This result is in line with the results of our extended HBM survey, as the perceived severity (SEV) determinant (which mapped to the punishment feature) scored in the top three HBM determinants for Saudi people, but not for Canadians. This implies that punishment is more effective for the Saudi group in motivating their physical activity behaviour compared to the Canadian group.

Reward: In contrast to punishment, the results show no significant difference in the scores for the reward feature between Canadian people (M = 6.13, SD =1.30) and Saudi people (M = 6.40, SD = 0.98); t (28) = -.632, p= 0.532.

Leaderboard: The results show no significant difference in the preference scores for the leaderboard feature between Canadian participants (M = 5.80, SD = 1.47) and Saudi participants (M = 6.60, SD = 0.73); t (20.588) = -1.881, p = 0.074. These are surprising results, as we expected Canadians to score higher than Saudis on the leaderboard feature, as Canadian people

are characterized as more competitive. However, this implies that Saudi people may have a competitive nature, too, and they can be motivated by competitive features such as a leaderboard to promote their physical activity behaviour.

Suggestions: The results reveal a significant difference in the scores for suggestion feature between Canadian people (M = 4.53, SD =1.80) and Saudi people (M = 5.87, SD = 1.18); t (28) = -2.388, p = 0.02. These results can be explained, as Saudi participants appreciated the suggestions from StepsBooster-S more often than Canadian participants.

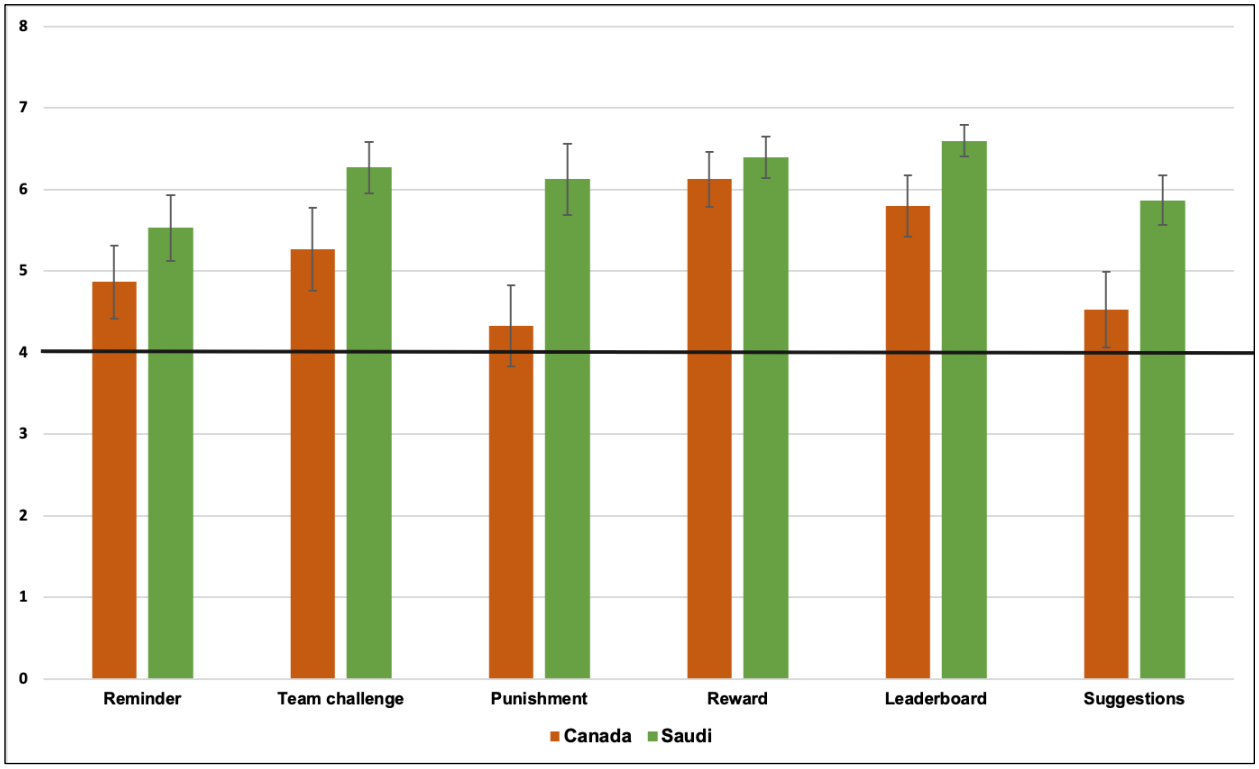


Figure 5.8 - A Bar Graph of the Mean of Feature Preference by Cultural Group. Error Bars Represent a 95% Confidence Interval.

5.5 Thematic Analysis

The qualitative part of the thesis, is the participant interviews (30 participants, 15 Saudi and 15 Canadians), was audio-recorded and transcribed verbatim. Interview transcripts were analyzed using inductive thematic analysis [11]. This type of analysis was selected because it allows for the analysis of a large data set in a systematic way that helps to understand the patterns found in

the text while considering the context [35]. It also allows us to examine the perspectives of different research participants, highlighting similarities and differences, and producing unanticipated insights and themes. Moreover, it is useful for summarizing key characteristics of a large data set, as it requires the researcher to take a well-structured approach to handle data and deliver a clear final report [67].

We followed Braun & Clarke's six-phase framework for conducting a thematic analysis [11]: (1) becoming familiarized with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. Saudi and Canadian transcripts were considered as two different datasets and were analyzed separately. The inductive thematic analysis we used means that we did not have predefined codes. Therefore, we developed, expanded, and modified the codes during the coding process as any new themes emerged. The principal investigator and another researcher individually coded some sample transcripts (5 Saudi and 5 Canadian interview transcripts) to identify a core set of codes. The researchers then compared initial codes, examined similarities and differences and collaboratively selected which codes to apply. The remaining transcripts were coded based on the initial codes, and the set were extended as necessary. For each new transcript, both researchers together manually examined all the texts from the interviews and coded them accordingly. After, they discussed and resolved any disagreement. A new code was generated if it did not match with any existing codes. The next phase involved searching for themes; both researchers reviewed the codes one by one and organized the findings to combine different codes that focus on similar aspects. Subsequently, the ordered data were organized into themes (See Figure 5.9, Figure 5.10, Figure 5.11, and Figure 5.12). After having determined and named themes, examples and quotes from relevant transcripts were chosen to illustrate themes. Some Saudi participants preferred to be interviewed in Arabic. Thus, the principal investigator translated the Arabic interviews into English during the transcribing process, as she is fluent in both languages. All datasets were analyzed in English in addition to coding, themes, and illustrative quotes.

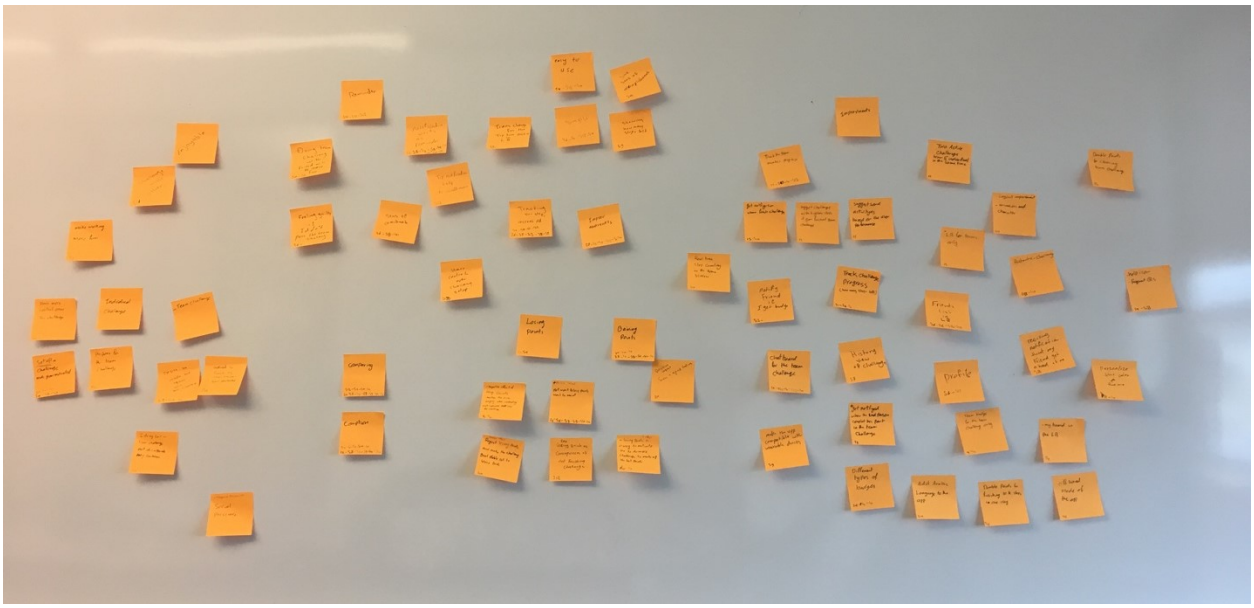


Figure 5.9 - Initial Codes of Thematic Analysis for the Saudi Sample

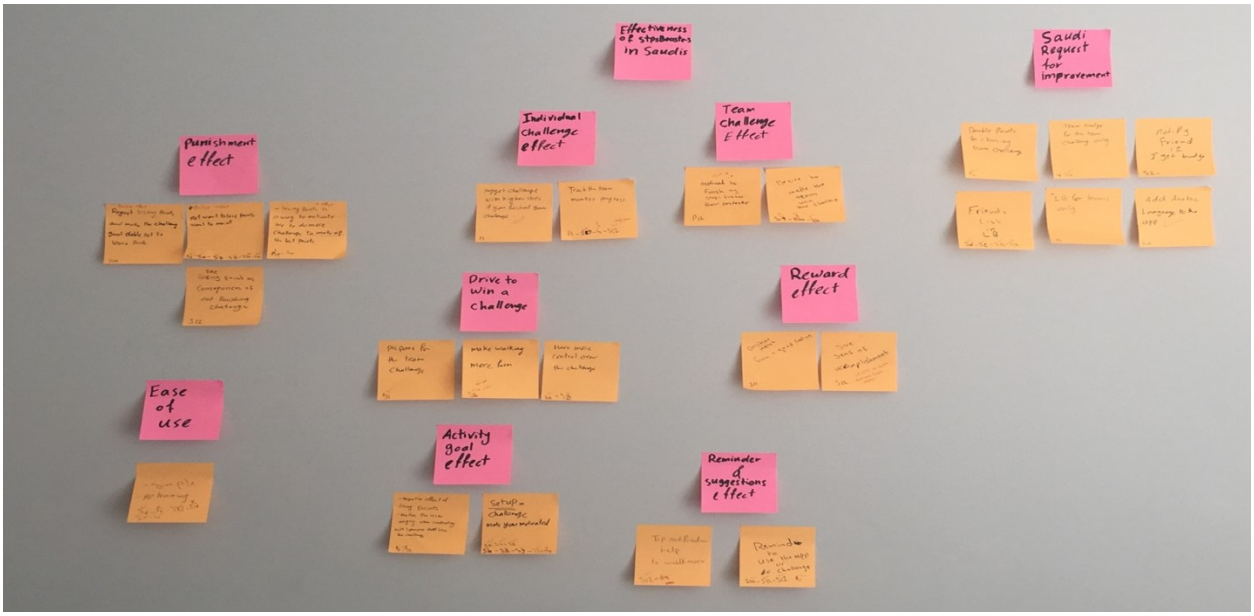


Figure 5.10 - Final Themes and Subthemes of Thematic Analysis for the Saudi Sample

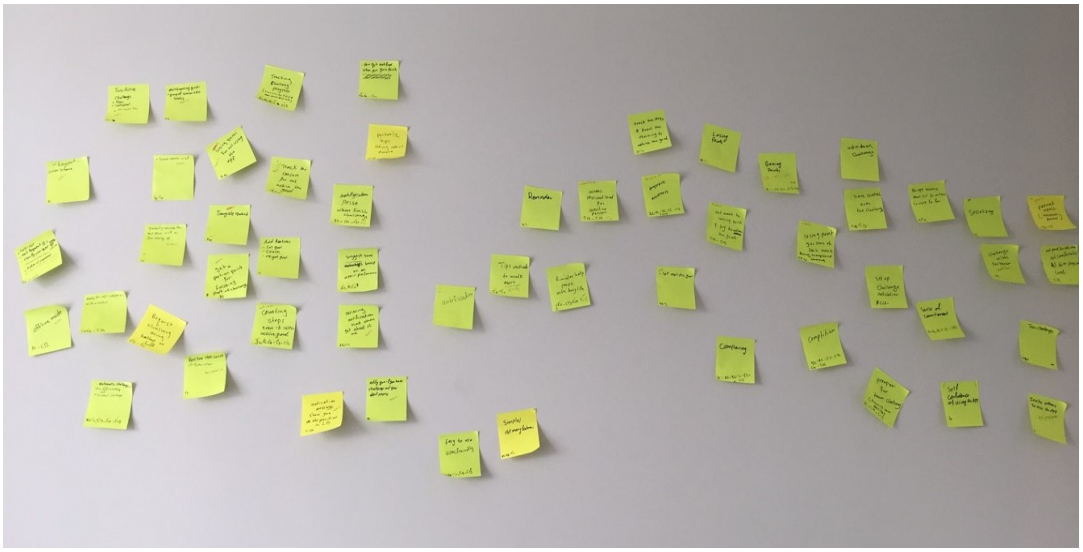


Figure 5.11- Initial Codes of Thematic Analysis for the Canadian Sample

Figure 5.12 - Final Themes and Subthemes of Thematic Analysis for the Canadian Sample

5.5.1 Thematic Analysis Results

In total, two main themes were developed to answer our research question "*How do Saudis and Canadians use the culturally tailored app to support their physical activity?*" and were labeled: "effectiveness of StepsBooster-S at enhancing physical activity" and "requests for improvement".

Overall, eight subthemes emerged from both Canadian and Saudi data with respect to the effectiveness of StepsBooster-S at enhancing their physical activity: "Individual challenge effect", "team challenge effect", "reward effect" "punishment effect," "drive to win a challenge," "activity goal effect," "reminder and suggestions effect", and "ease of use". Surprisingly, both the Saudi and Canadian datasets had exactly the same themes and subthemes. The only difference is on the main points and example comments that support each subtheme.

Effectiveness of StepsBooster-S at Enhancing Physical Activity

We refer to the participant's quotes on the Canadian side using [P-Cid], where C = Canadian participant and id = a unique number used for identifying each participant. Also, we refer to the participants' quotes from the Saudi side using [P-Sid], where S = Saudi participant and id = a unique number used in identifying each participant.

Subtheme 1: Individual Challenge Effect

Canadian

Many of our Canadian participants liked this type of challenge for five main reasons: (1) It gives them control, (2) Gives them a sense of commitment, and (3) prepares people and help them build self-confidence to embark in team challenge.

1- They have more control over setting up the number of steps in the challenges based on their schedule and availability. Some sample comments are as below:

- *"I liked the individual challenges, the fact that **I could control** how much I set myself up for, and I could change it anytime I wanted to. So, one day is a thousand steps, and other days it's going to be 500. So, it was really up to me"* [P-C12].

2- Setting up individual challenges motivated them and gave them a sense of commitment to complete their challenges. Some sample comments are as below:

- *"It's like a **schedule that you have to maintain**, you know, you have a goal set in mind. You want to achieve it"* [P-C7].

3- The individual challenges enable participants to gauge their own ability and prepare them for the team challenges as mentioned by participants below:

- *"I just was challenging myself in individual challenges just to see if I would stick to it, and then if I did, I would open myself up then I would go, okay, **I can do the team. I am confident to do it.**"* [P-C14].

Saudi Arabian

1- Individual challenges can be developed to become a habit for Saudi people. Some sample comments as below:

- *"I think by the time **it becomes a habit to set up challenges** and try to meet them"* [P-S15].

2- Saudi participants appreciate the flexibility of the individual challenges to fit their schedule. *"The individual challenge I feel it give me more **freedom to walk based on my schedule"*** [P-S15].

3- The individual challenge also helped Saudi participants to prepare for the team challenge

- *"At the beginning of using the app, I started with the individual challenge, it is like a **preparation phase for the team challenge"** [P-S13].*

Subtheme 2: Team Challenge Effect

Canadians

1- Some Canadian participants had a pleasant experience with the team challenge, as it helped them with socializing such as invite partners to use the app. Please note that the majority of our participants don't know each other, and few participants voluntarily asked their partners to use the app with them. Sample comments are below:

- "*This is my first experience counting my steps; it gave me a way to calculate how active I am, and I also like it and* ***told my husband about it so we can do the team challenge together***" [P-C1].

2- However, some participants had an uncomfortable experience with the team challenges, as it may demotivate introverted people and the ones who lack confidence in their physical activity level. Sample comments are below:

- *"I'm* ***an introvert****, so I like to do stuff on my own. Like when I go for my walk at lunch, and it's my thing to get away from everything. But someone who's more kind of influenced to do things in a group setting might like to have the team challenge"* [P-C5].

- *"I think that the team challenge is good for some people, but it would also be possibly* ***intimidating to other people who are not as comfortable about their exercise level****, and they would be reluctant to use it"* [P-C13].

Hence, theme challenge may be suitable for people who are confident in themselves and their ability to achieve the desired behaviour.

Saudi Arabian

The concept behind the team challenge is to make two users cooperate together to achieve the team step goal.

1- Team challenge maintains a sense of cooperation in Saudi participants. Cooperation is a known attribute of collectivist cultures, and team challenges fostered this attribute in Saudi participants. Sample comments are below:

- *"I was personally motivated to do the team challenge more than the individual because with real people,* ***it will create a sense of cooperation*** *"* [P-S13].

2- Team challenge made Saudis to behave as good supportive partners to win the challenge.

- *"*I motivated much to do my part of the challenge, ***so I don't want to be the one who is causing our team to lose****"* [P-S9].

- *"It motivates me to try **to be a good partner** in the team and do my part of the challenge so our team can win"* [P-S11].

Subtheme 3: Reward Effect

Canadian

There are three types of rewards in StepsBooster-S that users can gain when they completed their goals: hearts, badges, and health score. Canadian participants were interested in getting rewards more specifically badges, rewards gave them a good feeling when they accomplished their goals; therefore, they were motivated to do more challenges. Some sample comments below:

*"It's nice kind of getting the badges because **it makes you feel good when you see them adding up**."* [P-C5].

*"It's kind of a reward for me, and I really like the badges more as **I continue to do this, and I will, I will get more badges**"* [P-C14].

Saudi Arabian

1- Rewards in StepsBooster-S increased the engagement with the app for Saudi participants e.g.

- *"It keeps **me attached to the app**, to use it"* [P-S3].

2- Rewards gave Saudi participants a pleasurable feeling when earning any of the reward types (hearts, health score, badges). Example comments below:

- *"It makes me **feel good when I gain new hearts or badges** "* [P-S11].
- *"I **feel happy when I see my badges**; that is why I keep collecting "* [P-S14].

3- Rewards also gave Saudi participants a feeling of health improvements especially when the health score is increasing as this is our intended goal of designing this type of reward. Example comments below:

- *"I like the health score; it is very motivating, as you **feel that you are improving your health"*** [P-S15].
- *"feeling **rewarded for my health** actually"* [P-S5].

Subtheme 4: Punishment Effect

Canadian

Canadian participants perceived punishment differently as below:

1- Some saw punishment as motivating, and they felt they should complete their challenges to avoid losing any rewards, even if it was late at night, e.g.

- *"For me, definitely motivating. I don't like losing. I would say **there was no way I would ever lose a badge because no matter how late it was at night it was 11 o'clock at night** and I noticed that I had to do 1000 steps or lose, so I walk them"* [P-C15].

2- Others were motivated by punishment as it makes them do more challenges to make up the lost rewards *e.g.*

- *"When I lost two hearts, I **created another two challenges to get back these two hearts**"* [P-C2].

3- However, some Canadians perceived punishment as a demotivating factor for doing more challenges as it gives them a sense of failure if they accomplished part of their goals only. e.g.

- *"I think it would be more positive to earn part reward rather than losing rewards if I finished half of my challenge, like my challenge is 5000 and I did 2500, **so that is a fail, but I did accomplish something**"* [P-C3]

Saudi Arabian

Most of Saudi participants perceived punishment as a motivating factor to complete their challenges. Punishment was motivating and affected them positively toward achieving their activity goals. The number of Saudis who were motivated by punishment was high (11 out of 15), this validated our extended HBM model's results when Saudis scored high in perceived severity (SEV), and this proves that Saudis are motivated by punishment.

1- Saudi participants wanted to maintain their rewards and did not want to lose them e.g.

- "*If I already have a badge, then I lost it. I think it's a good feature because* ***you would want to maintain it****"* [P-S2].

2- Saudis were motivated to do more challenges to make up for any lost rewards. e.g.

- *"It will help by doing more challenges to* ***make up for my lost badges***." [P-S13].
- *"I will do another challenge* ***to make up the lost hearts****"* [P-S15].

3- Saudi participants perceived that punishment is a consequence of not completing their challenges, which indicates that their level of physical activity is decreasing, e.g.

- *"If I did not do my challenges, that means my performance is decreased, and* ***I will be punished by losing my rewards***" [P-S12].

4- However, few Saudi participants stated that punishment may discourage them by developing feel of anger and disappointment of the team member who did not complete his part of the team challenge, which results in deducting rewards from both users. *e.g.*

- ***"It makes me angry when I lost rewards*** *when I cooperate with someone and he did not do his part of the challenge"* [P-S5].

Subtheme 5: Drive to win a challenge

Canadian

Canadians are motivated to win challenges not only to earn rewards but also to score high in the leaderboard. Sample comments are below:

- *"It actually made me feel like I wanted to do more steps* ***just to get on top of the leaderboard****"* [P-C4].
- *" I think that's what kind of sort of pushed me to try the 3,000…. it's like* ***it'll bring me up to that next level****"* [P-C5].

- *"Every time I complete the challenge, I check the leaderboard and see where I am. Every single time I open the app,* ***I check my position in the leaderboard****"* [P-C15].

Saudi Arabian

1- Saudi participants are motivated to win challenges to get high positions in the leaderboard e.g.

- *"I had to walk more steps because I wanted* ***to have a higher ranking in the leaderboard****"* [P-S2].

2- Saudi participants cared more about their ranking on the leaderboard if it could be seen by friends. Saudi people are more impacted by social influence, which is considered positive in this case to motivate Saudis to walk more and improve their positions on the leaderboard e.g.

- *"****showing my rank between my friends and other users,*** *makes me try to improve my numbers"* [P-S10].

Subtheme 6: Activity Goal Effect

Canadian

1- Activity goals helped Canadians in improving their awareness of how many steps they take every day. Sample of their comments are below:

- *"I was concerned about how much I walk every day because I commute travelling between university, bus and home, but after using the app,* ***I got some knowledge about that****"*
  [P-C2].
- *" I never counted my steps before, and this kind of* ***gave me a sense of how many steps I was getting***" [P-C4].
- *" ....* ***It has made me more aware****"* [P-C13].

2- StepsBooster-S helped Canadians set realistic goals when they created their challenges, as they initially became more aware of their daily steps. Then, their challenge goals could be easier to accomplish or even ensure their ability to hit an activity goal. Examples comments are below:

- *"It **helps me to set a realistic goal**, so my initial challenge was 100 steps, so I accomplish that very quickly" [P-C3].*

- *" if I know it's gonna be the same kind of day, it will give me some education **on what the realistic goal would be**, so I would not put in 70,000 in one day but 5000 probably" [P-C3].*

- *"At first, I started doing 10,000 step challenges, and then I slowly decreased it just because **I wanted to be sure I could hit it**" [P-C4].*

Saudi Arabian

1- StepsBooster-s helped Saudis to have some education about how much time they need to complete certain number of steps. Sample example below:

- *"I have no idea how much I walk a day, but after using StepsBooster-S I am surprised by how many steps I walk so **I can do 100 steps few minutes**"* [P-S12].

2- One significant outcome that Saudi participants reported after using StepsBooster-S is that their physical activity level increased because they had to walk more (including indoor or outdoor walking) to finish their ongoing challenges. Sample examples below:

- ***"I feel my physical activity level significantly increased** after using the app because **I increased my outdoors walks more than four times a week**, as I have to complete my challenges"*[P-S7].
- *"It really **increased my physical activity**, as I **move more to complete my challenges**"* [P-S8].

Subtheme 7: Reminder and suggestions effect

Canadian

1- The reminder in StepsBooster-S helped Canadians complete their challenges, especially those with a busy lifestyle like mothers and teachers. Below are supported examples:

- *"There are some days that I really forgot about it,* ***so when I see the reminder on my screen, I say 'yes, I have to go and do my challenge****"* [P-C1].

- *"I am a teacher; I find for me, just based on my lifestyle,* ***I do find the reminders to be useful to do the challenges****"* [P-C13].

2- Sometimes the suggestions from the App works as a reminder to help in remembering the challenges. Some sample examples are below:

- *"When I get suggestions, I read them,* ***and I remember*** *because I set a challenge, and I know I have to do it"* [P-C8].
- *"They helped because* ***they remind me*** *if I forgot about my challenges, I go and set up one"*
  [P-C11].

3- Furthermore, suggestions motivated Canadians to walk more and reach their goal quickly when they noticed them on their phone screen. Sample examples are below:

- *"I like* suggestions, *especially the one to park further away so you can get more steps, and when I follow it,* ***that's the time to reach my goal very quickly****" [P-C1].*

- *"I remember a* suggestion *said like taking a longer walk or whatever. I know that seeing that* suggestions *kind of motivated me one day, it was a nice day, and I was kinda liked it, I could probably walk a little bit further. Then, I ended up* ***completing that challenge faster than I expected****" [P-C5].*

Saudi Arabian

1- Saudi participants reported that the reminder helped them to set their challenges early as they usually set the reminder in the morning so they can set up challenges during the day.

- *"It helps me that when I wake up in the morning, **I set my challenges and start them early** in the day"* [P-S12].

2- Saudi participants liked how the suggestions were structured and presented to them on the screen. This helped to accept and follow them easily without feeling like it is a nuisance. e.g.

- *"It's actually very good because they have some **nice way of saying these suggestions**, not like some other apps" [P-S4].*

Subtheme 8: Ease of use

Canadian

Canadians admired StepsBooster-S for the clarity in the interface design which helped to perform the tasks easily. Some sample comments below:

- *"it pretty **straightforward** and **not complicated**."* [P-C1].
- *" it is very straightforward and **very organized** "* [P-C8].
- *"it's **very intuitive**"* [P-C10].
- *"The interface is **very practical** and **very easy to use**"* [P-C13].
- *"**it's simple**. It's not complicated"* [P-C7].

Saudi Arabian

Saudis appreciated how StepsBooster-S is explicitly designed to use without require training or giving many instructions. Sample comments below:

- *"The app is **easy to use**, and **the design is clear to me**."* [P-S12].
- *"I like how **straightforward** is the app. It **does not need any education**"* [P-S14].
- *"It's very easy to use and **doesn't require training**"* [P-S4].
- *"I do like **the simplicity of the app** "* [P-S7].

Requests for Improvement:

Canadian

Canadian participants suggested some improvements and what they think could be done in the future to improve the app.

1- Canadians would appreciate it if the app could track not only steps but also other health goals such as fat goals, weight goals, and calories e.g.

- *"If it has a way to **track your weight and like your fat goals and calories**, because I know that's something people worry about"* [P-C6].

2- Canadians would like if the app could suggest some challenge goals based on the user's performance *e.g.*

- *"You've already **reached yesterday's goal**. Would you **like to set a new goal for today**?"* [P-C12]

3- They would like to be able to schedule multiple challenges for the next days

- *"I would like to be able to set up challenges or **schedule them for the future***" [P-C10].

4- Canadians would appreciate having the app be compatible with a watch or other wearable devices. e.g.

- *"If it were in **a more portable version** of it like **wearable devices**, something you can wear easily*" [P-C5].

Saudi Arabian

Saudi participants suggested some improvements and what they believe could be changed in the future to enhance the app.

1- As Saudis are more motivated by social influenced, they would appreciate double points for choosing team challenges besides establishing the team badges for winning multiple team challenges. e.g.

- "*If you choose to do the team challenge,* ***you double up your points, and you get the team challenge badge"*** [P-S13].

This supports our model that Saudis are motivated by social influence; hence, they prefer that more reward be awarded to them for cooperating with others.

2- A participant suggested if the app could notify her friends once she got a badge as recognition for her effort in the challenge and as a motivation to the others. *e.g.*

- *"Whenever* ***I get a badge****,* ***all of my friends should get notified*** *that I got that. I would want people to know that I got that badge"* [P-S2].

3- Saudi participants valued the concept of the leaderboard and suggested a specific category in the leaderboard for friends only e.g.

- *"It will be nice to* ***have a friends list in the leaderboard"*** [P-S2].

4- They also suggested implementing a team list beside the personal list in the leaderboard e.g.

- *"if there is a* ***leaderboard for teams*** *it's going to be interesting"* [P-S1].

5- Saudis stated that they would highly appreciate it if the Arabic language was added to the app in addition to the English language so the user could have the freedom to choose any language. e.g.

- *"I would like to* ***see the app in Arabic****, not only English"* [P-S14].

Theme	Subtheme	Key points for Canadians	Key points for Saudis
Effectiveness of StepsBooster-S at enhancing physical activity	Individual challenge effect	- Control over challenges - Sense of commitment to do challenges. - Prepare for team challenges	- Challenges become a habit - Fit schedule - Prepare for the team challenge
	Team challenge effect	- Improve socializing (invite partners) - May demotivate introverted and unconfident people	- Maintain sense of cooperation - Made Saudis behave as good challenge partners
	Reward effect	- good feeling when accomplish goal	- Increase engagement with the app - Pleasurable feeling - Feeling of improving health
	Punishment effect	- Fear of lose rewards - Make up the lost rewards - Sense of failure in partially completed goals	- Maintain rewards and did not lose them - Make up lost rewards - A consequence of not completing challenges - Developing feel of disappointment of a team member if not complete his part of the challenge
	Drive to win a challenge	- Score high in the leaderboard	- High positions in the leaderboard - Cared more about leaderboard ranking if seen by friends
	Activity goal effect	- Improve awareness of daily steps - Set realistic goals	- Gauge time needed for certain number of steps. - Increase physical activity level
	Reminder and suggestions effect	-Help busy people to do challenges -Suggestions act as a reminder - Suggestions help to reach the goal quickly	- Set challenges early - Admire suggestions' structure and presentation
	Ease of use	- Clear interface design	- Appreciate simple design as it doesn't require training

Requests for improvement		- Track other health goals (fat, weight, and calories) - Suggest challenge goals based on performance - Schedule multiple challenges for future - App compatible with wearable devices (watch)	- Double points for doing team challenges + team challenges badges - Notify friends when a badge awarded - Friends list in the leaderboard - Teams list in the leaderboard - Arabic language option

Table 5.16 - Summary of Themes, Subthemes, and Key Points of Thematic Analysis in Canadians and Saudis

5.6 Discussion:

This dissertation explored the importance of culture for tailoring persuasive technology for motivating physical activity. Our app, StepsBooster-S, was based on a large-scale study of extended HBM determinants influencing people's physical activity behaviour. The evaluation of StepsBooster-S, which is presented earlier in this chapter, shows that the level of physical activity increased in both Saudi and Canadian participants, and all the implemented persuasive strategies were more effective at motivating the physical activity of Saudi participants.

After ten days of using the app, Saudi participants were motivated more by team challenges compared to Canadian participants. This is because the team challenges foster a specific cultural attribute (cooperation) in Saudis. The team challenges also encourage Saudis to behave as a good supportive partner to complete the challenges. People in a collectivist society usually respond with whatever the collective expects without opposing the desire of the collective. Based on collectivist principles, these individuals enjoy doing what is requested from them, and self-advantages or personal goals do not play a significant role in their decisions or behaviours [54]. Within a collectivist framework, it is feasible to expect that Saudi participants are more engaged in the team challenges, and this positively affected their physical activity behaviour. This is as predicted by our models, that social influence which is mapped to the team challenge would motivate the Saudis more than the Canadians.

However, some Canadian participants were reluctant to take part in the team challenges. They seem to be very focused on their personal goals (individual challenges) and neglected the collective goals as our results revealed in the number of team challenges completed by Canadians. This clearly reflects the individualist characteristics of Canadians, as they are culturally characterized to be more autonomous and competitive. In the follow-up interviews, Canadians also explained that the team challenges may create uncomfortable experiences for introverted people. Another reason is that they may lack confidence in their activity level, which may cause them to experience some hesitation about cooperating with someone. One interpretation of this is that Canadians may have personal goals that are conflicting with the

goals of their team challenges. When inconsistency exists between the individual and the group, there is a natural tendency for the individual goal to override the collective goals in individualists culture.

In our Saudi and Canadian samples, we have married couple participants living together, which gives them more opportunities to try the team challenge, as they both had StepsBooster-S installed. Saudi couples created multiple team challenges and collectively reached their step goals, while Canadian couples never created a team challenge; instead, they challenged each other to get a higher ranking on the leaderboard. *"I am a very competitive person. I was determined to beat my wife, and I did"* [P-C15]. Despite Canadians' reluctance to create team challenges, some of them liked this feature, as their personalities are more open, and they are more likely to do any form of physical activity in a group setting.

Surprisingly, Saudi participants rated the leaderboard feature higher than Canadian participants, even though Saudis are culturally characterized as less competitive compared to Canadians. A possible explanation for this is that age may have impacted the level of competition of both Canadian and Saudi participants. According to the demographic results of the post-study questionnaire, five Canadian participants were over 46 years, and only one Saudi participant was over 46. Young people are generally more competitive than old people irrespective of culture [13][9]. This means that the vast majority of the Saudi sample (14 participants) were younger than 46. This is also in line with previous literature, which shows that younger individuals are more competitive compared to older ones [13][9]. This result suggested that age can affect the level of competitiveness in the target population despite different cultural orientation. Also, we suggest that a competition strategy can be implemented for people from collective societies if the target age group for the physical activity motivational intervention is younger adults (younger than 46 years). We also suggest that collaborative competition that allow people to cooperate within a team while competing with other teams [75] may even be more effective for the Saudi audience considering their inclination to communal living and the impact of social influence. Therefore, we suggest considering the influence of age along with cultural differences when designing physical activity motivational apps.

Furthermore, Saudi participants seemed to care more about their ranking on the leaderboard if it could be viewed by friends. The desire to show a positive image to other people is often at the top of their motivation for behavioural changes [7]. This also in line with the results from our model which shows that Saudis are positively impacted by social influence to increase their ranking on the leaderboard and perform more challenges. Based on the interviews, Canadians expressed a higher level of competitiveness, as they showed a greater desire to catch the person in first place on the leaderboard and score in a high position. This result is consistent with a previous study indicating that individualistic people are higher in general competitiveness than collectivistic people [26].

However, Saudi participants responded positively to punishment if a challenge was not completed. The positive effect of punishment on motivating Saudis validated our extended HBM modeling results that show that the perceived severity (SEV) scored in the top three determinants of the Saudis physical activity behaviour. Saudis attempted to maintain their rewards and make every possible effort to avoid losing already acquired rewards. They also attempted to create makeup challenges to compensate for the missing rewards. Punishment was also perceived in Saudis as a consequence of failing to complete the challenge and could incentivize them to walk more and reinforce physical activity behaviour. While for Canadians, punishment was shown to be somewhat motivating. Some explanations for the low preference for punishment in Canadians include its tendency to discourage and creating a sense of failure for incomplete or partially accomplished goals.

The reminder and suggestions were confirmed to be effective and preferred features by both Saudis and Canadians. They help to encourage participants to be more active as they nudges participants to take action, such as encouraging them to go for a walk. The reminder and suggestions results obtained from our app evaluation validated our previous extended HBM modeling results, where cue to action (CUA) scored as the top determinant that influence Canadians' physical activity and the second best that influence Saudis.

The simplicity and ease of use positively influenced all participants' perceptions of our app. The simple features of StepsBooster-S contribute to a positive user experience, and participants could

easily understand the app's purpose, with little or low learning curve. Straightforward, practical, and organized design are characteristics highlighted by our participants to express their admiration for the app. StepsBooster-S is not cognitively demanding; thus, it does not require a lot of education or instruction to use. This is important for avoiding negative user experiences, which can create barriers to engagement, adoption, and use of the app for behaviour change.

CHAPTER 6 CONCLUSION

In this chapter, we conclude by highlighting the limitations and contributions and suggesting some directions for future work.

6.1 Limitations

We believe that a ten-day study is not long enough to show true health behaviour change, since we did not examine if the resulted behaviour change in the physical activity level can last for a longer-term. Also, this short evaluation period is not enough to try all the app features, as some participants claimed to be preparing themselves for the team challenges and checking their physical activity level so they could feel confident about cooperating with others. A longer evaluation time such a six-month study [85] would yield more meaningful results.

Another limitation is self-reporting data in our survey and interview studies. The participants were guided to respond to the questions with sincere answers and reflect on their state of mind and the changes in their physical activity. This was done to mitigate the bias effect in the participants' responses. However, self-reporting is still the most common and valid approach for evaluating beliefs and attitudes in the field of HCI.

We can apply our extended HBM survey results to any two countries that are characterized culturally as collectivist and individualist societies to promote physical activity behaviour. However, other important factors for tailoring persuasive interventions such as gender, age, and religious beliefs may moderate the influence of the HBM determinants on physical activity behaviour. Considering these factors in the health intervention design will produce more effective and successful physical activity motivational tools. We considered the moderating effect of gender and age in the current study.

Saudi people are ranked among the top mobile users among other users from Gulf countries [66]. This means that most Saudi Arabians have access to apps and, therefore, have large opportunities to benefit from persuasive applications. We developed StepsBooster-S only for the Android platform, which limits the benefits of the intervention to Android users only. Developing the

StepsBooster-S App to fit other smartphone platforms such as iPhone, Windows Phone and Blackberry will result in a more comprehensive and heterogeneous sample.

Although StepsBooster-S is tailored to Saudi people, it was developed in the English language. This may restrict its effectiveness in some non-English-speaking Saudi users. This issue can be solved by improving our app to include Arabic and English language options. This is easily achievable and will be an immediate future work.

6.2 Future Work

We plan to expand our evaluation study to be more comprehensive by increasing the sample size and extending its duration to six months. We plan also to extend the baseline phase for a longer period as 3 days may not adequate to accurately measure the normal step count of the users before the intervention came into effect. This would help to fully understand the cultural differences in how people use the app to promote physical activity behaviour and how these differences affect the features being tested in the app.

Also, we will measure physical activity levels at different time points during the evaluation of the app. The first one is before using the app (baseline), which will help in testing the behaviour before the intervention. The second time point will be while using the app to allow us to compare the changes in the physical activity level accurately. The last time point is two months after the study to measure the sustainability of the behaviour change and to track the app's effectiveness at motivating physical activity behaviour over a long-term.

We will develop a Canadian version of the app (StepsBooster-C). The persuasive features that will be implemented in this version will be based on our extended HBM modelling results. As self-efficacy factor (EFF) is the main difference between the two versions, we plan to implement it as suggestions and feedback to improve the self-efficacy of the user towards his/ her physical activity milestones by suggesting some activity within the user reach or suggest smaller goals within the user ability to achieve the main physical activity milestone. We also will evaluate StepsBooster-C on both Canadian and Saudi participants. This will create opportunities for a

more comprehensive comparison between the results and allow us to examine how the results would differ from our current results.
We also plan to add an Arabic language option besides the English language for Saudi version. When the users have an option to use their native language, it tends to create a more emotional bond with the app, which increases the user's engagement with the app and, therefore, increases its effectiveness.

We plan to balance the competition and maintain the user's privacy in our leaderboard design by showing the percentages of the goal achieved as performance relative to the goal instead of showing the actual number of steps and see if this would make any difference.

6.3 Contributions

In this dissertation, we successfully designed and developed a culturally tailored persuasive app that can motivate physical activity behaviour. The app employed the user-centered design approach. Before the app design, we conducted a large-scale study to determine and compare factors influencing the physical activity behaviours among Canadian (individualists) and Saudi (collectivists) populations. We also investigated for the moderating effect of age and gender both within and between the cultural groups. Based on the results, we mapped the determinants to their corresponding persuasive strategies and app design features through several consultations and discussion with other researchers and experts in the area of persuasive technology. Finally, we iteratively designed and evaluated the StepsBooster-S app through design, feedback, and refinement phases.

Our app is effective and persuasive in promoting physical activity for all participants overall, however, it showed to be more effective at promoting physical activity among the Saudi audience in comparison to the Canadian audience. StepsBooster-S succeeds at motivating the physical activity of Saudis more than Canadians, as it is intentionally tailored to be culturally appropriate for the Saudi audience using the results from our models. We also conducted a successful short-term evaluation and showed that StepsBooster-S encourages a positive change in physical activity as demonstrated by the increase in step count from the baseline to the intervention stage. More importantly, our persuasive app proves its effectiveness in a non-

Western culture, which contributes to closing the research gap in the area of demonstrating the effectiveness of persuasive technology (physical activity motivating) apps in non-Western societies. Most existing persuasive technology research focused on the Western audience.

This work has led to one publication and two additional papers under preparation. Also, our published paper was presented at the ACM UMAP 2019 ADAPPT (Adaptive and Personalized Persuasive Technology) conference.

PAPER 1 [3]	
Paper Title	How Effective Are Social Influence Strategies in Persuasive Apps for Promoting Physical Activity?: A Systematic Review
Venue	UMAP 2019

PAPER 2	
Paper Title	The Moderating Effect of Culture and Gender in the Effectiveness of Physical Activity Using the Health Belief Model
Venue	Journal

PAPER 3	
Paper Title	StepsBooster-S: A Culturally Tailored Persuasive Application for Promoting Physical Activity
Venue	Journal

6.4 Conclusion

This dissertation makes a contribution to the field of persuasive technology within the human-computer interaction domain. We developed a culturally-tailored persuasive app for motivating physical activity. It explores how persuasive apps can be designed to promote behaviours while considering culture and with a special focus on physical activity behaviour. We designed and developed a persuasive app called StepsBooster-S to encourage physical activity behaviour tailored to be culturally-appropriate for the Saudi adults using the user-centered design approach. Before the app design, we conducted a large-scale study to determine and compare factors influencing the physical activity behaviours among Canadian (individualists) and Saudi (collectivists) populations. We also investigated for the moderating effect of age and gender both within and between the cultural groups. Based on the results, we mapped the determinants to their corresponding persuasive strategies and app design features through several consultations and discussion with other researchers and experts in the area of persuasive technology. Finally, we iteratively designed and evaluated the StepsBooster-S app through design, feedback, and refinement phases.

The results of our app evaluation on 30 participants answered our overarching research questions on the effectiveness of culturally appropriate persuasive app for promoting physical activity among collectivist cultural group (Saudi audience). Particularly, the results show that StepsBooster-S encouraged a positive change in the physical activity behaviour of all participants and, more importantly, in the Saudi participants as it intentionally tailored for this population.

The results also show that our app is highly persuasive and effective, as demonstrated by the significant score in persuasiveness and effectiveness of the app overall and the individual persuasive features. Finally, we observed that StepsBooster-S led to a significant increase in the (steps count) physical activity behaviour of Saudi participants compared with Canadian participants, as the app is tailored for the Saudi population. Considering the positive results, we can conclude that persuasive health apps are more effective if they are tailored to be culturally appropriate to the target audience, that is if culture is taken into account as an important factor in the design.

Finally, we demonstrate how behaviour change theory can be employed to inform persuasive intervention design and how the behavioural determinants from the theory can be translated into design components in the persuasive interventions. Persuasive apps informed by theory tend to be more effective than those based on the intuition [29], our app used the persuasive theory as the basic building block to inform the app design.

BIBLIOGRAPHY

[1] Abroms, L.C., Padmanabhan, N., Thaweethai, L. and Phillips, T. 2011. iPhone apps for smoking cessation: A content analysis. *American Journal of Preventive Medicine*. (2011). DOI:https://doi.org/10.1016/j.amepre.2010.10.032.

[2] Ajzen, I. 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes*. (1991). DOI:https://doi.org/10.1016/0749-5978(91)90020-T.

[3] Almutari, N. and Orji, R. 2019. How effective are social influence strategies in persuasive apps for promoting physical activity? A systematic review. *ACM UMAP 2019 Adjunct - Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization*. June (2019), 167–172. DOI:https://doi.org/10.1145/3314183.3323855.

[4] Anderson, E.S., Wojcik, J.R., Winett, R.A. and Williams, D.M. 2006. Social-cognitive determinants of physical activity: The influence of social support, self-efficacy, outcome expectations, and self-regulation among participants in a church-based health promotion study. *Health Psychology*. (2006). DOI:https://doi.org/10.1037/0278-6133.25.4.510.

[5] Al Ayubi, S.U., Parmanto, B., Branch, R. and Ding, D. 2014. A Persuasive and Social mHealth Application for Physical Activity: A Usability and Feasibility Study. *JMIR mHealth and uHealth*. 2, 2 (2014), e25. DOI:https://doi.org/10.2196/mhealth.2902.

[6] Ayubi, S.U. and Parmanto, B. 2012. PersonA: Persuasive social network for physical Activity. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS* (2012).

[7] Bandura, A. 1986. Social foundations of thought and action : a social cognitive theory / Albert Bandura. *New Jersey: Prentice-Hall, 1986*. (1986).

[8] Bang, M., Torstensson, C. and Katzeff, C. 2006. The powerhouse: A persuasive computer game designed to raise awareness of domestic energy consumption. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (2006).

[9] Böheim, R., Grübl, D. and Lackner, M. 2017. Gender differences in competitiveness. *CESifo DICE Report*.

[10] Boulos, M.N.K., Wheeler, S., Tavares, C. and Jones, R. 2011. How smartphones are changing the face of mobile and participatory healthcare: An overview, with example from eCAALYX. *BioMedical Engineering Online*.

[11] Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*. (2006). DOI:https://doi.org/10.1191/1478088706qp063oa.

[12] Carli, L.L. 2001. Gender and social influence. *Journal of Social Issues*. (2001). DOI:https://doi.org/10.1111/0022-4537.00238.

[13] Cashdan, E. 1998. Are men more competitive than women? *British Journal of Social Psychology*. (1998).

DOI:https://doi.org/10.1111/j.2044-8309.1998.tb01166.x.

[14] Chin, W.W. 1998. The partial least squares approach for structural equation modeling. *Modern methods for business research*.

[15] Ciman, M., Donini, M., Gaggi, O. and Aiolli, F. 2016. Stairstep recognition and counting in a serious Game for increasing users' physical activity. *Personal and Ubiquitous Computing*. 20, 6 (2016), 1015–1033. DOI:https://doi.org/10.1007/s00779-016-0968-y.

[16] Costello, A.B. and Osborne, J.W. 2005. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research and Evaluation*. (2005).

[17] Country Comparison - Hofstede Insights: *https://www.hofstede-insights.com/country-comparison/saudi-arabia/*. Accessed: 2020-03-10.

[18] Country Comparison - Hofstede Insights: *https://www.hofstede-insights.com/country-comparison/canada/*. Accessed: 2020-03-10.

[19] Cowan, L.T., van Wagenen, S.A., Brown, B.A., Hedin, R.J., Seino-Stephan, Y., Hall, P.C. and West, J.H. 2013. Apps of Steel: Are Exercise Apps Providing Consumers With Realistic Expectations?: A Content Analysis of Exercise Apps for Presence of Behavior Change Theory. *Health Education and Behavior*. (2013). DOI:https://doi.org/10.1177/1090198112452126.

[20] van Dantzig, S., Bulut, M., Krans, M., van der Lans, A. and de Ruyter, B. 2018. Enhancing physical activity through context-aware coaching. May (2018), 187–190. DOI:https://doi.org/10.1145/3240925.3240928.

[21] Dennison, L., Morrison, L., Conway, G. and Yardley, L. 2013. Opportunities and challenges for smartphone applications in supporting health behavior change: Qualitative study. *Journal of Medical Internet Research*. (2013). DOI:https://doi.org/10.2196/jmir.2583.

[22] Esakia, A., Harden, S.M., McCrickard, D.S. and Horning, M. 2017. FitAware: Channeling Group Dynamics Strategies with Smartwatches in a Physical Activity Intervention Andrey. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '17*. (2017), 2551–2559. DOI:https://doi.org/10.1145/3027063.3053249.

[23] Estrin, D. and Sim, I. 2010. Open mHealth architecture: An engine for health care innovation. *Science*.

[24] Fijneman, Y.A., Willemsen, M.E., Poortinga, Y.H., Erelcin, F.G., Georgas, J., Hui, C.H., Leung, K. and Malpass, R.S. 1996. Individualism-collectivism: An empirical study of a conceptual issue. *Journal of Cross-Cultural Psychology*. (1996).

[25] Fogg, B.J. 1999. Persuasive technologie301398. *Communications of the ACM*. (1999). DOI:https://doi.org/10.1145/301353.301396.

[26] Fogg, B.J. 2003. *Persuasive Technology: Using Computers to Change What We Think and Do*.

[27] Foster, D., Linehan, C., Kirman, B., Lawson, S. and James, G. 2010. Motivating physical activity at work: using persuasive social media for competitive step counting. *MindTrek 2010*. (2010), 111–116. DOI:https://doi.org/10.1145/1930488.1930510.

[28] Gefen, D., Straub, D. and Boudreau, M.-C. 2000. Structural Equation Modeling and Regression: Guidelines for Research Practice. *Communications of the Association for Information Systems*. (2000).

DOI:https://doi.org/10.17705/1cais.00407.

[29] Glanz, K. and Rimer, B.K. 2005. Theory at a Glance: A Guide for Health Promotion Practice. *U.S. Department of Health and Human Services, National Institutes of Health*. (2005). DOI:https://doi.org/10.1128/MCB.25.21.9532.

[30] Graham, C., Benda, P., Howard, S., Balmford, J., Bishop, N. and Borland, R. 2006. *"heh - keeps me off the smokes..."*: probing technology support for personal change. *Synthesis* (2006).

[31] Green, E.G.T., Deschamps, J.C. and Páez, D. 2005. Variation of individualism and collectivism within and between 20 countries: A typological analysis. *Journal of Cross-Cultural Psychology*. (2005). DOI:https://doi.org/10.1177/0022022104273654.

[32] Grimes, A., Bednar, M., Bolter, J.D., Grinter, R.E. and Atlanta, C.S. 2008. EatWell : Sharing Nutrition-Related Memories in a Low-Income Community. *CSCW 2008*. (2008).

[33] Grimes, A., Kantroo, V. and Grinter, R.E. 2010. Let ' s Play ! Mobile Health Games for Adults. *Ubicomp*. (2010).

[34] Gristwood, J. 2011. Applying the Health Belief Model to Physical Activity Engagement Among Older Adults Applying the Health Belief Model to Physical Activity Engagement Among Older Adults. *Illuminare: A student Journal In Recreaction, Parks ad Leisure Studies*. (2011).

[35] Guest, G., MacQueen, K. and Namey, E. 2014. Introduction to Applied Thematic Analysis. *Applied Thematic Analysis*.

[36] Guthold, R., Stevens, G.A., Riley, L.M. and Bull, F.C. 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *The Lancet Global Health*. (2018). DOI:https://doi.org/10.1016/S2214-109X(18)30357-7.

[37] Hair, J.F., Ringle, C.M. and Sarstedt, M. 2011. PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice*. (2011). DOI:https://doi.org/10.2753/MTP1069-6679190202.

[38] Hamari, J., Koivisto, J. and Pakkanen, T. 2014. Do persuasive technologies persuade? - A review of empirical studies. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (2014).

[39] Harjumaa, M., Segerståhl, K. and Oinas-Kukkonen, H. 2009. Understanding persuasive software functionality in practice: A field trial of polar FT60. *ACM International Conference Proceeding Series* (2009).

[40] Hoseini, H., Maleki, F., Moeini, M. and Sharifirad, G.R. 2014. Investigating the effect of an education plan based on the health belief model on the physical activity of women who are at risk for hypertension. *Iranian journal of nursing and midwifery research*. (2014).

[41] Hui, C.H. and Triandis, H.C. 1986. Individualism-Collectivism. *Journal of Cross-Cultural Psychology*. (1986). DOI:https://doi.org/10.1177/0022002186017002006.

[42] Immonen, J., Sjögren, T., Karvanen, J., Hakala, S., Rintala, A. and Heinonen, A. 2017. Effectiveness of technology-based distance interventions promoting physical activity: Systematic review, meta-analysis and meta-regression. *Journal of Rehabilitation Medicine*. 49, 2 (2017), 97–105.

DOI:https://doi.org/10.2340/16501977-2195.

[43] Jalilian, F., Matin, A.K., Mahboubi, M., Rahimi, S., Fazel, Z., Juibari, T.A. and Khashij, S. 2016. Predicting factors related to regular physical activity among Iranian medical college student: An application of Health Belief Model. *Social Sciences (Pakistan)*. (2016). DOI:https://doi.org/10.3923/sscience.2016.3688.3691.

[44] Janz, N.K. and Becker, M.H. 1984. The Health Belief Model: A Decade Later. *Health Education & Behavior*. (1984). DOI:https://doi.org/10.1177/109019818401100101.

[45] Johnson, J.L., Slentz, C.A., Houmard, J.A., Samsa, G.P., Duscha, B.D., Aiken, L.B., McCartney, J.S., Tanner, C.J. and Kraus, W.E. 2007. Exercise Training Amount and Intensity Effects on Metabolic Syndrome (from Studies of a Targeted Risk Reduction Intervention through Defined Exercise). *American Journal of Cardiology*. (2007). DOI:https://doi.org/10.1016/j.amjcard.2007.07.027.

[46] Kamel Boulos, M.N., Brewer, A.C., Karimkhani, C., Buller, D.B. and Dellavalle, R.P. 2014. Mobile medical and health apps: state of the art, concerns, regulatory control and certification. *Online Journal of Public Health Informatics*. (2014). DOI:https://doi.org/10.5210/ojphi.v5i3.4814.

[47] Kasmaei, P., Amin Shokravi, F., Hidarnia, A., Hajizadeh, E., Atrkar-Roushan, Z., Karimzadeh Shirazi, K. and Montazeri, A. 2014. Brushing behavior among young adolescents: Does perceived severity matter. *BMC Public Health*. (2014). DOI:https://doi.org/10.1186/1471-2458-14-8.

[48] Kasser, S.L. and Kosma, M. 2012. Health beliefs and physical activity behavior in adults with multiple sclerosis. *Disability and Health Journal*. (2012). DOI:https://doi.org/10.1016/j.dhjo.2012.07.001.

[49] Ketchen, D.J. 2013. A Primer on Partial Least Squares Structural Equation Modeling. *Long Range Planning*. (2013). DOI:https://doi.org/10.1016/j.lrp.2013.01.002.

[50] Khaled, R., Barr, P., Biddle, R., Fischer, R. and Noble, J. 2009. Game design strategies for collectivist persuasion. (2009).

[51] Khaled, R., Barr, P., Fischer, R., Noble, J. and Biddle, R. 2006. Factoring culture into the design of a persuasive game. *ACM International Conference Proceeding Series* (2006).

[52] Khaled, R., Biddle, R., Noble, J., Barr, P. and Fischer, R. 2006. Persuasive Interaction for Collectivist Cultures. *Conferences in Research and Practice in Information Technology Series* (2006).

[53] King, K.A., Vidourek, R.A., English, L. and Merianos, A.L. 2014. Vigorous physical activity among college students: Using the health belief model to assess involvement and social support. *Archives of Exercise in Health and Disease*. (2014). DOI:https://doi.org/10.5628/aehd.v4i2.153.

[54] Lau, P.W.C., Cheung, M.W.L. and Ransdell, L. 2007. Sport identity and sport participation: A cultural comparison between Collective and Individualistic Societies. *International Journal of Sport and Exercise Psychology*. (2007). DOI:https://doi.org/10.1080/1612197x.2008.9671813.

[55] Lee, I.M. et al. 2012. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *The Lancet*. (2012). DOI:https://doi.org/10.1016/S0140-6736(12)61031-9.

[56] Lim, B.Y., Shick, A., Harrison, C. and Hudson, S. 2011. Pediluma: Motivating physical activity through contextual information and social influence. *Proceedings of the 5th International Conference on Tangible*

Embedded and Embodied Interaction, TEI'11 (2011).

[57] Lisa M. Vaughn, Farrah Jacquez and Raymond C. Bakar 2009. Cultural Health Attributions, Beliefs, and Practices: Effects on Healthcare and Medical Education. *The Open Medical Education Journal*. 2, 1 (2009).

[58] Luo, Y., Lee, B., Yvettewohn, D., Rebar, A.L., Conroy, D.E. and Choe, E.K. 2018. Time for break: Understanding information workers' sedentary behavior through a break prompting system. *Conference on Human Factors in Computing Systems - Proceedings* (2018).

[59] Mamykina, L., Strub, H.B., Lindtner, S., Lin, J.J. and Delajoux, G. 2006. Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game. (2006), 261–278. DOI:https://doi.org/10.1007/11853565_16.

[60] Matthews, J., Win, K.T., Oinas-Kukkonen, H. and Freeman, M. 2016. Persuasive Technology in Mobile Applications Promoting Physical Activity: a Systematic Review. *Journal of Medical Systems*. 40, 3 (2016), 1–13. DOI:https://doi.org/10.1007/s10916-015-0425-x.

[61] Meyer, J., Beck, E., von Holdt, K., Gansefort, D., Brand, T., Zeeb, H. and Boll, S. 2018. ActiStairs: Design and Acceptance of a Technology-Based Intervention to Advocate Stair-Climbing in Public Spaces. *Proceedings of the 3rd International Workshop on Multimedia for Personal Health and Health Care*. (2018), 59–66. DOI:https://doi.org/10.1145/3264996.3264997.

[62] Miller, A.D., Mynatt, E.D., Miller, A.D. and Mynatt, E.D. 2014. StepStream: A School-based Pervasive Social Fitness System for Everyday Adolescent Health. *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*. (2014), 2823–2832. DOI:https://doi.org/10.1145/2556288.2557190.

[63] Mollee, J.S., Middelweerd, A., Velde, S.J. te and Klein, M.C.A. 2017. Evaluation of a personalized coaching system for physical activity. *Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare - PervasiveHealth '17*. (2017), 315–324. DOI:https://doi.org/10.1145/3154862.3154933.

[64] Morio, C., Nicol, C., Barla, C., Barthèlemy, J. and Berton, E. 2012. Acute and 2 days delayed effects of exhaustive stretch-shortening cycle exercise on barefoot walking and running patterns. *European Journal of Applied Physiology*. (2012). DOI:https://doi.org/10.1007/s00421-011-2242-3.

[65] Munson, S.A. and Consolvo, S. 2012. Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. *2012 6th International Conference on Pervasive Computing Technologies for Healthcare and Workshops, PervasiveHealth 2012* (2012).

[66] Naeem, Z. 2014. Health risks associated with mobile phones use. *International Journal of Health Science*.

[67] Nowell, L.S., Norris, J.M., White, D.E. and Moules, N.J. 2017. Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*. (2017). DOI:https://doi.org/10.1177/1609406917733847.

[68] Oinas-Kukkonen, H. and Harjumaa, M. 2008. A systematic framework for designing and evaluating persuasive systems. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (2008).

[69] Oinas-Kukkonen, H. and Harjumaa, M. 2009. Persuasive systems design: Key issues, process model, and system features. *Communications of the Association for Information Systems*. (2009).

[70] Orji, R. and Mandryk, R.L. 2014. Developing culturally relevant design guidelines for encouraging healthy eating behavior. *International Journal of Human Computer Studies*. 72, 2 (2014), 207–223. DOI:https://doi.org/10.1016/j.ijhcs.2013.08.012.

[71] Orji, R., Mandryk, R.L., Vassileva, J. and Gerling, K.M. 2013. Tailoring persuasive health games to gamer type. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*. (2013), 2467. DOI:https://doi.org/10.1145/2470654.2481341.

[72] Orji, R. and Moffatt, K. 2018. Persuasive technology for health and wellness: State-of-the-art and emerging trends. *Health Informatics Journal*. (2018). DOI:https://doi.org/10.1177/1460458216650979.

[73] Orji, R., Nacke, L.E. and Di Marco, C. 2017. Towards personality-driven persuasive health games and gamified systems. *Conference on Human Factors in Computing Systems - Proceedings* (2017).

[74] Orji, R., Orji, F., Oyibo, K. and Ajah, I.A. 2018. Personalizing health theories in persuasive game interventions to gamer types: An African perspective. *ACM International Conference Proceeding Series* (2018).

[75] Orji, R., Oyibo, K., Lomotey, R.K. and Orji, F.A. 2018. Socially-driven persuasive health intervention design: Competition, social comparison, and cooperation. *Health Informatics Journal*. (2018). DOI:https://doi.org/10.1177/1460458218766570.

[76] Orji, R., Tondello, G.F. and Nacke, L.E. 2018. Personalizing persuasive strategies in gameful systems to gamification user types. *Conference on Human Factors in Computing Systems - Proceedings* (2018).

[77] Orji, R., Vassileva, J. and Mandryk, R. 2012. Towards an Effective Health Interventions Design: An Extension of the Health Belief Model. *Online Journal of Public Health Informatics*. (2012). DOI:https://doi.org/10.5210/ojphi.v4i3.4321.

[78] Orji, R., Vassileva, J. and Mandryk, R.L. 2013. LunchTime: A slow-casual game for long-term dietary behavior change. *Personal and Ubiquitous Computing*. (2013). DOI:https://doi.org/10.1007/s00779-012-0590-6.

[79] Orji, R., Vassileva, J. and Mandryk, R.L. 2014. Modeling the efficacy of persuasive strategies for different gamer types in serious games for health. *User Modeling and User-Adapted Interaction*. (2014). DOI:https://doi.org/10.1007/s11257-014-9149-8.

[80] Orji, R.O. 2014. Design for Behaviour Change: A Model-driven Approach for Tailoring Persuasive Technologies. *University of Saskatchewan, Canada*. (2014). DOI:https://doi.org/10388/ETD-2014-06-1555.

[81] Orji, R.O. and Orji, R.O. 2014. DESIGN FOR BEHAVIOUR CHANGE : A MODEL- DRIVEN APPROACH FOR TAILORING PERSUASIVE TECHNOLOGIES A Thesis Submitted to the College of Graduate Studies and Research in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Dep. (2014).

[82] Oyibo, K., Orji, R. and Vassileva, J. 2018. Developing Culturally Relevant Design Guidelines for Encouraging Physical Activity: a Social Cognitive Theory Perspective. *Journal of Healthcare Informatics*

Research. 2, 4 (2018), 319–352. DOI:https://doi.org/10.1007/s41666-018-0026-9.

[83] Oyibo, K., Orji, R. and Vassileva, J. 2017. The Influence of Culture in the Effect of Age and Gender on Social Influence in Persuasive Technology. *Adjunct Publication of the 25th Conference on User Modeling, Adaptation and Personalization - UMAP '17*. (2017), 47–52. DOI:https://doi.org/10.1145/3099023.3099071.

[84] Peeters, M., Megens, C., Van Den Hoven, E., Hummels, C. and Brombacher, A. 2013. Social stairs: Taking the piano staircase towards long-term behavioral change. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (2013).

[85] Prochaska, J.O., DiClemente, C.C. and Norcross, J.C. 1992. In search of how people change: Applications to addictive behaviors. *American Psychologist*. (1992). DOI:https://doi.org/10.1037//0003-066x.47.9.1102.

[86] Product | SmartPLS: *https://www.smartpls.com/*. Accessed: 2020-03-19.

[87] Proto.io - Prototypes that feel real: *https://proto.io/*. Accessed: 2020-03-23.

[88] Riffe, D., Stephen, L. and Frederick, F. 2014. *Analyzing media messages: Using quantitative content analysis in research, Third edition*.

[89] Ringle, C.M., Silva, D. and Bido, D.S. 2014. Structural Equation Modeling with the Smartpls. *REMark - Revista Brasileira de Marketing*. (2014). DOI:https://doi.org/10.5585/remark.v13i2.2717.

[90] Rosenstock, I.M. 1966. Why people use health services. *The Milbank Memorial Fund quarterly*. (1966). DOI:https://doi.org/10.2307/3348967.

[91] Rosser, B.A. and Eccleston, C. 2011. Smartphone applications for pain management. *Journal of Telemedicine and Telecare*.

[92] Smartphone users in Saudi Arabia 2018-2023 | Statista: *https://www.statista.com/statistics/494616/smartphone-users-in-saudi-arabia/*. Accessed: 2020-02-23.

[93] Sohn, M. and Lee, J. 2007. UP health: Ubiquitously Persuasive Health Promotion with an Instant Messaging System. *25th SIGCHI Conference on Human Factors in Computing Systems 2007, CHI 2007*. (2007). DOI:https://doi.org/10.1145/1240866.1241059.

[94] Sun, T., Horn, M. and Merritt, D. 2004. Values and lifestyles of individualists and collectivists: A study on Chinese, Japanese, British and US consumers. *Journal of Consumer Marketing*. 21, 5 (2004), 318–331. DOI:https://doi.org/10.1108/07363760410549140.

[95] Takahashi, M., Kawasaki, H., Maeda, A. and Nakamura, M. 2016. Mobile walking game and group-walking program to enhance going out for older adults. (2016), 1372–1380. DOI:https://doi.org/10.1145/2968219.2968415.

[96] Top Countries/Markets by Smartphone Penetration & Users | Newzoo: *https://newzoo.com/insights/rankings/top-countries-by-smartphone-penetration-and-users/*. Accessed: 2020-02-23.

[97] Torning, K. and Oinas-kukkonen, H. 2009. Persuasive System Design : State of the Art and Future Directions. *Information Systems Journal*. (2009). DOI:https://doi.org/10.1145/1541948.1541989.

[98] Toscos, T., Faber, A., An, S. and Gandhi, M.P. 2006. Chick clique: persuasive technology to motivate

teenage girls to exercise. BT - In CHI '06 Extended Abstracts on, Human Factors in Computing Systems (CHI EA '06). *CHI '06 Extended Abstracts on Human Factors in Computing Systems*.

[99] Triandis, H.C. and Gelfand, M.J. 1998. Converging Measurement of Horizontal and Vertical Individualism and Collectivism. *Journal of Personality and Social Psychology*. (1998). DOI:https://doi.org/10.1037/0022-3514.74.1.118.

[100] Triandis, H.C. and Hofstede, G. 1993. Cultures and Organizations: Software of the Mind. *Administrative Science Quarterly*. (1993). DOI:https://doi.org/10.2307/2393257.

[101] Wang, Y., Fadhil, A., Lange, J.P. and Reiterer, H. 2019. Integrating taxonomies into theory-based digital health interventions for behavior change: A holistic framework. *Journal of Medical Internet Research*.

[102] Young, M.M. 2010. Twitter me: Using micro-blogging to motivate teenagers to exercise. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (2010).

[103] Zuckerman, O. and Gal-Oz, A. 2014. Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity. *Personal and Ubiquitous Computing*. 18, 7 (2014), 1705–1719. DOI:https://doi.org/10.1007/s00779-014-0783-2.

APPENDIX A. Comprehensive Literature Review all studies

Study	Year	paper tittle	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
Foster et al. (2010)	2010	Motivating physical activity at work: Using persuasive social media extensions for simple mobile devices	Facebook app + Pedometer	Step Matron	21 days	None	Competition, comparison.	Behavior	Adults	10	Positive	UK
Toscos et al. (2008)	2008	Encouraging Physical Activity in Teens Can technology help reduce barriers to physical activity in adolescent girls?	mobile phone app + pedometer	mobile App	3 weeks	None	Competition, reminder, tracking, recognition, comparison	Behavior	Teenage girls (13 years)	8	Partially positive	US
McCreadie et al. (2006)	2006	Persuasive Technology for Leisure and Health: Development of a Personal Navigation Tool	Mobile app	Personal Navigation Tool	30-45 mins	none	tracking, feedback(BCT)	not specified	Elderly 72-86)	5	Partially positive	UK
Harjumaa et al. (2009)	2009	Understanding Persuasive Software Functionality in Practice: A Field Trial of Polar FT60	Heart Rate Monitor	FT60	3 months	none	tracking, personalization, reduction, praise, reward, reminder,	Behavior	Adults (23-40)	12	Positive	Finland
Sakai et al. (2011)	2011	Personalized persuasion in ambient intelligence: The APStairs system	Publicly displayed screen	APStair	5 weeks	None	authority, commitment(BCT)	behavior	Adults	34	Partially positive	Netherlands
Munson and Consolve (2012)	2012	Exploring Goal-setting, Rewards, Self-monitoring, and Sharing to Motivate Physical Activity	Mobile	Mobile App	4 weeks	Goal setting	Goal setting(BCT), self-monitoring, social comparison, reminder, reward	behavior	Adults (20-49)	23	Partially positive	USA
Albaina et al. (2009)	2009	Flowie: a persuasive virtual coach to motivate elderly individuals to walk.	touch-screen photo frame + pedometer	Virtual Coach - Participatory design.	11 days	Goal setting, classic learning theory;	Tracking and self-monitoring, goal setting(BCT)	Behavior	Elderly	2	Partially positive	Netherlands
Young (2010)	2010	Twitter me: using micro-blogging to motivate teenagers to exercise	Combination of Web, phone, and pedometer	Twitter me	4 weeks	None	Tracking/monitoring, Competition, praise , goal setting, reward, social comparison, reminder	behavior	Teenage girls (15-17 years)	4	Positive	Netherlands

Study	Year	paper tittle	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
Lim et al (2011)	2011	Pediluma: motivating physical activity through contextual information and social influence.	Shoe physical activity tracker	Pediluma	2 weeks	TTM	tracking, visual feedback, reward, comparison	behavior	Adult (30 mean age)	18	Positive	USA
Lacroix et al. (2009)	2009	Understanding user cognitions to guide the tailoring of persuasive technology-based physical activity interventions	wearable device	Physical activity tracker	10 days	Self-determination	Tracking, visual feedback.	self-efficacy	Adults (25-55 years)	58	Positive	Netherlands
Consolvo et al. (2008)	2008	Activity Sensing in the Wild: A Field Trial of UbiFit Garden	Mobile + Activity sensor	UbiFit Garden	3 weeks	TTM	Tracking and self-monitoring, Visual feedback and reward, praise	Behavior, Motivation	Adults (25-35 year)	12	Positive	USA
Berkovsky et al. (2012)	2012	Physical Activity Motivating Games: Be Active and Get Your Own Reward	Game	PLAY MATE!	Not specified	Operand conditioning and Premack's principle	Tracking, reward	Behavior, motivation	Children (9-12)	225	Positive	Australia
Arteaga et al. (2010)	2010	Mobile System to Motivate Teenagers' Physical Activity	Mobile Game	Mobile App	8 day	TPB, Theory of Meaning Behavior, Personality Theory	Competition and Reward	Motivation	Teenager (12-17)	5	Positive	USA
Eyck et al (2006)	2006	Effect of a Virtual Coach on Athletes' Motivation	Virtual Coach	Virtual Coach cycling machine	15 mins	none	tailoring, tunneling, praise	Motivation	Adults(17-28)	20	Positive	Netherlands
Foster et al. (2010)	2010	Motivating physical activity at work: using persuasive social media for competitive step counting	web	Web App	21 days	none	Tracking, Competition, comparison, recognition	Behavior	Adults	10	Positive	UK
Fritz et al. (2014)	2014	Persuasive technology in the real world: a study of long-term use of activity sensing devices for fitness	Activity Sensing Devices	Activity monitoring technologies	3-54 months - 14.8months	none	tracking, reward	Behavior	Adults	30	Positive	USA
Toscos et al. (2006)	2006	Chick clique: persuasive technology to motivate teenage girls to exercise	Mobile + Pedometer	Chick Clique	4 days	none	tracking, comparison , positive feedback, competition, cooperation	habit and behavior	Teenager (13-17)	7	Positive	USA
Fujinami and Reikki (2008)	2008	A case study on an ambient display as a persuasive medium for exercise awareness.	Ambient Mirror Display	Ambient Mirror	1 week	none	competition, comparison	awareness	Adults (23-69)	6	Positive	japan
Spruijt-Metz et al.(2008)	2008	Reducing sedentary behavior in minority girls via a theory-based, tailored classroom media intervention	Computer-based application	Get Moving!	3 months	Self Determination Theory (SDT) and Theory of Meanings of Behavior (TMB)	suggestion	Motivation	Adolescent (12.5 mean)	459	Positive	USA

Study	Year	paper tittle	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
Fujiki et al.(2008)	2008	NEAT-o-Games: Blending Physical Activity and Fun in the Daily Routine	Mobile Game	NEAT-o-Games	8 days	none	Tracking, competition, comparison	Behavior	Adults (28-37)	10	Positive	USA
Peeters et al. (2013)	2013	Social Stairs: taking the Piano Staircase towards long- term behavioral change	Intelligent musical staircase	Social Stairs	3 weeks	none	reward	Motivation	not Specified	not specified	Positive	Netherlands
Chen et al. (2014)	2014	Opportunities for persuasive technology to motivate heavy computer users for stretching exercise	Mobile Sensing and Game	SP-Stretch - Social Persuasion System	4 weeks	none	Tracking, competition	Behavior	Adults	25	Positive	Taiwan
Clinkenbeard et al. (2014)	2014	What's Your 2%? A Pilot Study for Encouraging Physical Activity Using Persuasive Video and Social Media	Social Network	Social network app	3 days	none	tunneling, reduction, suggestion	Attitude	Adults	61	Positive	USA
Lin et al. (2006)	2006	Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game	Animated virtual fish	Fish'n'Steps	14 weeks	TTM	goal setting (BCT),Tracking /monitoring, feedback, competition, cooperation	Behavior	Adults (23-63)	19	Positive	USA
Khalil and Abdallah (2013)	2013	Harnessing social dynamics through persuasive technology to promote healthier lifestyle.	Mobile	SET UP	2 weeks	TRA	Tracking, feedback	Behavior	Adults (23 mean)	8	Positive	United Arab Emirate
Nakajima and Lehdonvirta (2013)	2013	Designing motivation using persuasive ambient mirrors	Ambient Mirror	Persuasive Art	31 days	Goal Setting and Operand conditioning	Tracking, reward, Liking, feedback	behavior	Adults (22-24 years)	14	Unsuccessful	Japan
Zwinderman et al. (2012)	2012	Phone row: A smartphone game designed to persuade people to engage in moderate-intensity physical activity	Phone-based Game	Mobile application and accopanying website for social - displaying and comparing players performance.	4 days	None	Competition, recognition, feedback, and social comparison via facebook	Behavior	Adults	32	Unsuccessful - due usability issues and because it's not fun enough to keep users intereste d.	Netherlands
Fanning et al. (2017)	2017	A smartphone ''app''-delivered randomized factorial trial targeting physical activity in adults	Mobile	Mobile App	12 weeks	goal-setting +points-based feedback	tracking, feedback	Behavior	Adults	116	Positive	USA
Meyer et al. (2018)	2018	ActiStairs: Design and Acceptance of a	monitor and sensor for stair climbing	ActiStairs	3 days	none	reward, coopera tion	not specified	Adults	358	Partially positive	Germany

Study	Year	paper tittle	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
		Technology-Based Intervention to Advocate Stair-Climbing in Public Spaces										
Ornelas et al. (2015)	2015	CrowdWalk: Leveraging the wisdom of the crowd to inspire walking activities	Mobile	CrowdWalk	not specified	none	Competition, co operation	Behavior	Adults	65	Positive	Portuguese
Stanley et al. (2010)	2010	PiNiZoRo: A GPS-based exercise game for families.	Mobile Game	PiNiZoRo	not specified	none	competition, co operation	Behavior, Motivation	children (4-12) + Adults	4	Positive	Canada
Jensen et al. (2010)	2010	Studying PH. A. N. T. O. M. in the wild: a pervasive persuasive game for daily physical activity.	Mobile Game	PH.A.N.T.O.M.	not specified	none	reward, tracking, competition, comparison	Behavior	Adults	9	Partially positive	Denmark
Fialho et al. (2009)	2009	ActiveShare: Sharing challenges to increase physical activity	web service application +accelerometer+social networks	ActiveShare	1 week	social goal setting	Tracking, competition, comparison, feedback	Behavior	Adults	12	Partially positive	Netherlands
Hirano et al. (2013)	2013	WalkMinder: Encouraging an Active Lifestyle Using Mobile Phone Interruptions	Mobile app	WalkMinder	4 weeks	none	Tracking	Behavior	Adults (25-69)	8	Partially positive	USA
Cercos and Mueller (2013)	2013	Watch your steps	Fitbit and semi-public display	Watch your Steps	8 weeks	self-determination theory, social cognitive theory, and the transtheoretical model	Tracking , cooperation, competition, comparison	Behavior	Adults	15	Partially positive	Australia
Akker et al. (2011)	2011	A Self-Learning Personalized Feedback Agent for Motivating Physical Activity	Mobile app + sensor	Feedback Agent	not specified	none	feedback, tailoring, tacking , personalization	Behavior	Adults	not specified	Partially positive	Netherlands
Kishino and Kitamura (2014)	2014	Virtual Marathon System Where Humans and Agents Compete.	Mobile app	Virtual Marathon System	1 week	None	Competition, tracking	Behavior	Adults	20	Partially positive	Japan
Miller and Mynatt (2014)	2014	StepStream: A School-based Pervasive Social Fitness System for Everyday Adolescent Health	pedometers + website	StepStream	4 weeks	social comparison and social support	Competition, comparison, cooperation	Attitude	Adolescent	42	Positive	USA
Ciman et al. (2016)	2016	Stairstep recognition and counting in a serious Game for increasing users' physical activity	Mobile Game	ClimbTheWorld	9 days	none	competition, cooperation, reward, social comparison	Behavior	Adults (24-30)	13	Positive	Italy
Altmeyer et al. (2018)	2018	SilverCycling: Evaluating Persuasive Strategies to Promote Physical Activity among Older Adults.	augmented portable bike + persuasive mirror	SilverCycling	not specified	none	competition and cooperation, Comparison, recognition,praise,reward	Behavior	Adults (57- 69)	9	Partially positive	Germany
Burkow et al. (2018)	2018	Promoting exercise training and physical	Mobile app	mobile App	4 weeks	none	reward, tracking,	Behavior	Adults (45-69)	10	Partially positive	Norway

Study	Year	paper tittle	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
		activity in daily life: A feasibility study of a virtual group intervention for behaviour change in COPD					competition,					
Takahashi et al. (2016)	2016	Mobile walking game and group-walking program to enhance going out for older adults.	Mobile Game	San-Poki	4 weeks	None	reward, coopera tion, competition	Behavior, Motivation	Elderly (70-80)	30	Positive	Japan
Zhang and Jemmott III (2019)	2019	Mobile App-Based Small-Group Physical Activity Intervention for Young African American Women: a Pilot Randomized Controlled Trial.	Mobile app+ Fitbit	PennFit	3 months	social support	Tracking , Reminder, competition	Behavior	women (18 - 35)	91	Partially positive	US
Esakia et al. (2017)	2017	FitAware: Channeling Group Dynamics Strategies with Smartwatches in a Physical Activity Intervention	smartwatch + Android app, and website	FitAware	8 weeks	social support	competition, tracking, cooperation	Behavior	Adults (35 - 69)	7	Partially positive	US
Mollee et al. (2017)	2017	Active2Gether: A Personalized m-Health Intervention to Encourage Physical Activity	Mobile app	Active2Gether	12 weeks	none	personalization, social comparison, tailoring, competition	Behavior	Adults (18 to 30)	92	Partially positive	Netherlands
Melton et al. (2015)	2015	Evaluating a Physical Activity App in the Classroom: A Mixed Methodological Approach Among University Students	Mobile app	Fitocracy fitness app	20 days	Self-determination theory (SDT)	cooperation, competition	Behavior, Motivation	Adults (18 - 25)	48	Positive	US
Dantzig et al. (2018)	2018	Enhancing physical activity through context-aware coaching	Mobile app	mobile App	4 weeks	none	personalization, tracking, suggestion	Behavior	Adults (18 - 65)	70	Partially positive	Netherlands
Glynn et al. (2014)	2014	SMART MOVE - a smartphone-based intervention to promote physical activity in primary care: Study protocol for a randomized controlled trial	Mobile app	SMART MOVE	8 weeks	none	tracking, feedback	Behavior	Adults	90	Positive	Ireland
Bragina et al. (2017)	2017	Development and evaluation of two web-based interventions for the promotion of physical activity in older adults: study protocol for a community-based controlled intervention trial.	web site	not specified	10 weeks	self regulation theory	Tracking , cooperation,	Behavior	Elderly (75-85)	684	Partially positive	Germany

Study	Year	paper tittle	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
Gupta et al. (2018)	2018	Designing pervasive technology for physical activity self-management in arthritis patients	web application + Fitbit	FitViz	4 weeks	Goal setting	tracking, personalization, goal setting(BCT)	Behavior	Adults (47-69)	20	partially successful	Canada
Zuckerman and Gal-Oz (2014)	2014	Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity	Mobile app	StepByStep	3 months	none	Virtual reward , Social comparison , tracking, recognition	Behavior	Adults (23 -54)	40	Positive	Israel
Marcu et al. (2018)	2018	Designing a Physical Activity Intervention for Breast Cancer Survivors.	Mobile app	Bounce	3 weeks	behavior change theory	tracking, personalization, cooperation, reward,	Behavior	Adults average age = 35	4	Positive	US
Al Ayubi et al. (2014)	2014	A Persuasive and Social mHealth Application for Physical Activity: A Usability and Feasibility Study	Mobile app	PersonA	4 weeks	social support	Tracking , cooperation, competition, comparison	Behavior, Motivation	Adults (24 - 45)	14	Positive	US
Edney et al. (2017)	2017	“Active Team” a social and gamified app-based physical activity intervention: Randomised controlled trial study protocol.	Mobile app	Active Team	1 year	social support	tracking, praise, reward, cooperation, competition	Behavior	Adults (18 - 65)	440	Positive	Australia

APPENDIX B. The social influence strategies studies

Study	Study title	Year	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
Foster et al. (2010)	Motivating physical activity at work: Using persuasive social media extensions for simple mobile devices	2010	Facebook app + Pedometer	Step Matron	21 days	None	Competition, comparison.	Behavior	Adults	10	Positive	UK
Toscos et al. (2008)	Encouraging Physical Activity in Teens: Can technology help reducte barriers to physical activity in adolescent girls?	2008	mobile phone app + pedometer	mobile App	3 weeks	None	Competition	Behavior	Teenage girls (13 years)	8	Partially positive	US
Young (2010)	Twitter me: Using micro-blogging to motivate teenagers to exercise.	2010	Combination of Web, phone, and pedometer	User Centered - predesign interview	4 weeks	None	Competition and social comparison	behavior	Teenage girls (15-17 years)	4	Positive	Netherlands
Arteaga et al. (2010)	Mobile system to motivate teenagers' physical activity.	2010	Mobile Game	Mobile App	8 day	TPB, Theory of Meaning Behavior, Personality Theory	Competition	Motivation	Teenager (12-17)	5	Positive	USA
Foster et al. (2010)	Motivating physical activity at work: using persuasive social media for competitive step counting	2010	web	Web App	21 days	none	Competition, comparison	Behavior	Adults	10	Positive	UK
Toscos et al. (2006)	Chick clique: persuasive technology to motivate teenage girls to exercise	2006	Mobile + Pedometer	Chick Clique	4 days	none	comparison	habit and behavior	Teenager (13-17)	7	Positive	USA
Fujinami and Reikki (2008)	A case study on an ambient display as a persuasive medium for exercise awareness.	2008	Ambient Mirror Display	Ambient Mirror	1 week	none	competition, cooperation	awareness	Adults (23-69)	6	Positive	japan
Chen et al. (2014)	Opportunities for persuasive technology to motivate heavy computer users for stretching exercise	2014	Mobile Sensing and Game	SP-Stretch - Social Persuasion System	4 weeks	none	competition	Behavior	Adults	25	Positive	Taiwan
Lin et al. (2006)	Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game	2006	Animated virtual fish	Fish'n'Steps	14 weeks	TTM	competition, cooperation	Behavior	Adults (23-63)	19	Positive	USA
Zwinderman et al. (2012)	Phone row: A smartphone game designed to persuade people to engage in moderate-intensity physical activity	2012	Phone-based Game	Mobile application.	4 days	None	Competition and social comparison	Behavior	Adults	32	Negative	Netherlands
Meyer et al. (2018)	ActiStairs: Design and Acceptance of a Technology-Based Intervention to Advocate Stair-Climbing in Public Spaces	2018	monitor and sensor for stair climbing	ActiStairs	3 days	none	cooperation	not specified	Adults	358	Partially positive	Germany
Ornelas et al. (2015)	CrowdWalk: Leveraging the wisdom of the crowd to inspire walking activities	2015	Mobile	CrowdWalk	not specified	none	Competition, cooperation	Behavior	Adults	65	Positive	Portuguese
Stanley et al. (2010)	PiNiZoRo: A GPS-based exercise game for families.	2010	Mobile Game	PiNiZoRo	not specified	none	competition and cooperation	Behavior, Motivation	children (4-12) + Adults	4	Positive	Canada
Jensen et al. (2010)	Studying PH. A. N. T. O. M. in the wild: a pervasive persuasive game for daily	2010	Mobile Game	PH.A.N.T.O.M.	not specified	none	competition	Behavior	Adults	9	Partially positive	Denmark

Study	Study title	Year	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
	physical activity.											
Fialho et al. (2009)	ActiveShare: Sharing challenges to increase physical activity	2009	web service application +accelerometer+social networks	ActiveShare	1 week	social goal setting	competition, comparison	Behavior	Adults	12	Partially positive	Netherlands
Cercos and Mueller (2013)	Watch your steps	2013	Fitbit and semi-public display	Watch your Steps	8 weeks	self-determination theory, social cognitive theory, and the transtheoretical model	cooperation and competition	Behavior	Adults	15	Partially positive	Australia
Kishino and Kitamura (2014)	Virtual Marathon System Where Humans and Agents Compete.	2014	Mobile app	Virtual Marathon System	1 week	None	Competition	Behavior	Adults	20	Partially positive	Japan
Miller and Mynatt (2014)	StepStream: A School-based Pervasive Social Fitness System for Everyday Adolescent Health	2014	pedometers + website	StepStream	4 weeks	social comparison and social support	Competition, comparison, cooperation	Attitude	Adolescent	42	Positive	USA
Ciman et al. (2016)	Stairstep recognition and counting in a serious Game for increasing users' physical activity	2016	Mobile Game	ClimbTheWorld	9 days	none	competition, cooperation	Behavior	Adults (24-30)	13	Positive	Italy
Altmeyer et al. (2018)	SilverCycling: Evaluating Persuasive Strategies to Promote Physical Activity among Older Adults.	2018	augmented portable bike + persuasive mirror	SilverCycling	not specified	none	Competition, cooperation, Comparison	Behavior	Adults (57-69)	9	Partially positive	Germany
Bratvold et al. (2018)	Promoting exercise training and physical activity in daily life: a feasibility study of a virtual group intervention for behaviour change in COPD	2018	Mobile app	mobile App	4 weeks	none	competition	Behavior	Adults (45-68)	10	Partially positive	Norway
Takahashi et al. (2016)	Mobile walking game and group-walking program to enhance going out for older adults.	2016	Mobile Game	San-Poki	4 weeks	None	cooperation, competition	Behavior, Motivation	Elderly (70-80)	30	Positive	Japan
Zhang and Jemmott III (2019)	Mobile App-Based Small-Group Physical Activity Intervention for Young African American Women : a Pilot Randomized Controlled Trial	2019	Mobile app+ Fitbit	PennFit	3 months	social support	cooperation, competition	Behavior	Adults (18 - 35)	91	Partially positive	US
Esakia et al. (2017)	FitAware: Channeling Group Dynamics Strategies with Smartwatches in a Physical Activity Intervention	2017	smartwatch + Android app, and website	FitAware	8 weeks	social support	competition, cooperation	Behavior	Adults (35 - 69)	7	Partially positive	US
Mollee et al. (2017)	Evaluation of a personalized coaching system for physical activity.	2017	Mobile app	Active2Gether	12 weeks	none	social comparison, competition	Behavior	Adults (18 to 30)	92	Partially positive	Netherlands
Harris et al. (2015)	Evaluating a Physical Activity App in the Classroom: A Mixed Methodological Approach Among University Students	2015	Mobile app	not specified	20 days	Self-determination theory (SDT)	cooperation, competition	Behavior, Motivation	Adults (18 - 25)	48	Positive	US
Bragina et al. (2017)	Development and evaluation of two web-based interventions for the	2017	web site	not specified	10 weeks	self regulation theory	cooperation	Behavior	Elderly (75-85)	684	Partially positive	Germany

Study	Study title	Year	Technology	Application	Duration	Theories	Motivational Strategies	Targeted Outcome	Audience	No. of Participant	Findings	Region
	promotion of physical activity in older adults: study protocol for a community-based controlled intervention trial.											
Gupta et al. (2018)	Designing pervasive technology for physical activity self-management in arthritis patients	2018	web application + Fitbit	FitViz	4 weeks	Goal setting	cooperation	Behavior	Adults (47-67)	20	Partially positive	Canada
Zuckerman and Gal-Oz (2014)	Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity	2014	Mobile app	StepByStep	3 months	none	Social comparison	Behavior	Adults (23 - 54)	40	Positive	Israel
Marcu et al. (2018)	Designing a Physical Activity Intervention for Breast Cancer Survivors.	2018	Mobile app	Bounce	3 weeks	behavior change theory	cooperation and competition	Behavior	Adults	4	Positive	US
Al Ayubi et al. (2014)	A Persuasive and Social mHealth Application for Physical Activity: A Usability and Feasibility Study	2014	Mobile app	PersonA	4 weeks	social support + HBM	cooperation, competition	Behavior, Motivation	Adults (24 - 45)	14	Positive	US
Edney et al. (2017)	"Active Team" a social and gamified app-based physical activity intervention: Randomised controlled trial study protocol.	2017	Mobile app	Active Team	1 year	social support	cooperation, competition	Behavior	Adults (18 - 65)	440	Positive	Australia

APPENDIX C. The Extended Health Believe Model Survey

Demographic Questions

1. Please choose your age range:

○ Under 18

○ 18-25

○ 26-35

○ 36-45

○ Over 46

2. Please choose your gender:

○ Male

○ Female

○ Other (please specify) …….

3. What is the highest level of education you have completed?

○ Less than High school

○ High School or equivalent

○ College diploma

○ Bachelor's degree

○ Master's degree

○ Doctoral degree

○ Other (please specify) …….

Throughout the survey when we used the word "exercise or physical activity" it means any form of activity from a simple as an additional movement beyond your regular activity to more formal activity such as going to the gym.

Please rate your level of agreement with the following statements in a 7-point scale. Choosing 1-Strongly Disagree to 7-Strongly Agree.

Self-efficacy

	1-Strongly Disagree						7- Strongly Agree
If I want, I could easily exercise within the next two weeks	1	2	3	4	5	6	7
Whether or not I exercise in the next week is entirely up to me	1	2	3	4	5	6	7
I believe I have the ability to exercise next week	1	2	3	4	5	6	7
I am confident that I could exercise within the next two weeks if I want	1	2	3	4	5	6	7
I am confident that I can participate in outdoor physical activity during bad weather.	1	2	3	4	5	6	7
I am confident that I can participate in regular physical activity when on vacation	1	2	3	4	5	6	7

Susceptibility

Please rate your level of agreement with the following statements in a 7-point scale. Choosing 1-Strongly Disagree to 7-Strongly Agree.

	1-Strongly Disagree						7- Strongly Agree
If I do not stick to regular exercise, I will be at high risk for some physical inactivity related diseases (e.g. diabetes, high blood pressure, and heart disease)	1	2	3	4	5	6	7
If I don't exercise, there is a good possibility that I will gain weight in the next 3 months.	1	2	3	4	5	6	7

Severity

Please rate your level of agreement with the following statements in a 7-point scale. Choosing 1-Strongly Disagree to 7-Strongly Agree.

	1-Strongly Disagree						7- Strongly Agree
The thought of ending up in the hospital due to physical inactivity related diseases scares me.	1	2	3	4	5	6	7
If I gain weight in the next 3 months, it will be a bad thing.	1	2	3	4	5	6	7
Physical inactivity could seriously affect my social life.	1	2	3	4	5	6	7

Perceived Benefit

On a scale of 1to 7, how much do you agree or disagree that being physically active most of the time would

	1-Strongly Disagree						7- Strongly Agree
Be beneficial to you.	1	2	3	4	5	6	7
Help you to maintain your general health.	1	2	3	4	5	6	7
Decrease your chances of becoming obese/overweight	1	2	3	4	5	6	7
Decrease your chances of getting heart diseases	1	2	3	4	5	6	7
Decrease your chances of getting cancer	1	2	3	4	5	6	7
Decrease your chances of getting high blood pressure	1	2	3	4	5	6	7
Decrease your chances of becoming diabetic	1	2	3	4	5	6	7
Improve appearance	1	2	3	4	5	6	7
Maintain a healthy weight	1	2	3	4	5	6	7

Help to lose weight	1	2	3	4	5	6	7
Improve fitness	1	2	3	4	5	6	7
Increase strength	1	2	3	4	5	6	7
Reduce stress	1	2	3	4	5	6	7
Increase energy	1	2	3	4	5	6	7
Improve self-esteem	1	2	3	4	5	6	7
Help to do something active with others	1	2	3	4	5	6	7
Help to meet new people (socializing)	1	2	3	4	5	6	7
Improve mental alertness	1	2	3	4	5	6	7

Perceived Barrier

Please rate your level of agreement with the following statements in a 7-point scale. Choosing 1-Strongly Disagree to 7-Strongly Agree.

	1-Strongly Disagree						**7- Strongly Agree**
A major barrier to physical activity for me is cost (e.g. exercise outfits and gym contract).	1	2	3	4	5	6	7
A major barrier to physical activity for me is not having enough time	1	2	3	4	5	6	7
A major barrier to physical activity for me is inconvenience.	1	2	3	4	5	6	7
A major barrier to physical activity for me is that exercise interferes with my schedule (e.g. work, school)	1	2	3	4	5	6	7
A major barrier to physical activity for me is lack of motivation.	1	2	3	4	5	6	7
A major barrier to physical activity for me is that exercise is boring.	1	2	3	4	5	6	7
A major barrier to physical activity for me is that exercise interferes with social/family activities.	1	2	3	4	5	6	7

A major barrier to physical activity for me is lack of knowledge about how to exercise/workout .	1	2	3	4	5	6	7
A major barrier to physical activity for me is lack of facilities.	1	2	3	4	5	6	7
A major barrier to physical activity for me is a limiting health reason.	1	2	3	4	5	6	7
A major barrier to physical activity for me is being too lazy.	1	2	3	4	5	6	7
A major barrier to physical activity for me is bad weather	1	2	3	4	5	6	7
A major barrier to physical activity for me is illness.	1	2	3	4	5	6	7
A major barrier to physical activity for me is injury.	1	2	3	4	5	6	7

Intention to be physically active

Please rate your level of agreement with the following statements in a 7-point scale. Choosing 1-Extremely Unlikely to 7-Extremely Likely.

	1 Extremely unlikely						**7- Extremely likely**
I intend to exercise more during the next two weeks.	1	2	3	4	5	6	7
I will try to walk for an hour every day during the next two weeks.	1	2	3	4	5	6	7
I intend to go to the gym three times a week during the next two weeks.	1	2	3	4	5	6	7
I will try to use stairs instead of elevator during the next two weeks.	1	2	3	4	5	6	7

Cue to Action

Please rate your level of agreement with the following statements in a 7-point scale. Choosing 1-Strongly Disagree to 7-Strongly Agree.

	1-Strongly disagree						**7- Strongly agree**
I will be more physically active if family members are active.	1	2	3	4	5	6	7
I am motivated to exercise if I gain weight and not fit in my clothing.	1	2	3	4	5	6	7
I would be more physically active if I am participating in competitive activities or fitness challenges	1	2	3	4	5	6	7
I would pay attention to exercise if I see pictures of physically fit people in magazines and TV	1	2	3	4	5	6	7
I would pay attention to exercise if I read about exercise in newspapers	1	2	3	4	5	6	7
I will be more physically active if I watch people exercise on social media	1	2	3	4	5	6	7
I will be more physically active if I receive motivational email reminders to exercise	1	2	3	4	5	6	7
I would pay attention to exercise if I wanted to look physically fit	1	2	3	4	5	6	7
I will be more physically active if my friends are physically active	1	2	3	4	5	6	7
I would start physical activity program if recommended by a doctor	1	2	3	4	5	6	7
I would start physical activity program if suggested by friends and family members	1	2	3	4	5	6	7
I will be more physically active if I live close to the gym	1	2	3	4	5	6	7

Social Influence

Please rate your level of agreement with the following statements in a 7-point scale. Choosing 1-Strongly Disagree to 7-Strongly Agree.

	1-Strongly disagree						**7- Strongly agree**
My family makes time to be more physically active	1	2	3	4	5	6	7
My family takes short breaks to be physically active during the day	1	2	3	4	5	6	7
My family uses the stairs at work or school instead of an elevator	1	2	3	4	5	6	7
My friend goes to the gym regularly	1	2	3	4	5	6	7

APPENDIX D. Research Ethics Board Approval Letter for the Extended HBM Survey Study

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board
Letter of Approval

July 23, 2018

Najla Almutari
Computer Science\Computer Science

Dear Najla,

REB #: 2018-4509
Project Title: Design Intervention for Physical Activity Promotion Using Social Media

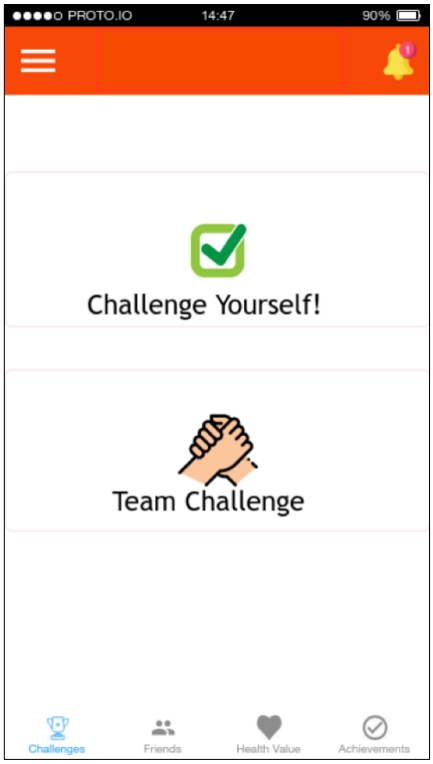
Effective Date: July 23, 2018
Expiry Date: July 23, 2019

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

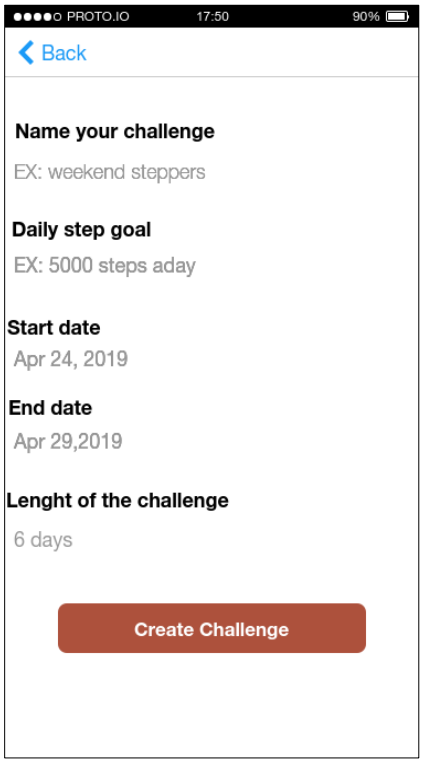
Sincerely,

Dr. Karen Beazley, Chair

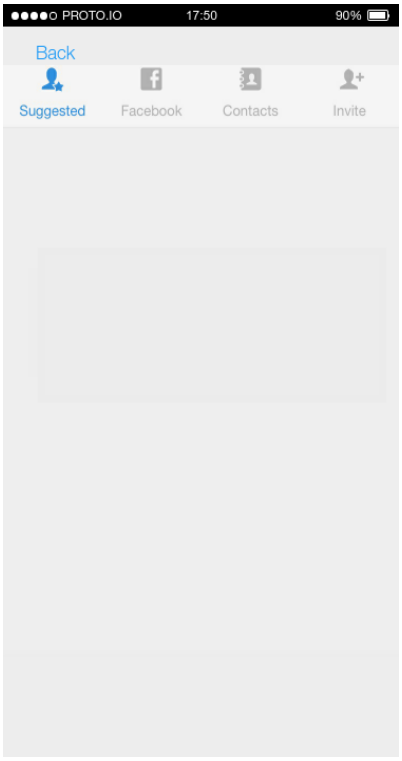
APPENDIX E. The First Prototype of StepsBooster-S



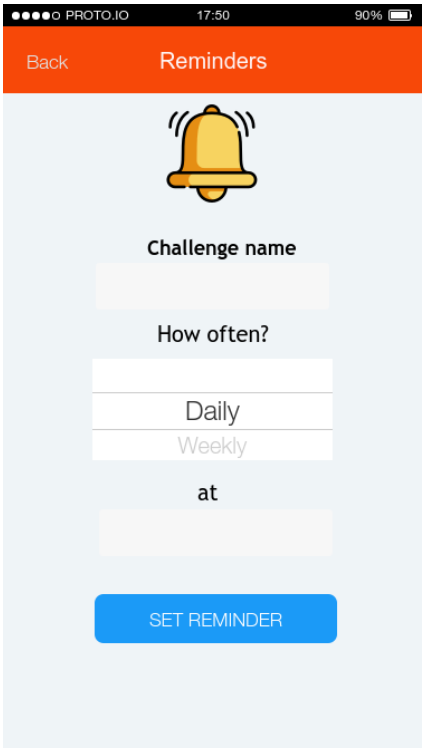
Main screen of the app



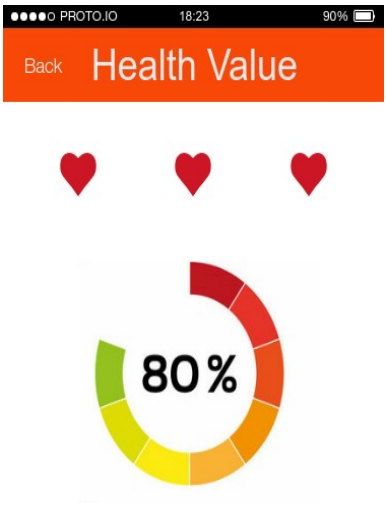
Create challenge screen



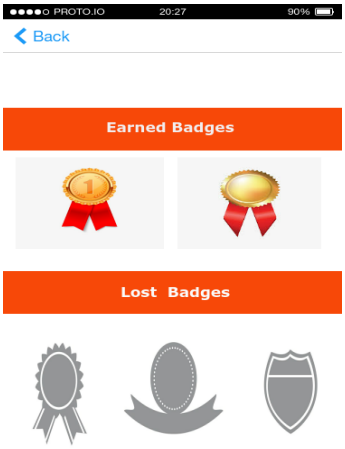
Invite friend screen



Reminder screen



Health value screen



Badges screen

APPENDIX F. Research Ethics Board Approval Letter for StepsBooster-S Evaluation Study

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board
Amendment Approval

June 26, 2019

Najla Almutari
Computer Science\Computer Science

Dear Najla,

REB #: 2018-4509
Project Title: Design Intervention for Physical Activity Promotion Using Social Media

The Social Sciences & Humanities Research Ethics Board has reviewed your amendment request and has approved this amendment request effective today, June 26, 2019.

Sincerely,

Dr. Karen Beazley, Chair

APPENDIX G. StepsBooster-S Pilot Study Observations

DALHOUSIE UNIVERSITY

StepsBooster Pilot Test Observation

Name:

**** Please write your comments to improve StepsBooster****

There are some issues:
- Total steps did not increase (still showing 0) after creating a challenge.
- Challenge disappeared before the expiration date
- Navigation issues (e.g. unable to exit from the Achievement screen since there is no back button)

DALHOUSIE UNIVERSITY

StepsBooster Pilot Test Observation

Name: [redacted]

**** Please write your comments to improve StepsBooster****

1. Login without Google Fit :
   - Created Challenge. Individual challenge had challenge code
   - Shared with swatish
   - Swatish got error message : challenge code in use
2. Tried to Share challenge
   - The generated message had generic text, not the challenge code
3. After installing Google Fit
   - Unable to login. Authentication failed
   - Or App closes automatically.

APPENDIX H. The Consent Form of the App Evaluation Study

Title of the study: Design Intervention for Physical Activity Promotion
Principal Investigator: Najla Almutari, Master student
Academic supervisor: Dr. Rita Orji, Faculty of Computer Science, Dalhousie University
Contact Person: Najla Almutari, Najla.Almutari@dal.ca

Purpose of the research study
The purpose of the study is to evaluate the effectiveness of a mobile application to promote physical activity behavior.

What you will be asked to do
To help us understand what features influence the effectiveness of using physical activity promotion application, you will first meet with the researcher for 30 minutes at Mona Campbell building, 4th floor "conference room" to sign the consent form and to install the application on your phone .After the App installation, you will be shown how to use it as the study require you using the App for (10 days). After 10 days, you will complete an interview that is audio recorded. Najla Almutari will be available by email and text to answer any questions about the study or help with any problems you have while using the App.

Possible benefits, risks and discomforts
Participating in the study might not benefit you directly, but we might learn things that will benefit others. An indirect benefit of the study is to contribute to knowledge about motivating physical activity behavior using mobile applications.

What you will receive for taking part in our study?
To thank you for your time, we will give you a compensation of $15 after the completion of the study in final interview.

How your information will be protected
All personal data will be kept private and will not be shared. If you agree to let us quote you in publications, we will use a participant ID number instead of your name. This means that you will not be identified in any way in our reports. All electronic records will be kept secure in a password-protected, encrypted file on the researcher's personal computer or on a Dalhousie University secure server. This consent form and all research data will be kept in a secure location that only the researchers can access.

If you decide to stop participating

You are free to leave the study at any time. If you decide to stop participating at any point during the study, please contact Najla Almutari. You can also decide whether you want any of the information that you have contributed up to that point to be removed or if you will allow us to use that information. If you leave the study, you are qualified for the study compensation of $15.

Please answer yes/no to each of the following questions:

All of the following are REQUIRED to participate in the study.

"*I agree to share my challenge code with other participants"*	Yes No
"*I agree to let you quote any comments or statements made in any written reports and I understand that the you will use participant ID number to refer to me instead of my name."*	Yes No
"I understand that my responses during the final interview will be audio recorded, and that is a requirement of participation."	Initials:
"I would like to be notified by email when results are available via a publication." *If yes, please give an email address:* _____	Yes No

"I have read the explanation about this study. I have been given the opportunity to address any questions. By signing below, I consent to take part in the study. However, I understand that my participation is voluntary and that I am free to withdraw from the study at any time"

Participant	**Researcher**
Name:	**Name:** Najla Almutari
Signature:	**Signature:**
Date:	**Date:**

APPENDIX I. Semi-Structured Interview for the App Evaluation

1. How did you use the App to support your physical activity in general?
2. Tell me how the app affected your overall physical activity level?
3. Overall, tell me what features of the App you enjoyed?
4. Why did you like them?
5. How did you use these features?
6. Overall, tell me what features of the App you did not like so much?
7. Why don't you like them?
8. What is the most interesting feature of the App? (you can list more than one feature)
9. What do you think about the leaderboard?
10. How did you use the leaderboard?
11. How did the leaderboard help in motivating you?
12. What do you think about losing hearts, health score, badges?
13. How does losing hearts, health score / badges helped in motivating you?
14. What do you think about gaining rewards?
15. How does gaining rewards help in motivating you?
16. What do you think about challenges, both individual challenge and team challenge?
17. How does the team challenge help in motivating you?
18. How does individual challenge help in motivating you?
19. Did you use the reminder?
20. How does the reminder help in reminding you to do the challenges?
21. How did the suggestions in the App notification help in motivating you?
22. Please, suggest how you would like to see the App improved?
23. Do you see yourself using the App for a longer period of time? Why?
24. Did you find the App useful?
25. Provide any other comments

APPENDIX J. The Post-Study Questionnaire for the App Evaluation

Demographic Questions

1. Please choose your age range:

○ Under 18
○ 18-25
○ 26-35
○ 36-45
○ Over 46

2. Please choose your gender:

○ Male
○ Female
○ Other (please specify) …….

3. What is the highest level of education you have completed?

○ Less than High school
○ High School or equivalent
○ College diploma
○ Bachelor's degree
○ Master's degree
○ Doctoral degree
○ Other (please specify) …….

Measuring perceived persuasiveness of the App

After using StepsBooster-S application, on a scale of 1 to 7 (1-Strongly disagree and 7-Strongly agree), to what extent do you agree with the following statements:

	1-Strongly Disagree						**7- Strongly Agree**
The App influenced me to increase my physical activity behavior	1	2	3	4	5	6	7
The App convinced me to be more physically active	1	2	3	4	5	6	7
The App is personally relevant for me	1	2	3	4	5	6	7
The App made me reconsider my physical activity behavior	1	2	3	4	5	6	7

Measuring effectiveness of the App

After using StepsBooster-S application, on a scale of 1 to 7 (1-Strongly disagree and 7-Strongly agree), to what extent do you agree with the following statements:

	1-Strongly Disagree						**7- Strongly Agree**
The App motivated me to be physically active	1	2	3	4	5	6	7
The App increased my physical activity level	1	2	3	4	5	6	7
The App made me conscious about my physical activity	1	2	3	4	5	6	7

Measuring the user's preference for the features

After using StepsBooster-S application, on a scale of 1 to 7 (1-Strongly disagree and 7-Strongly agree), to what extent do you agree with the following statements:

	1-Strongly Disagree						**7- Strongly Agree**
The reminder feature in the App is helpful to remind me of my challenges	1	2	3	4	5	6	7
The team challenge is helpful in motivating me to be physically active	1	2	3	4	5	6	7
Losing hearts and health scores /badges motivated me to finish my challenges	1	2	3	4	5	6	7
Rewarding me with hearts and health scores /badges motivated me to finish my challenges	1	2	3	4	5	6	7
The leaderboard helped me to be physically active because I want to be on top	1	2	3	4	5	6	7
The App suggestions motivated me to be physically active	1	2	3	4	5	6	7

APPENDIX K. Permission to Use

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