GreenMed: A sustainable physical activity tracking application

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Abstract

Evidence suggests that physical activity brings substantial health benefits while its absence causes several health issues. As people become more aware of negative health outcomes associated with physical inactivity, the shift from sedentary lifestyles to healthier ones occurs, and physical activity tracking apps may help in this regard. While mobile applications for tracking physical activity are abundant, most of of them fail to deliver evidence-based recommendations. This is a major drawback especially when these apps are designed to guide users towards healthy lifestyles. This paper presents a prototype application that could provide evidence-based recommendations about how much physical activity adults should do to stay healthy according to the user's current activity level. A new visualisation approach which uses animal representations for activity levels is also introduced to enhance user experience, increase motivation and create a good base for further integration of gamification principles. Early testing showed that users found the prototype very useful and expressed great interest towards the animal representations.

INTRODUCTION

Time and again, scientific evidence has proved that engaging in physical activity and exercise has enhanced the quality of life and brought positive health outcomes. According to Kruk (2007), physical activity helps reduce mortality risks by preventing several chronic diseases such as cardiovascular problems, cancers, diabetes, hypertension and obesity. Improving physical well-being through exercise also helps generate more positive emotions and significantly reduce depression and anxiety (Strohle, 2009). These health benefits apply to both genders of all ages from all over the world (Department of Health and Human Services, United States), (Chi Pang Wen et. al, 2011).

Physical inactivity on the other hand associates with many health problems. Each year, this 'fourth leading underlying cause of death' (World Health Organization, 2009) killed more than 3.3 million people around the globe (Pratt et al., 2014). Along with morbidity and premature deaths, sedentary lifestyle also places a large burden on the health-care system. In 2013, it cost the worldwide health care system approximately 53.8 billion US dollars on both public and private sector (Ding et al., 2016). Despite the well-known benefits and consequences, a large part of the world population remains inactive. According to a Eurobarometer survey (TNS Opinion &

Social, 2014), approximately 59% of Europeans never or seldom play sports and these figures had not experienced any significant changes since 2009. When it comes to the intensity of exercise, more than 44% of all respondents admitted that they did not perform any moderate or vigorous activity within a week and roughly 13% of them did not walk for at least 10 minutes in some given days. In Asia, the proportion of physically inactive citizens is even higher, accounting for 40% to 80% of the population (Wen et al., 2011).

At the same time, the world also experienced a rapid growth in the mobile phone market. There were approximately 7.5 billion mobile subscriptions worldwide in 2016 with slightly more than half of them using smartphones (Ericsson, 2016). Within a relatively short period of time, ubiquitous mobile devices have reinvented our daily lives by providing not only standard facilities (e.g. calls, messages) but also other advanced functionality (e.g. GPS tracking, sensing ability). This has offered an enormous opportunity to tackle many social challenges including physical inactivity.

When these two trends converge (Steinhubl et al., 2015), the wish of having a mobile application that can guide user towards a healthy living style is made possible (Silva et al., 2015). Since the very beginning, this area has received a tremendous amount of attention and constantly grows over time. In 2013, there were approximately 23,490 and 17,756 apps in both the Apple store and Google Play respectively categorised in the health and fitness section (Middelweerd et al., 2014). Most applications provide tracking of physiological variables (e.g. physical activity, calorie intake, and sleep quality) while detecting behaviour pattern changes and informing users of the changes (Silva et al., 2015). Measurements provided by fitness apps are deemed to be more accurate compared to self-reported ones (Prince et al., 2008), (Dyrstad et al., 2014), giving users a more comprehensive view about their activity levels.

While the number of mobile applications for health and fitness has spiked quickly over the past few years, research pointed out that two major gaps remain. Firstly, while studies on the sufficient amount of physical activity/exercises are abundant, most of the available applications failed to deliver evidence-based recommendations about the sufficient amount of physical activity adults should perform to gain considerable health benefits (Knight et al., 2015). This is a major drawback especially when these apps are designed to guide users towards healthy living styles. Secondly, available apps on the market are primarily focused on improving accuracy and making the app more appealing to users while paying much less attention to the long-term usage and its sustainability.

This research addresses the two aforementioned shortcomings by incorporating the latest research results on physical activity and sustainable designs into an application called GreenMed which helps users to keep track on their physical activities, gives evidence-based recommendations, and delivers insights (e.g. statistics, behaviour patterns). We also propose a new approach to visualise physical activity levels, using animal representations which may bring fun to the visualisation and create a good base for further incorporation of gamification aspects and behaviour changing techniques.

RELATED WORK

As health awareness improves, the need for personal tracking tools that can reflect daily physical activities also grows. Traditionally, activity assessments are carried out through subjective methods such as diaries, questionnaires and surveys. Although these methods are simple and inexpensive, they are prone to bias since the data qualification depends primarily on self-observation and individual interpretations (Prince et al., 2008; Dyrstad et al., 2014). Technological interventions, on the other hand, provide more objective measurements through various methods. Mobile applications are increasingly useful in this area area (Fanning et al., 2012) thanks to the ubiquity and growing capability of personal devices. Built-in sensors (e.g. accelerometer, gyroscope and GPS) in smartphones are very effective in delivering physical activity information (Yang et al., 2010) while giving users a better sense of privacy compared to video recording methods.

Various mobile applications support tracking of user's physical activity, and many of them aim for promoting fitness or weight loss (Gemma Flores Mateo et al., 2015; Middelweerd et al., 2014). The common goals are usually to determine types, duration and intensity of user's motion during a period of time while generating feedback in the form of notifications of statistics based on the collected data. MyFitnessMap (free version) (MyFitnessMap, n.d.), for example, allows the user to record a workout session in various measures (e.g. duration, distance, pace, speed, calories burned and travelled route). The app encourages users to work out more for weight management purpose but does not provide any evidence-based guidelines for users who exercise just to stay healthy.

To improve the estimation of activity detection, additional wearable devices (Mukhopadhyay, 2015) such as hip/wrist bands or smartwatches are sometimes required. Although these devices are still in their early stage of diffusion, various research (Mercer et al., 2016; Yang et al., 2016) suggested that users have strong interests in them. However, when it comes to supporting health and fitness apps, these devices are considered more of facilitators than drivers (Patel et al., 2015).

Gamification is very common among health and fitness applications (Lister et al., 2014). Game-likened rewards and incentives are added as ways to improve users' motivation and engagement (King et al., 2013). Change in a user's behaviour may occur as a result from its impact (Ferguson, 2012).

Applications within the fitness category also adopt various behaviour changing techniques

(Middelweerd et al., 2014; Conroy et al., 2014; Yang et al., 2015), aiming to establish and cultivate healthy lifestyles. The most common technique is providing instructions or demonstrations of specific physical activities (Conroy et al., 2014). Other techniques such as providing feedback on performance, goal setting/reviewing and social support are also very popular although some of them only appear in paid apps.

METHODOLOGY

The methodology can be largely divided into three parts, including application development, application implementation and survey design.

Application development

This paper proposes an application which helps users track their physical activities (e.g. types of activity, time, and duration), gives evidence based suggestions about the remaining amount of physical activity that users should do and highlights behavior patterns by extracting insights from the collated information.

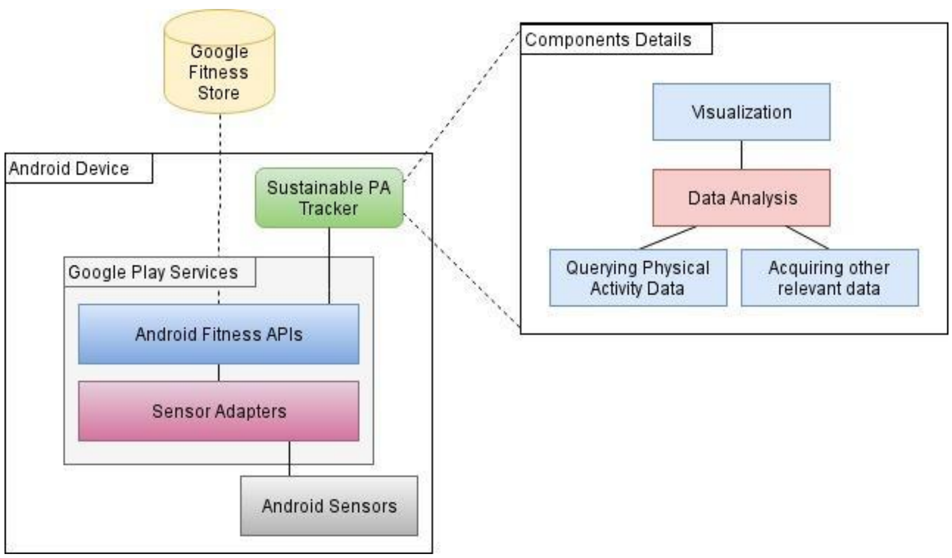


Figure 1. System Architecture

As illustrated in Figure 1, GreenMed was developed based on Google Fitness APIs, a service of Google Play Services. Physical activity data (types and durations) and relevant environmental and locality data such as weather, sunrise and sunset time, etc. are collected and stream to the analysis component where the application calculates physical activity levels and generates recommendations. Data analysis also provides statistical data of physical activities that users performed daily, weekly and monthly, giving the user a glimpse into their behavior patterns. Finally, the app visualised data conveyed in the analysis component to the user.

Different types of physical activities with different durations and intensities have different impacts on health. Vigorous-intensity activities (e.g. cardiorespiratory fitness, running, sports) yield larger mortality reductions while moderate-intensity activities in daily living (e.g. gardening, doing chores) and physical activities for transportation (e.g. cycling, walking) deliver smaller health benefits. Based on several physical activity guidelines (Leitzmann et al., 2007; Physical Activity Guidelines Advisory Committee, 2008; World Health Organization, 2010), adults should exercise for at least 150 minutes of moderate-intensity activities or 75 minutes of vigorous-intensity activities, or an equivalent combination of both to achieve substantial health benefits. For even greater health benefits, adults should exercise for 300 minutes of moderate - intensity, or 150 minutes of vigorous-intensity activities every week. Other research also suggests that health benefits can still be found even with smaller doses of physical activity compared to the recommended levels (Wen et al., 2011; Lee et al., 2014). For example, with 15 minutes a day of moderate intensity activities such as walking and cycling or 5 - 10 minutes of moderate to vigorous intensity activities such as running and jogging, people can reduce mortality risks by 14%.

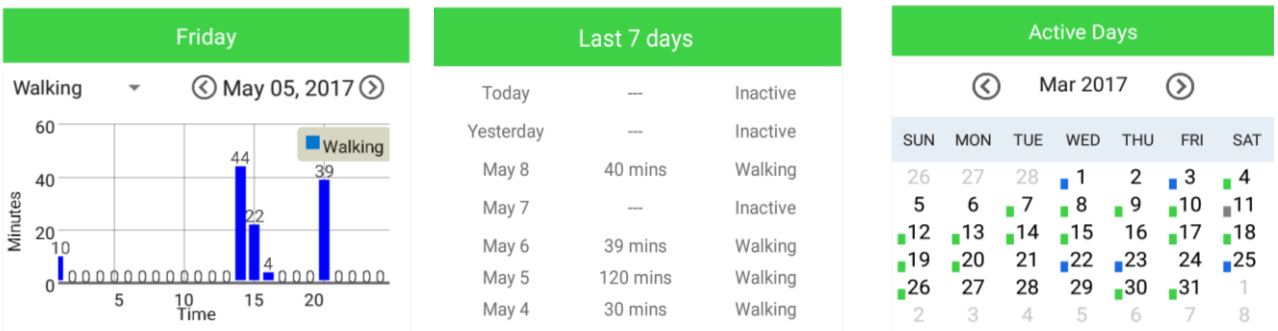
To give suitable recommendations, a user's physical activity is first categorised into four activity levels depending on activity types, intensity and durations:

- *Inactive*: Little (less than 5 minutes) or no physical activity;
- *Slightly Active*: The user has done some physical activities but under the minimum level (15 minutes of moderate-intensity activity or 5-10 minutes of vigorous-intensity activity);
- *Moderately Active*: The user has done more physical activity than the minimum level but still under the recommended level (at least 30 minutes a day); and
- *Highly Active*: The user's physical activity level is above the recommended level.

Based on a user's current activity level and environmental data, recommendations are generated. These recommendations are designed to guide users toward the next level in the activity scale, step by step until they have reached the recommended levels. Relevant information such as weather, sunrise, sunset time and current temperature will also be given, helping users to plan their day better so they could make room for appropriate physical activities during the day. For example, if sun sets after 8:00 PM and the weather is nice, users are suggested outdoor activities. Recommendations will be given not only daily but also weekly, encouraging users to stay active every day rather than being highly active one day and then being inactive for the rest of the week.

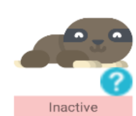
In Data Visualisation, along with recommendation, details of activity data are also visualised, giving the user a comprehensive view into their activity patterns. Figure 2 presents screenshots of the prototype. The left shows activity logs per hour, while the middle is for the past 7 days and the right shows monthly logs. In this log, for each day, if a user performed some physical activities, it will be marked with a small square. A green square represents Highly Active level, a blue square represents Moderately Active level and a grey square represents Slightly Active level.

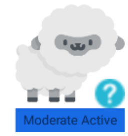
Figure 2. Activity logs



In this prototype, we also apply animal representations into visualising the user's physical activity levels. Depending on the user's current activity levels, they will get an animal that shares a similar activity pattern as an avatar. When the user touches this avatar, a pop up will appear with some general information and fun facts about the animal. This way, the app helps by stimulating curiosity and improves awareness about the animals living around us. This also adds an element of gamification to using the app (e.g. achievement), (Lister et al., 2014). Table 1 presents how research on physical activity and the animal representation are integrated into demonstrating activity levels. For example, bees are very active, therefore, if a user's activity level is classified as highly active, one will get a bee. Similarly, if user is inactive or slightly active, one could get a cat, a sloth or a panda due to the perceived similarity in their behaviour patterns.

Table 1. Animal representation of physical activity levels

Daily Activity Levels	***Example Animal***	***Scientific Ref***	***Example Picture***
Inactive (0 to 5 minutes)	Sloth Cat Panda	(Wen et al., 2011)	
Slightly Active (> 5 to 15 minutes)	Sloth Cat Panda	(Wen et al., 2011)	

Moderately Active (15 to 30 minutes)	Dog Sheep Cow	(Lee et al., 2014; Wen et al., 2014; Franklin et al., 2006; van Gent et al., 2007)	
Highly Active (> 30 minutes)	Bee Humming Bird Squirrel	(Department of Health and Human Services, United States; Leitzmann et al., 2007; Physical Activity Guidelines Advisory Committee, 2008; World Health Organization, 2010)	

Application implementation

Android Fitness APIs were used for developing the first prototype of GreenMed. It was a reasonable choice concerning sustainable aspects, mainly for two reasons. Firstly, it reduces data redundancy and improves data re-usability by collecting sensing data once and sharing it among compatible apps. Given the fact that multiple vendors such as Asus, HTC, LG, Intel and many more vendors are now joining the ecosystem, using Android Fitness APIs can make the most out of the same set of data. Secondly, Google Fit APIs help ease the device integration process by acting as a transparent layer connecting the application and device hardware. If the device is compatible with the Google Fit platform, the application can retrieve data from the device.

Survey Design

To evaluate the prototype, an installation file, a video demo and an online survey about the application were published on social media for a week. If people showed interest in the video, they could install and try out the app. Volunteers were asked to try using the app for at least a day to understand the application functionality before completing the survey for feedback. The survey focuses on evaluating the usefulness of information delivered by the app, but also asked about views on the animal representations as well as the sustainability of the app. Users were also asked about their satisfactions levels, asked for suggestions to improve the app, and if they would be willing to use the app when it is ready to be published.

RESULTS

11 volunteers participated in testing the application with 27.27% female and 72.73% male individuals. Most participants have a computer science background with 45.45% of them having working experience in mobile development.

In terms of functionality and usefulness, the information delivered by the app was perceived as very useful by the majority with 72.7% of respondents (Figure 3). Participants also showed great interest in the animal representations, where some users even cited them as the most inspiring thing in the app. When users were asked about how likely they would be willing to try this software again when it is ready for public usage, 10 out of 11 respondents ranked their likelihoods from 7 to 10 (the respondents could reply between 1 and 10, where 1 is the lowest likelihood and 10 is the highest likelihood) with more than 50% of the answers falling into 9 and 10 category. Similar ratios were found when users were asked how likely they would recommend the app to their friends and loved ones.

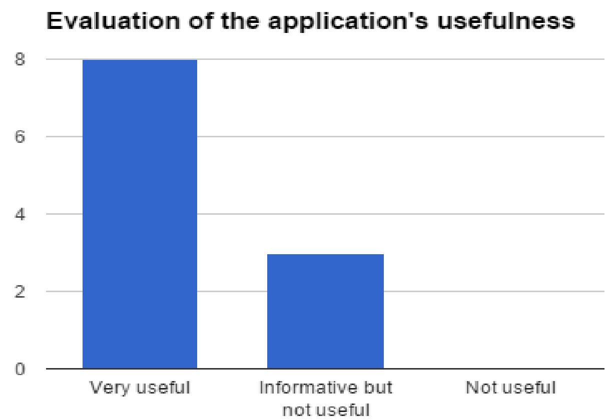


Figure 3. Evaluation of the application's usefulness

When it comes to sustainability, the application has to balance between the accuracy of physical activity classification and the battery consumption, so volunteers were asked about their experience with these two metrics. For the accuracy of activity classification, 54.5% of respondents reported that they were very satisfied while the rest claimed that they were somewhat satisfied. Battery consumption also received positive feedback with 63.6% users stating that they barely noticed any battery drain while the remaining 36.4% said that the battery consumption was acceptable.

The app received some interesting suggestions from the volunteer testers. One reviewer thought the app should allow users to manually add their activity records, since some users prefer not to bring their phone while going out for a run, for example. Users with a strong mobile development background suggested improvements in user experience (e.g. notifying users with new recommendations, better handling exceptions), and some users mentioned adding information about calories.

DISCUSSION

Compared to available health and fitness applications, our proposed prototype application addresses the shortcomings on providing evidence-based recommendations and introduces animal representations for physical activity levels to entice or inspire users. Since physical activity patterns in humans share a lot in common with those of animals, using animal representations not only gives diverse categories of activity patterns to represent users, but also paves the way for further integration of educational and gamified elements into health and fitness applications.

There are several ways one could develop this idea further. One such way is to include reward systems. An example reward system can reward users for being active during the week by giving them the type of animal that matches their behaviour patterns. With this animal in their collection, they could share it on social media or even trade it with their friends if they already have it. Another way to further gamify the app is to develop mini games that utilise the animal characters that the users get every day.

Although the prototype fulfilled the lack of evidence-based recommendations in available apps, there are several limitations. Firstly this study had few participants, more users with various backgrounds and ages are needed to improve the generalisation. Secondly, giving users information about the minimum amount of exercise they should do to gain health benefits is very useful but it is not enough for cultivating and maintaining a healthy living style. Further incorporation of other aspects such as gamification or behaviour changing techniques may help in this regard. Finally, the app uses Google Fit APIs, despite many advantages brought by this approach, using APIs means having platform dependencies and very little control over the accuracy of activity detection, if at all.

CONCLUSION

This paper presents a prototype application that keeps track of physical activity levels while effectively visualising it to users and giving evidence-based recommendations according to the user's current activity level. A new approach to visualising activity levels using animal representations is proposed and integrated into the prototype. The majority of volunteer test users (72.7%) found the prototype useful while the remaining 27.2% agreed on its informativeness. Respondents also showed great interest towards the animal representations that are introduced in the app. Further improvements could be incorporating gamified elements and behaviour changing techniques into the prototype; enhancing the reliability and publishing the app into Google Play Store for a larger scale test.

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