The Myth of 10,000 Steps: A New Approach to Smartphone-based Health Apps for Supporting Physical Activity

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Abstract: This paper introduces an alternative approach to conventional pedometer apps which measure the wide-spread goal of 10,000 steps a day. Instead we focus on the intensity of physical activity, which is in line with recent recommendations of renowned health institutions such as the WHO. These promote a minimum of moderate to vigorous physically active time per week to achieve the desired health benefits. The paper discusses how the guidelines have been implemented. It also outlines how we help maintain user motivation over time (e.g. by integrating and personalising "nudges") and how we intend to solve the challenges posed by different fitness levels and personal lifestyles.

1 INTRODUCTION

The importance and the positive effects of regular physical activity (PA) are well known and have been confirmed in many studies (e.g. Warburton et al., 2006, Piercy et al., 2018). In developed countries, around 1% to 3% of the total health care costs can be attributed directly to physical inactivity. The indirect costs are likely to be more than double of the direct costs (Pratt et al., 2014). Encouraging people to engage in more PA is a global priority to reduce the burden of noncommunicable disease (World Health Organization, 2015).

PA can take on many different forms, e.g. walking, running, hiking, cycling, swimming, yoga, resistance training etc. The more complex the movement, the more difficult it is to track and monitor. For walking and running, a smartphone with an accelerometer is sufficient. For more complex activities a combination of several sensors worn on the body or placed in the environment are necessary (Dernbach et al., 2012).

Pedometer apps (pure step counters) and running apps are wide-spread. The Runtastic app, for example, has over 300 million downloads (Adidas Runtastic. 2019), the app “Pedometer – Step Counter” has over 30 million downloads (Pedometer - Step Counter - Apps on Google Play, n.d.). Moreover, brisk walking, jogging and running are among the most popular sports in the world and have a significant impact on health and longevity (Lee et al., 2017).

People who use such apps tend to be much more active than non-users and have a lower body mass index (BMI) (Litman et al, 2015). App-based interventions aimed at encouraging PA have shown significant health improvements for children and adults (Schoeppe et al, 2016). The evidence to support the health benefits of regular physical activity has become increasingly compelling (see e.g. Department of Health and Social Care, 2019).

However, most PA apps that are currently available, have some severe deficits, especially those which promote activities such as running or walking. These are regarded as the most basic activities to achieve an active lifestyle and are therefore also recommended by international health organisations. On the whole, current apps tend to rely on the wide-spread goal of completing 10,000 steps per day. Such a goal may be easy to implement in technical terms, but rather hard to incorporate into an average user’s everyday life. Moreover, this activity goal is quite controversial among experts who doubt that counting steps is the best approach towards an active lifestyle (Wattanapisit & Thanamee, 2017).

This paper describes an alternative approach to supporting an active lifestyle which is not based on the numbers of steps per day. Our approach is based on the most recent recommendations, for example the Department of Health and Social Care (2019). These guidelines recommend moderate aerobic exercise for 150 minutes a week or vigorous aerobic exercise for at least 75 minutes a week. Section 2 describes the shortcomings of the currently available apps which are mostly based on the 10,000 steps per day. In Section 3 we present our alternative approach which aims at overcoming these shortcomings and which also tackles the problem related to incorporating regular PA into a user's everyday life. Section 4 discusses how we are evaluating the app and see how its impact differs from apps with conventional features. Section 5 outlines some challenges to target in future work and possible solutions.

2 SHORTCOMINGS OF EXISTING APPS SUPPORTING PHYSICAL ACTIVITY

Most of the currently available apps for tracking activity including smartwatches and electronic pedometers promote the widespread and well-known goal of 10,000 steps per day. The origin of this marker goes back to a Japanese pedometer nicknamed "Manpo-kei" which can be translated as "10,000 steps meter" (Tudor-Locke & Bassett, 2004). There is some scientific evidence that 10,000 steps/day may have health benefits (Kang et al., 2009). However, to integrate that step goal into one's everday life is challenging. Moreover, counting steps does not represent an exact and scientific way to measure energy expenditure. Neither is it in line with widely approved international health recommendations which focus on accumulated time of moderate to vigorous physical activity (MVPA) in the course of a week.

Walking 10,000 steps per day does not guarantee that past nor current PA recommendations have been met (Le-Masurier, 2003). Several approaches have been tried in a variety of projects to achieve the daily 10,000 steps' goal, largely without success. Most people fail to reach that goal, missing on average approximately 4000 steps (Choi et al., 2007). An additional six hours and forty minutes of walking would be necessary per week to reach the 10,000 steps' goal (70 steps/min).

This corresponds to the factor of 2.5 of the metabolic equivalent of task (MET), an objective measure of energy expenditure. One MET is the equivalent of the energy cost of sitting quietly. Based on a cadence of 100 steps per minute to reach a moderate intensity level, i.e. MET level 3.5, it would be enough to do 3000 steps in 30 minutes on five days a week instead (Tudor-Locke et al., 2018; Hendelman et al., 2000). The threshold for vigorous PA is about 130 steps per minute, which is the equivalent of 6 MET (Tudor-Locke et al., 2018).

Instead of aiming for 10,000 steps a day with questionable impact on one's health it would be possible to reach the recommended health goals based on intensity with an equivalent of about 3000 steps within 30 minutes on five days per week. Other studies found that 6500 to 8500 steps per day would suffice to achieve the recommended amount of PA energy expenditure (Ayabe et al., 2008), which however does not consider intensity.

All quantitative goals, be it just counting 10,000 steps per day or simply adapting the goal posts in line with the number of steps already performed – a common practice in many apps -, fall short of the current health recommendations. This is due to the fact that they fail to take into account the intensity and thus the quality of the PA.

Although gamification elements and social support, e.g. the interaction with peers, can contribute to maintain people's motivation to use a PA app, this tends to decline considerably over time and adherence is marked by high variability (Marin et al., 2019; Ryan et al., 2017). The effects of step counting apps such as those shown in Figure 1 are modest at best (Bort-Roig et al, 2014, Coughlin et al., 2016).

Figure 1: Two typical pedometer apps with 10,000 steps goal (Steps, Stepz).

3 ALTERNATIVE APPROACH TO APPS SUPPORTING PHYSICAL ACTIVITY

We intend to overcome the shortcomings of typical apps promoting physical activity by designing and implementing a new approach.

3.1 Design Principles

As already said, pedometer apps which just count steps are available in huge numbers. To our knowledge, however, there are no apps which focus on the intensities recommended for physical activity. Whilst counting steps is rather trivial, incorporating measurements and goals based on intensities is far more challenging. This is especially true if no physiological parameters like heart rate (HR) or heart rate variability (HRV) are available.

These days, smartphone cameras are able to measure HR and HRV based on changes in blood volume in the fingers (photoplethysmography, PPG) (Peng et al 2015). However, such measurements may be difficult to carry out whilst running or jogging. Other methods would require additional devices like chest straps, smartwatches or other body sensors.

We propose to drop daily goals altogether and integrate weekly goals as promoted in current health recommendations from WHO and others. From a health perspective, it makes more sense to adopt open and continuous time windows instead of focusing on single days or a 7-day calendar week pattern.

One advantage of longer timeframes is that the user has more freedom to incorporate activities into his or her routines without the need to perform an activity every day. The downside could be that users are tempted to postpone activities from one day to the next. This could result in having to perform all the activities required to achieve the weekly goal within one or two days, for example on the weekend. Although it would be better to engage in regular physical activity, it is still better to be active only on one or two days instead of not at all.

We have developed an approach that anticipates the tendency to procrastinate and highlights the consequences of postponing activity to later. Every day without activity increases the amount of activity needed to reach the goal.

3.2 Implementation

The above-mentioned design principles were translated into a prototype by a team of researchers with expertise in user experience and behavioural economics.

For example, to counteract people's tendency to postpone activity till later, the consequences of such behaviour are visualized by a specifically designed bar chart which has been integrated into the graphical user interface (GUI), see Figure 4.

The aim of the bar chart is to encourage people to engage in regular physical activity instead of just going for a run or brisk walk at the weekend. We do not rely on the calendar week for visualising the PA delta but have opted for a continuous floating 7-day activity goal. Users can shift the visualized period forth and back to see how the activities of different intensities influence the PA necessary to achieve the desired health benefits. The app calculates the effort still required to reach the goal depending on the past activities. The more days are taken into account from the past, the fewer days are left for future activities to reach the goal and vice versa. In line with the above-mentioned health recommendations, the total period to reach the activity goal is always 7 days (Figures 2 and 3). This helps the user to learn the benefits and advantages related to frequent and regular rather than extended isolated activities. This is illustrated in Figure 3, which shows what happens if an extended single activity drops out of the visualization period. As a result, the effort to reach the 7-day goal goes up to the maximum.

Figure 2: More frequent activities have a smaller effect on the activity recommended to achieve the goal if the observation window is moved by one day.

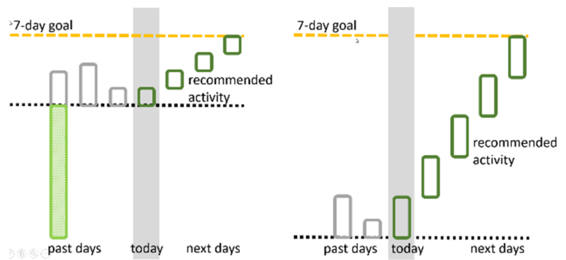

Figure 3: Single active days have a big effect on the effort required to achieve the goal if they drop out of the observation window.

As shown in Figure 2, the user has accumulated a total of 90 minutes of physical activity at moderate intensity over a period of three days, which means that there are still 15 minutes to go on each of the following four days. If the window is shifted forward one day, the total activity amounts to 60 minutes and 18 minutes to go for each of the following five days. The impact of moving the observation window therefore is low.

In Figure 3, the user also has accumulated 90 minutes of physical activity at moderate intensity, but in a single day with 15 minutes to go on each of the following four days. If the observation window is shifted forward by one day, the activity count drops to zero, and 30 minutes of moderately intense PA is recommended for each of the following five days. In addition to intensity derived from walking cadence our app considers the height profile of a track, which is a critical factor for intensity as well. Our algorithm is based on the formula of Naismith, which implies that 1m of ascent is equivalent to 8m of horizontal travel (Scarf, 2007).

The app brings together all the relevant information in one single screen. There is no need to go through a series of menus to collect relevant information with goal achievement being the most important. The default view shows the current day in the centre of the 7-day window. It also shows the activity over the last three days and the average activity required to reach the goal within the next four days including the current day. The area of visualization can be shifted via touchscreen. Moderate physical activity is visualized in light green, vigorous activity in dark green and light activity is grey. Only green activity is relevant for achieving the goal and therefore stacked to fill the accumulated bar on the right-hand side of the screen (Figure 4, both left and right example).

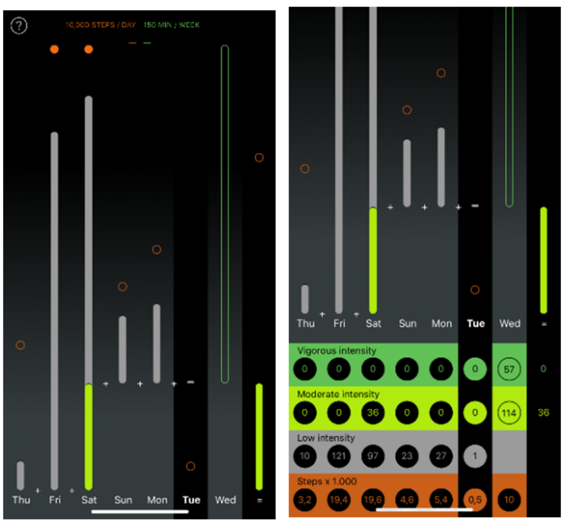

Figure 4: App interface of the prototype.

To highlight the difference between quantifying steps and MVPA, the total of steps per day is shown as an orange circle for the current and past days. A filled circle means the threshold of 10,000 steps has been reached. However, it does not mean that any MVPA has been achieved (see Figure 4, day Friday) This is an important message conveyed by the app and the interface.

The interface can be swiped up to get more insight into the data. Active time in MVPA is shown for every past day. It also shows the time with low intensity (e.g. from slow walking) and the total steps per day. The columns to the right of the current day show how much MVPA is needed to reach the goal. The column on the right shows the total active time in each intensity zone (Figure 4).

3.3 Maintaining Motivation

As mentioned above, a major challenge is to maintain user motivation over time (Nagler et al., 2013). Our approach incorporates features based on insights from behavioural economics which have been translated into brief persuasive interventions, often described as "nudges". These may take on the form of alerts or reminders as well as regular and possibly immediate feedback on a user's behaviour (Reimer et al., 2016).

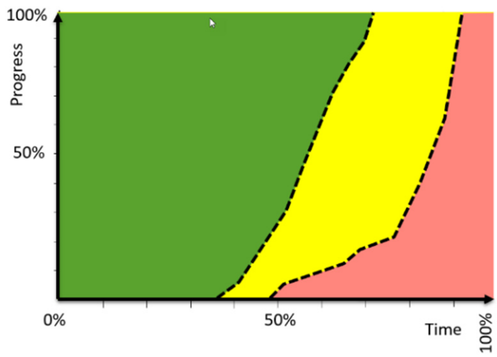

Figure 5: Adaptive goal-achievement graph for triggering situation-specific nudges.

Besides, we use a self-learning framework to generate personalized and situation-specific interventions because it has been shown that the "one-size-fits-all" approach which disregards individual preferences and contextual aspects fails to maintain motivation (Reimer et al., 2016). The core element for generating notifications is an adaptive goal-achievement graph (see Figure 5). The graph triggers different types of nudges depending on the time and the progress towards the floating 7-day goal. A learning algorithm adapts the segments to the reactions of the user and thus continually improves the chances to trigger the right type of nudge at the most appropriate time.

4 EVALUATION

The prototype has been pre-tested with a small group of users (n=12) in an iterative process. Seven participants were recruited from a school class (age = 14), five from the authors' work environment (age 25 – 67). For the pre-test we used both interviews and questionnaires (in the case of the pupils) which addressed the following aspects: motivation for app usage, goals related to physical activity, joy of use, ease of use, other usability aspects such as error tolerance and questions about the nudging approach.

The test users identified several shortcomings related to the interface and interaction design, the algorithm to trigger the appropriate nudges and some technical issues (e.g. high energy consumption). As a result of their feedback we have made minor changes to the interaction design and the GUI, e.g. the colour scheme. Currently, we are working on the onboarding process which explains the main elements and the benefits of the app after installation.

For the main evaluation we shall publish the app via the Apple AppStore to reach larger numbers of potential users. We expect to reach at least 150 to 200 users in the initial phase. To counteract the drop-off effect, the evaluation process can be extended and supported by online marketing activities if necessary. Once it has been downloaded and installed, the app will randomly activate one of two different approaches for user motivation. The static version uses the traditional approach known from most of the common PA-promoting apps and makes use of a reduced and hard-wired set of nudges. The dynamic version includes the goal-achievement graph which adapts over time in line with a user's individual performance. The graph should then trigger nudges at promising times of the day and select nudge types that are adapted to the individual user. The users will not know which version they get to prevent bias.

The evaluation will examine the differences in terms of PA between the two interventions groups. PA can be measured by counting the number of steps per single session of PA, steps per day, or per week or to which extent the PA recommendations have been reached. Additional parameters are number of floors climbed and changes in walking cadence. We also compare PA before the installation of the app with the period from the installation and start of the app usage. This can be done via access to the history of PA data stored in the health applications of the operating systems (e.g. HealthKit from iOS).

An important aspect besides the motivation to be physical active is the motivation to use the app. Both aspects shall be evaluated. Parameters for app usage are number of times the app is opened, interactions within the app and the time per session. We also differ between nudge triggered and arbitrarily triggered user interactions.

Additional outcome parameters are the users' reactions to specific nudge types and their engagement over time. The evaluation will investigate both short-term (4 to 6 weeks) and long-term effects (several months). Apart from the data collected from the app we also plan to use a questionnaire to obtain basic socio-demographic information about the users (age, gender) and gain further insights about usability, acceptance, and motivation.

5 OUTLOOK & FUTURE WORK

One unsolved challenge is the problem of not knowing if someone is within his or her individual range of moderate or vigorous intensity. Currently we rely on correlations between step frequency and average intensity. The threshold for moderate intensity is around 100 steps/min or 3.5 METs, for vigorous intensity the threshold is around 130 steps/min or 6 METs (Tudor-Locke et al., 2018). We are exploring different ways to optimize the measurement of individual effort during exercise or PA.

For example, we may calibrate the individual intensity thresholds based on measuring the breathing frequency whilst talking. The test can be used when calibrating for the first time to define the individual threshold and can be repeated to measure if the user is in good or bad shape.

In the future, we also want to include optional tracking of the heart rate to get a better feedback for PA apart from walking and running. The idea is to let the user select specific types of PA like cycling, yoga or swimming and to derive the intensity based on movement and heart rate. Using the METs as suggested by Ainsworth et al. (2000), these activities could then be added to the physically active time shown by the app.

Another possibility to improve the app could consist in combining the two approaches with information from additional sensor data (GPS sensor, accelerometer, barometer, gyro sensor, compass, ambient sensor, ambient light sensor etc.). The data could be used to learn how to identify situations of higher physical intensity. This method would incorporate machine learning so as to be able to recognize patterns in the sensor data gathered from wearables, for instance, and as a result learn how to identify high intensity activity based on data patterns.

Finally, we have to be aware of the fact that it might be difficult for sedentary adults or older adults to meet the recommended PA goals. We should therefore consider adapting the MPVA thresholds given in the guidelines to the individual fitness level which could then be raised over time if a person's fitness improves. The positive effects of even low-dose activity for older adults have already been confirmed in various studies (e.g. Sparling et al. 2015, Hupin et al. 2015). Besides, there is evidence for a dose–response relationship between physical activity and premature mortality (Warburton et al., 2017). Inspired by these findings, we intend to further develop our approach.

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