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On the Design and Prototyping of CrowdWalk: Leveraging the Wisdom of the Crowd to Inspire Walking Activities

MASTER DISSERTATION

Tiago João Franco de Ornelas

MASTER IN INFORMATICS ENGINEERING

UNIVERSIDADE da MADEIRA

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Funchal - Portugal, September 2017

Abstract

Individuals often struggle to move from the intention of attaining healthy lifestyles to their set goal. Long-lasting behaviors are hard to achieve, and despite the initial premises, the effectiveness of self-tracking tools has been found to wear off with time.

In this work, we foster an alternative approach to the dominant narrative of quantification. We present CrowdWalk, a mobile application that leverages the wisdom of the crowd to produce location-based "walking challenges", thus supporting behavior change through highlighting opportunities for physical activity.

We first present a study on how people find ways to perform physical activity in their daily routines. Based on these insights, we developed CrowdWalk, a tool that encourages those types of activities thus concluding with our design considerations for persuasive technologies. We present our full design and prototyping process along with a usability evaluation of the final tool.

To begin with, we present a study on how people find ways to perform physical activity in their daily routines and then, we present CrowdWalk as a tool that encourages those types of activities thus concluding with our design considerations for persuasive technologies.

Keywords: Activity tracking; Self-quantification; Behavior change; Persuasive technologies; Crowdsourcing.

Resumo

Existe uma grande dificuldade nos indivíduos em transformar a intenção de adotar um estilo de vida saudável em objetivos concretos. Comportamentos sustentáveis dificilmente persistem e, apesar de todas as premissas, tem-se vindo a descobrir que a eficácia das ferramentas de monitorização de atividade física diminui com o passar do tempo.

Neste trabalho é desenvolvida uma abordagem alternativa à temática da quantificação. Apresentamos o CrowdWalk, uma aplicação móvel que beneficia a sabedoria das pessoas para criar "desafios para andar a pé" baseados em localizações e assim, incentivar a mudança de comportamentos destacando oportunidades para exercer atividade física.

Efetuamos um estudo acerca de que atividades as pessoas praticam no seu dia a dia, apresentamos o CrowdWalk como uma ferramenta que incentiva essas mesmas atividades, e concluímos considerações relativas ao design para tecnologias persuasivas que encorajam a atividade física.

Palavras-chave: Monitorização de atividade física, Auto quantificação, Tecnologias Persuasivas, *Crowdsourcing*.

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1 Introduction

Sedentary lifestyle is one of the most worrisome and challenging public health problems of our time. Linked to fast rise of several serious health problems such as cardiovascular disease, obesity or diabetes, the World Health Organization poses physical inactivity among the top 10 leading causes of death worldwide(World Health Organization, 2009). As a preventable public health problem, numerous interventions have been developed with the aim of increasing individual's physical activity in daily life. Take as an example Activity Trackers. Activity tracker rest on the assumption that by "helping individuals to monitor physical activity, they will be encouraged to attain a healthy behavior by *reflecting* on historical data" (Ornelas, Caraban, Gouveia, & Karapanos, 2015). One limitation of this reflecting-based approach is its reliance on user motivation to explore the data (or at least pay attention to it) and identify opportunities for action. This motivation is not always there, and self-regulation does not work for everyone.

Researchers have raised concerns over the long-term adoption and effectiveness of activity trackers(Fritz, Huang, Murphy, & Zimmermann, 2014; Gouveia, Karapanos, & Hassenzahl, 2015; Karapanos, 2015; Shih & Pennsylvania, 2014). Despite one in ten Americans over 18 owning an activity tracker(Ledger & McCaffrey, 2014), keeping the users loyal to their tracking device has proven to be a hard thing to accomplish. Over the years, brands like Jawbone, Fitbit, Nike and Misfit have made several attempts to build more engaging activity trackers however, not all users have managed to feel inspired by these tools. User engagement rates are deplorable in a way that 75% of users stop using them after only 4 weeks of usage(Shih & Pennsylvania, 2014). Gouveia R. et al (Gouveia et al., 2015)found 66% of participants used the tracker longer than two days, 38% longer than a week, and only 14% longer than two weeks.

We believe that activity trackers neglect how to lead users from the intention to action as reflecting does not always lead to insightful outcomes. In this work, we foster an alternative approach to the dominant narrative of quantification and explore the use of contextual information (e.g. places) to highlight opportunities for physical activity that encourage changes in behavior. This thesis presents *CrowdWalk*, a mobile app that leverages

the wisdom of the crowd to produce location-based "walking challenges" that support behavior change in everyday life. What we intend with our study is to use crowdsourcing to provide novel walking activities that will be performed by the users on a community that will feel inspired by them over the time.

1.1 *Goals*

In order to motivate users to walk more and sustain change, we identified three key requirements for the development of an activity tracker:

- help users boost and sustain their daily amount of walking
- support habit formation
- sustain engagement over time.

Walking is an activity that often needs inspiring in order to form habit. By identifying how one can perform these activities on the current context and by presenting them at the best time, at the ideal location, we hope to create walking habits within users.

To boost the daily amount of walking we decided to highlight walking activities that are present in individuals' daily routines (e.g. taking the longest route to the coffee shop). Our long-term goal is that individuals create habits by the repeated performance of such activities, motivated by the progress noticed on their well-being and health condition by providing such opportunities to do so. We believe that if we can timely provide these activities, individuals will engage on a series of consecutive walking performances that can induce habit formation. Also, by allowing performance comparison with their walking activity records they can be more aware of the progress they made during the activity tracker usage period.

As a strategy to diminish the high disengaging rates at which activity trackers are susceptible, we decided to present users with novel challenges which are correlated with geo and contextual locations, provided by the community (e.g. a walking challenge that suggests taking the stairs instead of the elevator). By tailoring activities to one's location, we expect users to have higher likelihood of engaging in it, since those activities are highly

contextualized. Finally, the subliminal goal here is to inspire all users to create and add walking activities into one repository by making them realize how their day to day choices can be passed on and shared with others. The ultimate goal is to provide user's satisfaction by making them look for novel challenges on the locations they usually go through daily.

Previous studies have found individuals to feel demotivated towards tracking when lacking credit for their activities (e.g. forgetting to wear a tracker, or running out of battery). "The cost of tracking often leads to abandonment, consistent with prior health and wellness results [4,5,11]. People find tracking "a hassle," feel "lazy," or "lose interest" and stop tracking (20, 16, and 6 people). The habit of collecting data can often be difficult to maintain in tools that require regular manual entry, such as financial spreadsheets or food journals [5,6]: "I got behind on keeping up with it and could not find the time to start back up" (p112, 18 others). Others find tracking too tiring "I got burnt out on [keeping a financial spreadsheet]" (p14)." (Epstein et al., 2016).For these reasons, we track every steps the user performs even when CrowdWalk is only running on background on one's mobile phone. Our goal was to build an android app that will be always present on the user routine since it is a tool that most people carry today. Taking advantage on the fact that users are now familiar with mobile apps and by understanding how users want to interact with the activity tracking tool, the goal is to build a user interface that does not require a lot of interaction effort and can track user's activity levels without almost none interaction steps.

2 Literature review

2.1 *Personal tracking tools*

Personal tracking tools are devices that quantify people's behaviors in terms of physical activity by measuring inputs like: number of steps, calories intake, heart rate, amongst others. Activity trackers can simply store user activity to display historical data or can implement strategies to provide feedback to the user on how to adapt actions in order to improve and attain a healthier lifestyle. Aside from activity trackers, there are also tools designed and used to monitor sports activity, these devices are named sports trackers (also referenced as fitness trackers) and record user data as well but their main role is to store data for consultation.

2.1.1 Related work

Devices like *Fitbit*, *Jawbone*, *Moov*, *Xiaomi band* and applications like *Moves* and *Human* are amongst the most popular activity trackers today. Lately, smartwatches like Apple Watch, Samsung Gear Motorola's 360 have also added activity tracking features into the devices in order track user's activity levels by collecting number of steps and heart rate. All of these tools commonly aim to change behaviour upon individuals through researched techniques used to get the most out of the use of them.

Mercer et al. (Mercer, K., Li, M., Giangregorio, L., Burns, C., & Grindrod, 2016) studied which behavior change techniques were more present on wearable activity trackers, see Figure 1 - Behavior change techniques present on wearable activity trackers. From the analysis of the study results, it is possible to verify that the *Presentation of Self in Everyday Life* theory has a strong presence on activity trackers ("Provides information about others' approval", "Provide normative information about others' behavior", "Facilitate social comparison", "Plan social support/social change"). Goal-setting theory is also verified on most devices ("Prompt review on behavioural goals", "Goal setting (behaviour)", "Goal setting (outcome)") which is kind of expected since most users that acquire an activity tracker are on determination and action phases of the *Transtheoretical Model*(Fahrenwald & Walker,

2007). Self-monitoring also seems to be a commonly used factor on activity trackers ("Prompt self-monitoring of behaviour", "Prompting focus on past success", "Provide feedback on performance") since it provides motivation with the results obtained thus reducing the dropout rates.

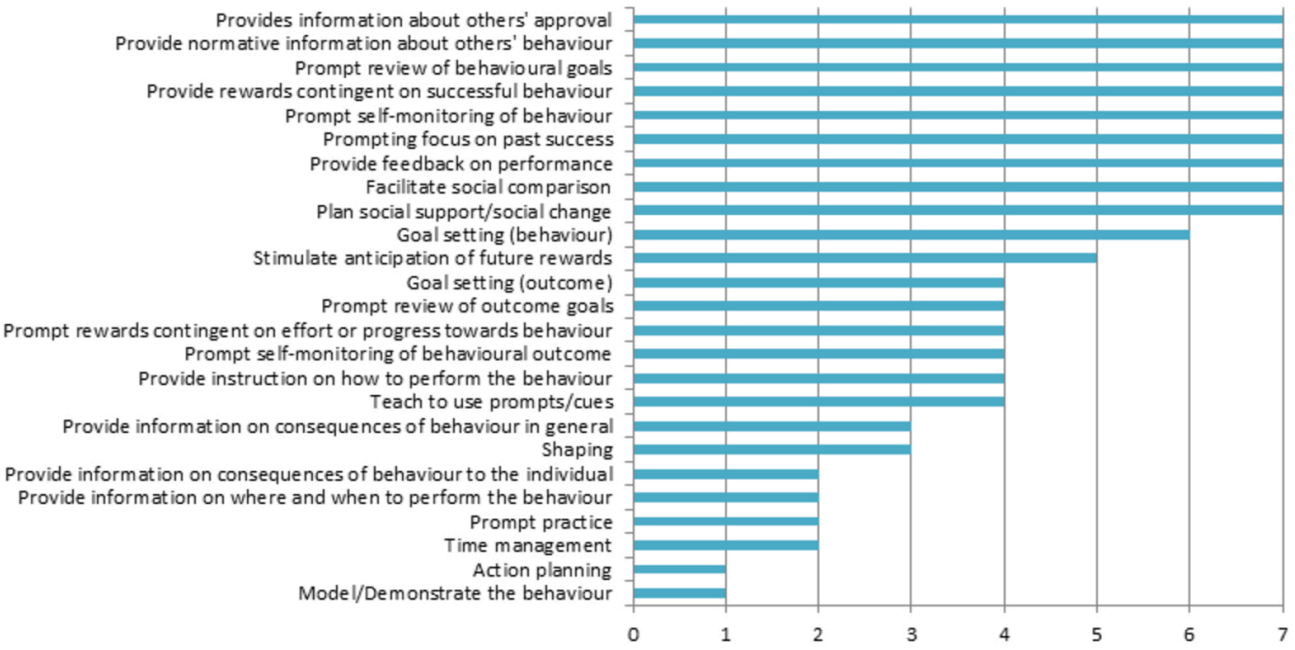

Figure 1 - Behavior change techniques present on wearable activity trackers

Some study systems were also built like *Fish 'n' Steps*(Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006), *UbiFit* (refer to Goal setting theory section) and *Habito*(Gouveia et al., 2015)to test the effectiveness of behaviour change techniques on physical activity.

Fish 'n' steps is a system much like UbiFit which combines the amount of physical activity with a graphical representation, in this case, a fish on a fish-tank. The testing process consisted on a daily upload of the number of steps taken by each user to the database and the consequent update of the fish state as shown on Figure 2 and on Figure 3. Every day the goal was incremented and was based on the initial goal defined to each user and in the user's performance. Lin et al. found that "A significant number of study participants (14 out of 19) developed a certain emotional attachment to their virtual pet" which reveals motivation toward a goal. Participants were divided by teams and each one had control over one fish-tank which motivated them to cooperate to overcome other teams' results.

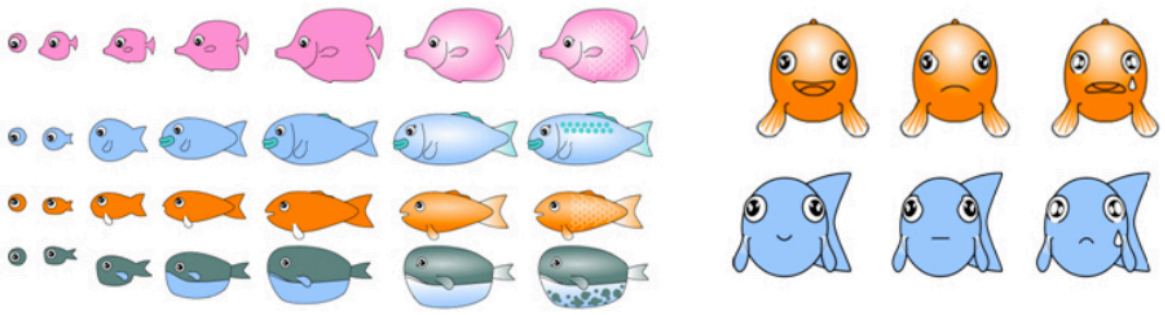

Figure 2 - Fish 'n' steps, fish states

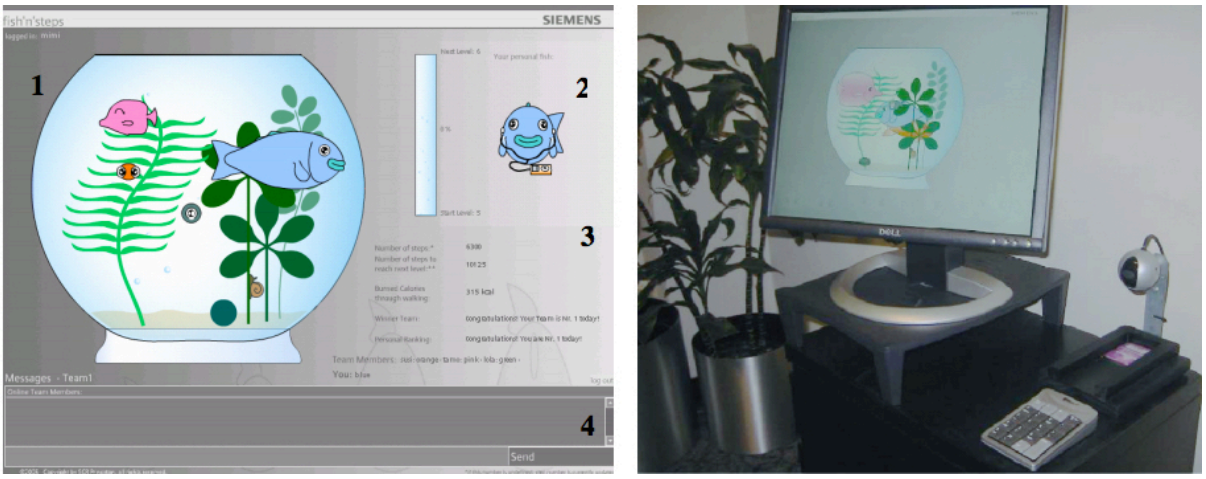

Figure 3 - Fish 'n' steps, fish-tank application

Habito (Gouveia et al., 2015) is the result of a study about activity trackers engagement rates and consists on an activity tracker android application that tracks user's step count. By presenting user tailored messages about his activity performance, Gouveia et al. attempted to build a system that sustains users' interest on this type of tools. Another approach on Habito is the goal-setting theory that allows user to set a daily goal which is then divided into sub-goals in order to encourage users to not convey the negative message that the goal is still far from being reached.

The application consists of two main views: the current day's view on which the user can consult how much is left to reach the daily goal and consults suggestions on how to improve the activity performance and the historical view on which users can review past

performances and positive, novel and dynamic feedback on how well they performed (see Figure 4)

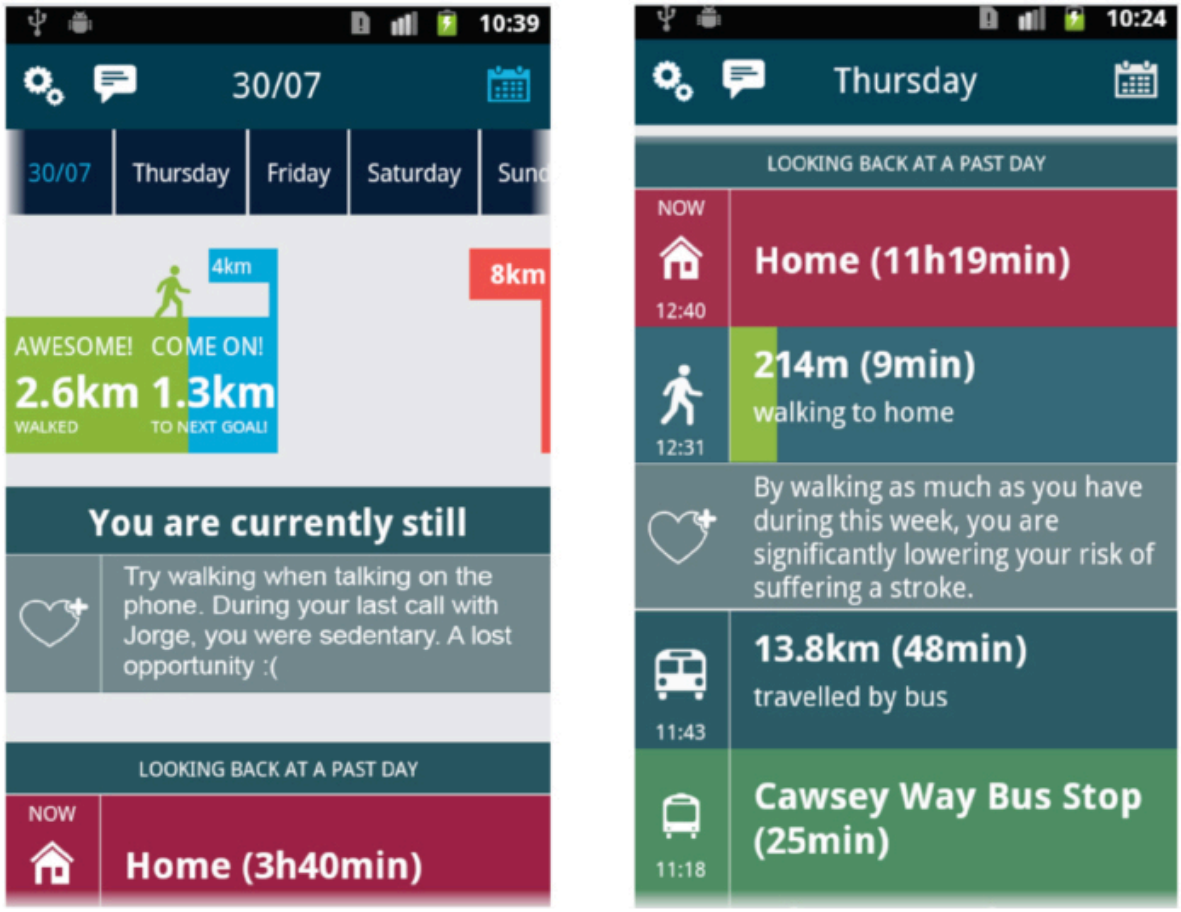

Figure 4 – Habito's user interface. On the left, the current day screen, on the right, the historical of the performance

The analysis that proceeded the application usage study indicates that "readiness is a strong predictor of adoption" since the study results indicate that Contemplation and Preparation are the two behavior change phases on which individuals are most likely to sustain activity tracker usage.

Oddly, Habito registered very low interactions with the contextualized feedback regarding past days: "Contrary to conventional wisdom in personal informatics that portrays behavior change as the result of deep knowledge about one's own behaviors, users lack the interest to reflect on past behaviors".

Crowdwalk aims to fill in a gap left by all these examples that is inspiring users to perform walking activities. By providing contextualized information to the user and by providing walking activities made up by the users themselves, we believe we can increase the levels of sustainability of these types of applications.

2.2 *Behavior change theories*

Studies from the last decade show changing behavior is a complex and multifaceted phenomenon with multiple levels of influences (Buchan, Ollis, Thomas, & Baker, 2012).

Throughout the time, multiple behavior change theories emerged and were implemented and verified. In the following sections, we review the behavior change theories that motivated our study.

2.2.1 Goal setting theory

Goal setting theory was first mentioned by Locke et al.(Tosi, Locke, & Latham, 1991)and aimed to urge behavior change by establishing a concrete goal motivated by a certain set of factors, with the premise of one achieving higher chances of changing behavior. Whether the goal will be attained depends on how strongly the four steps motivate and sustain the motivation of individuals through the process. Figure 5 demonstrates the four-step goal setting created By Cullen et al and consists on the following:

1. Recognizing need for change
2. Establishing a goal
3. Monitor Goal-related activity
4. Self-reward for goal attainment

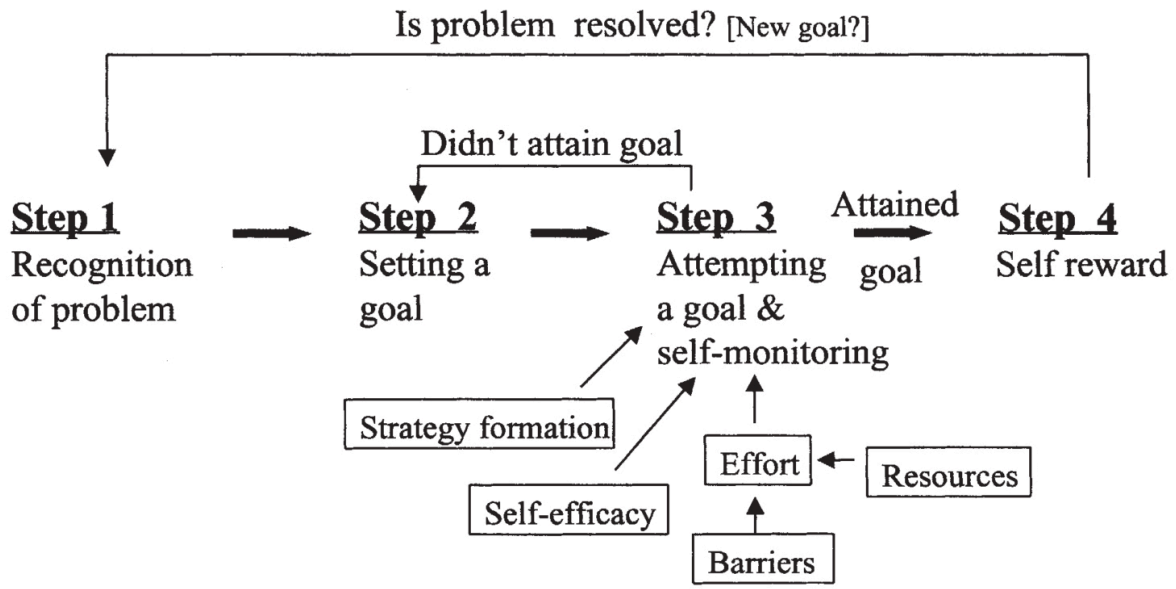

Figure 5 - Four step process diagram(Cullen, Baranowski, & Smith, 2001)

The first step, *recognizing need for change*, consists on setting the mind to accomplish the goal. This trigger moment can occur either by an internal or external source and can take the form of an emotion or an affective experience.

Secondly, *establishing a goal* lies on determining what's the target. The level of specific of the goal can differ depending on the context the person set the goal as long as it is something achievable.

The third step is the *Monitor Goal-related activity* which can be correlated to self-monitoring. This step consists on continuous monitoring of the effort made during the progress to achieve the goal.

Finally, the fourth step is Self-rewarded goal attainment. The rewards can be internal as, for instance, an impulsive reaction as consequence of the satisfaction contracted through the monitoring of positive results or can be external like receiving frequent feedback on the progress made. If the problem that the goal was supposed to fix is not fixed at this stage, the whole process runs again.

UbiFit (Consolvo, Klasnja, McDonald, & Landay, 2009) is an system designed to test the application of the goal setting theory on physical activity performance and consists on a

glanceable display (as the user's device background image, see Figure 6) an interactive application with the records of physical activity and a fitness device that tracks the activity levels and communicates them to the interactive app and to the display. The main functionality of the app is to populate/decorate the digital garden that lies on the glanceable display based on user's level of physical activity. The "Fittest/Prettiest" correlation works as motivation to change.

Figure 6– UbiFit

Amongst several conclusions, the study results of UbiFit state that "Most participants would prefer to set their goal themselves" and that users also prefer "the calendar week to a rolling seven-day window because it gives them a clear deadline".

2.2.2 Presentation of Self in Everyday Life

This theory represents how people behave when exposed to social circles by negotiation and validation of identities. When an individual sees itself on the presence of others, "they commonly seek to acquire information about him or to bring into play information about him already possessed." (Goffman, Hughes, Dalton, & Schein, 1989). This phenomenon goes through many iterations phases until one can shape a mental concept of the other. Even then, individuals' behavior may lead to a re-shape of that concept. This means

that one will always try to refine its definition amongst others so their relation can remain sustainable.

In a behavior change standpoint, giving others access to an individual's current habits and behaviors may force him to change himself regarding those behaviors that he may feel judged about. Nowadays, all sorts of activity tracking and sports tracking tools allow users to share achievements through social channels. Either by using social networks or other built-in-app social components (like leaderboards) users feel encouraged to share accomplishments with others in order to establish some kind of position within their social circle. Strava("Strava," n.d.) users for instance, can enable *flyby* option that allows other users (not necessarily known users) to compare their performances when they both exercised on the same course (See Figure 7 - Strava's FlyBly interface).

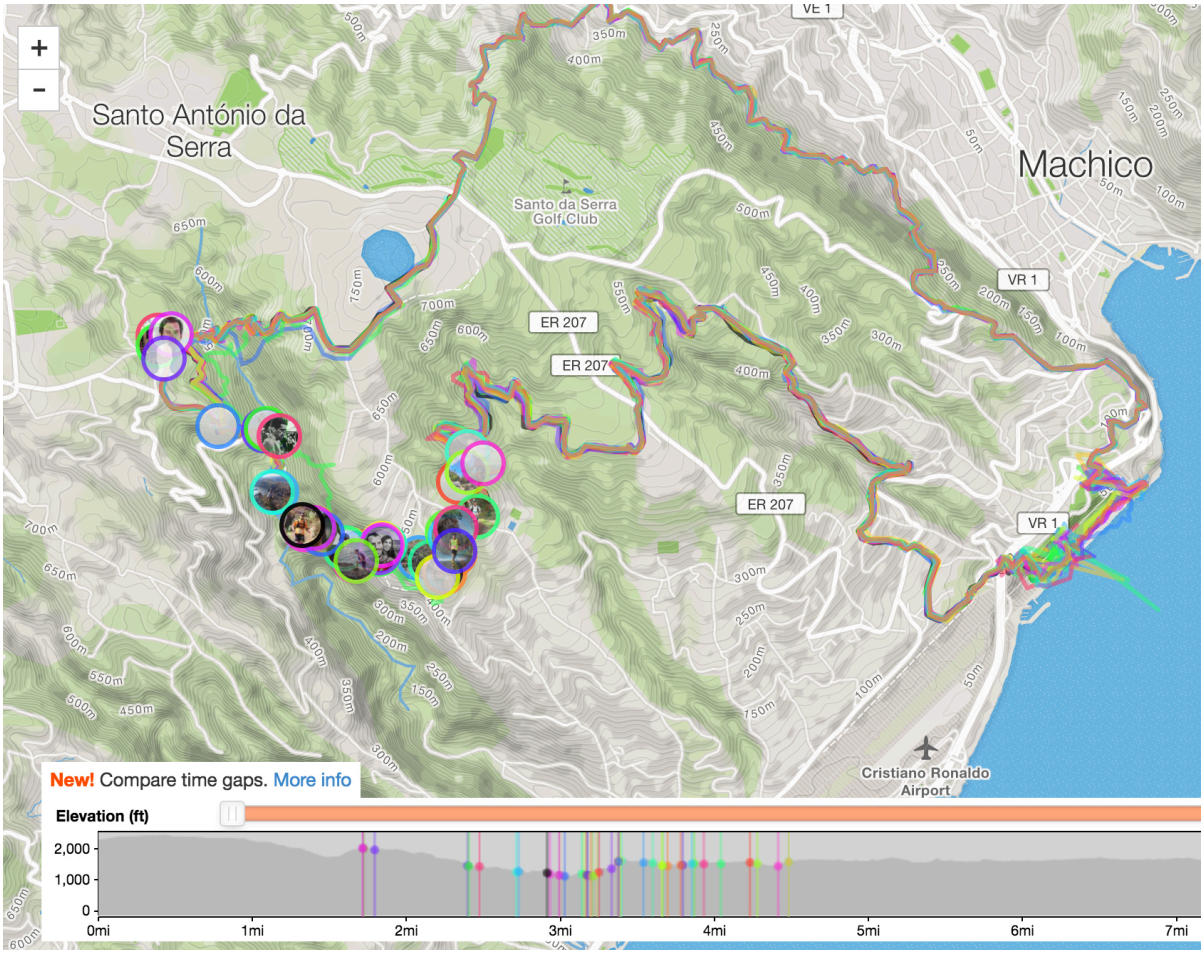

Figure 7 - Strava's FlyBly interface

On UbiFit (Consolvo et al., 2009), by having the garden being displayed on the phone's background image, visible to surrounding individuals, users may feel pressured to enhance their performance levels in order to have a nice and pretty garden that can be comfortably displayed with no shame.

2.2.3 Transtheoretical Model

The Encyclopedia of Behavioral Medicine(Fahrenwald & Walker, 2007) defines the transtheoretical model as "intentional process that unfolds over time and involves progress through a series of six stages of change. TTM integrates processes and principles of change from across leading theories, hence the name Transtheoretical". Figure 8 displays the model's cycle.

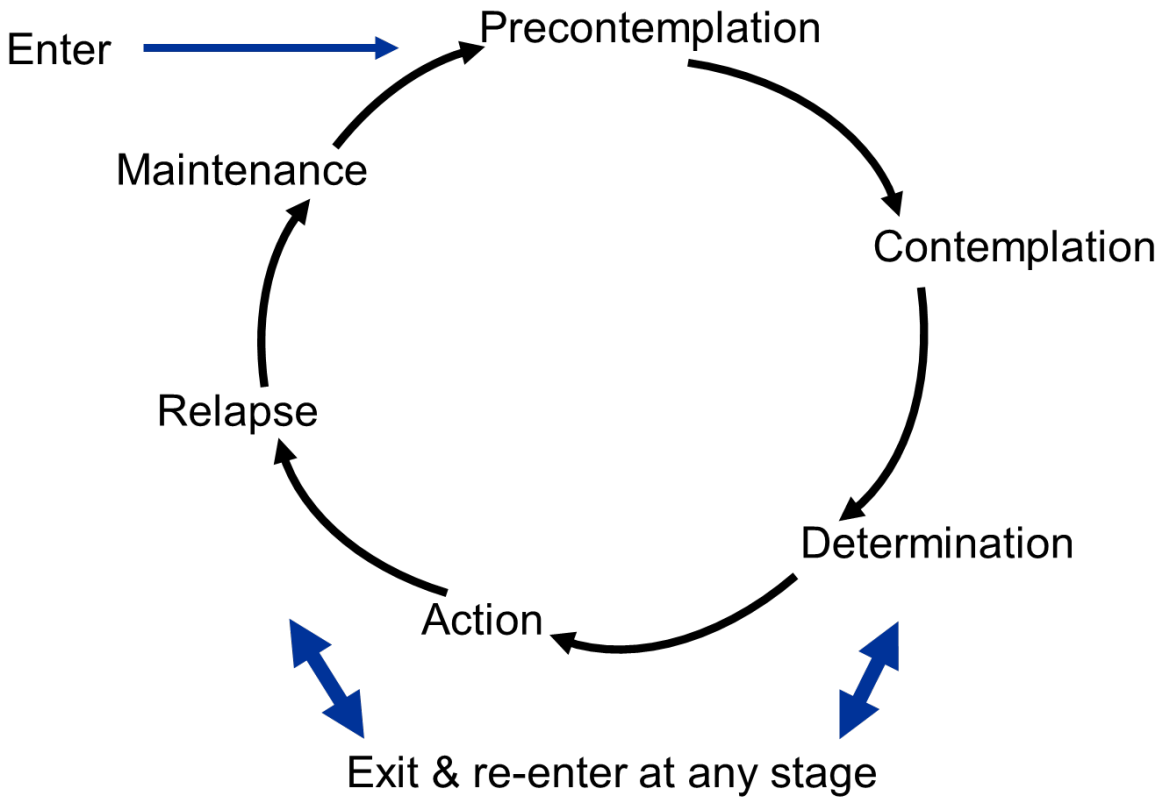

Figure 8 – Stages of the Transtheoretical Model of Behavior Change

Stage 1 – *Precontemplation*: This is the opening stage. Individuals can stay on this stage for undetermined time until they become aware of the consequences of not changing a certain behavior.

Stage 2 – *Contemplation*: On this stage, individuals are aware of the need to change but don't feel the urge of doing it right away. On this stage, pros and cons about the behavior change are weighted in and could lead to a decisional conflict.

Stage 3 – *Determination*: At this stage, individuals are preparing themselves to get into action soon (in a one month time window). They start getting concerned about how and if they will be successful during the action. As Figure 8 specifies, some can withdraw at this phase with some chances of coming back to the same stage later on.

Stage 4 – *Action*: This is where change takes place. On this stage, individuals move towards the goal like: by quit smoking, practicing more exercise or going on a diet for instance.

Stage 5 – *Relapse*: This stage is often omitted by some authors since they consider that relapse can occur in any of the stages and not between action and maintenance. When relapse occurs, individuals feel ashamed and e embarrassed which can lead to lack of moral to continue. This will cause falling back to an earlier stage, like Precontemplation, for long periods of time.

Stage 6 –*Maintenance*: Consists on sustaining habits to maintain the gains obtained on the action stage. Here, individuals struggle to not fall into relapse. When the behavior is considered as changed, the individual reached the state of *Termination*.

Prochaska et al. (Prochaska, DiClemente, & Norcross, 1993) studied how most people move through the stages, see Figure 9 - Spiral model of the stages of change. This spiral model demonstrates how tangled are the stages of Transtheoretical Model since, for motivation purposes, most people fall into relapse during the process of behavior change. "85% of smokers, for example, recycle back to the contemplation or preparation stages". The contemplation phase is another stage that can be repeated when relapse occurs, "fully 60% of unsuccessful New Year's resolvers make the same pledge the following year".

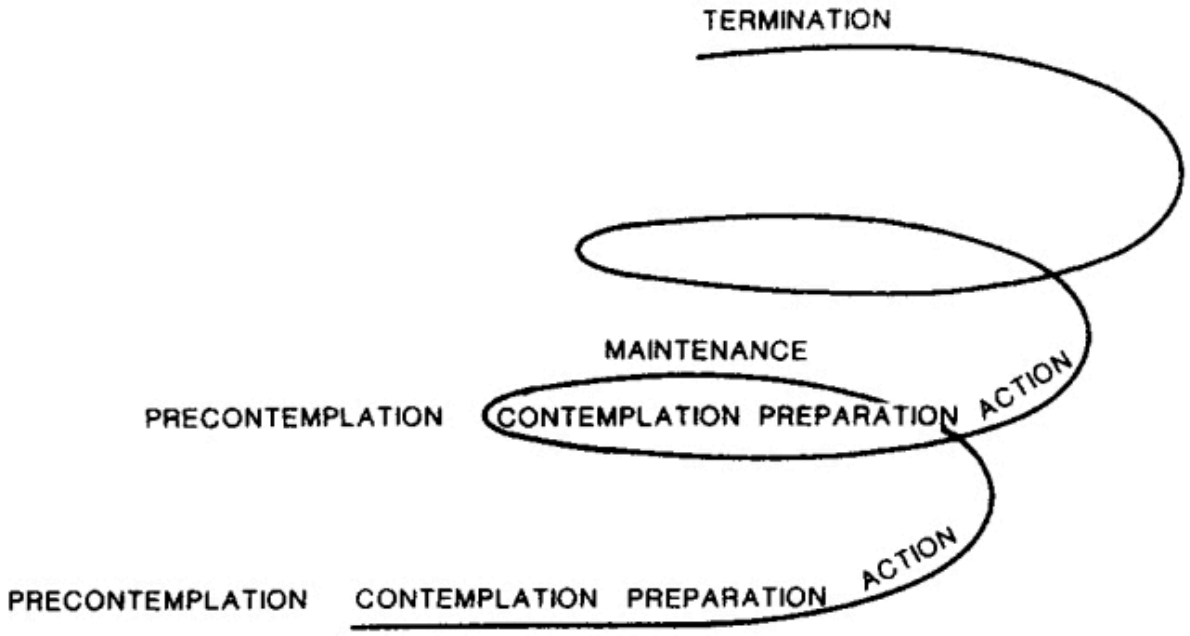

Figure 9 - Spiral model of the stages of change (Prochaska et al., 1993)

2.2.4 Social cognitive theory

"According to social cognitive theory, human motivation and action are extensively regulated by forethought" (Conner & Norman, 2005). This theory relies on cognitive factors that justify behavior change, such as *perceived self-efficacy* and *outcome expectancies* by setting up motivation to perform actions.

Perceived self-efficacy consists on individuals' beliefs that they can take control over defiant demands and can be a contemplation stage motivation to perform action to alter behavior. If one lacks self-efficacy, either goals will be under-set or behavior change could never occur and that is why this is considered the core of social cognitive theory.

Through the application of this theory on an activity tracker, for example by providing a goal setting option, we intend to encourage users to overcome themselves on their usual walking habits.

2.3 *Crowdsourcing*

Crowdsourcing was first mentioned in 2006 by Jeff Howe on Wired magazine("The Rise of Crowdsourcing," 2006). It designates "the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call".

This web-based business model considers peers input (i.e. the wisdom of the crowds) to succeed on an overall problem solving scenario. The normal setup to apply this model works by collecting all peers input and then, evaluate them (by filtering or prioritizing) in most cases, using other peers' evaluation criteria. At the same time, best inputs are being selected from the pool and peers are getting inspired to produce better inputs themselves.

A successful application of this model is Threadless ("Threadless," 2000), a web-based t-shirt company that functions as a forum where users with a minimum design skillset submit their t-shirt designs (which needs to comply to Threadless t-shirt template) and then get rating on those designs by other users. Ultimately, the company keeps on picking the highest rated designs in the forum to move them to production and commercialization of the t-shirts. The selected designs owners get $1,500 in cash and $500 worth of gift vouchers on Threadless website. The company end's up benefiting from crowdsourcing since they do not need to hire designers to produce material and hence they can sell t-shirts that will get approval from the customers (since it was rated by people, i.e. costumers) at a fair price, normally around $20 per t-shirt.

We hope to leverage the inspiration provided by this model and inspire users in our community to try novel activities and also, to contribute to their pool.

3 Preliminary study

3.1 *Research questions*

The main purpose of this project was to develop an activity tracking prototype that would present walking challenges based on activities provided by users, through crowdsourcing. To that end, we conducted a preliminary study with the goal of understanding what kind of activities would users provide to a system of this nature. In a more concrete way, we wanted to have the notion on how people would take opportunities during their routines to increase their walked distance for the day, whether they had an activity tracker to monitor those distances or not.

Besides this, we also wanted to gain insights on the characteristics of the surrounding environment while performing these activities. Later we realized that these attributes like the weather, location, or even the topography of the route could be the key to categorize walking activities.

Ultimately, the study goal was to analyse and categorize walking habits in order to conceive guidelines for the app interface. The data analysis is described further on.

3.2 *Study proposal*

Essentially, the survey consisted of 2 parts, the personal/demographical questions and the activity questions. On the second part, users were asked to describe in detail, between one and three, walking habits that they had embedded on their routines in order to walk more. Consult the Preliminary study questionnaire on the Appendices section.

The study was conducted by publishing a survey, elaborated using Qualtrics tool(Smith, Smith, Smith, & Orgill, 2002) on activity trackers forums, social groups and on Amazon Mechanical Turk(Harinarayan, 2005). Regarding the activity trackers forums and social groups, people answered by free will. On the other hand, by taking the survey on Amazon Mechanical Turk, people got 0,30$ as a compensation if they completed the survey with valid answers (analysed and approved by us).

For three and a half weeks, 140 people opened the survey but, after excluding unfinished surveys, duplicated responses and invalid answers, we got a final sample of 65 valid surveys, being 44 from Mechanical Turk and 21 from activity trackers forums and social groups. Regarding the individuals (with a mean age of 26 years) from the final sample, 35 of them were women and 30 were men. Moreover, 30 of them (46%) were from USA, 16 (25%) from India and 7(11%) from Australia.

3.3 *Results*

The first accentuated factor obtained is the fact that 57% of the walking activities stated were performed on a daily basis, 24% between two to three times a week, and 10% once a week meaning that, only 9% were performed at least two to three times a month. These results, presented on the Figure 10- Walking activities' frequency on preliminary study, could mean that, our result sample is highly trustworthy since the walking activities described were performed frequently and therefore are more likely to be accurately described.

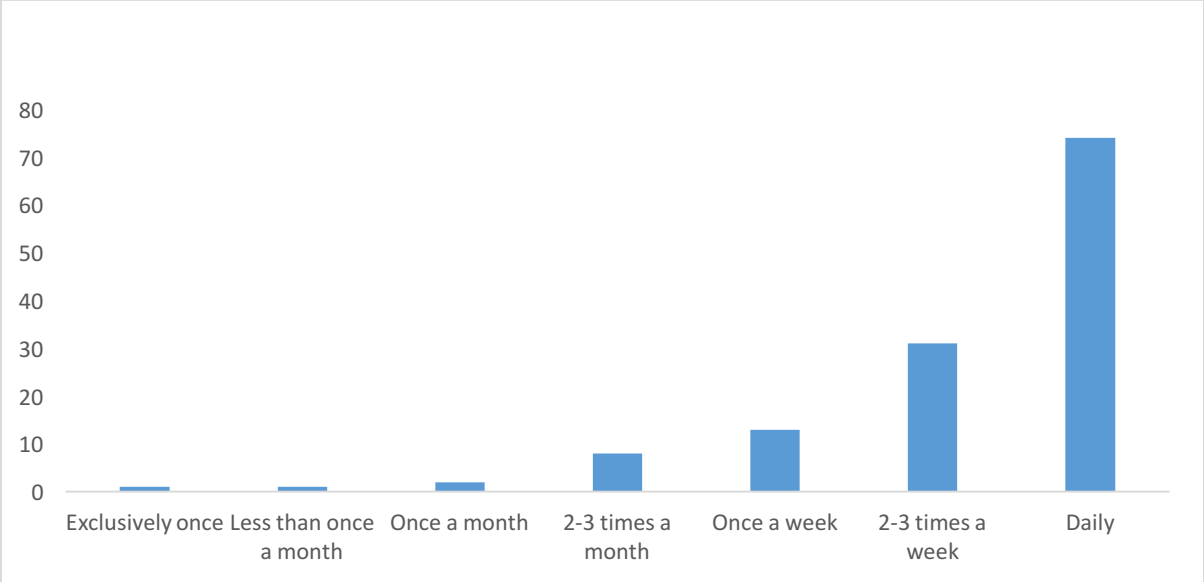

Figure 10- Walking activities' frequency on preliminary study

Secondly, we gathered the data regarding the walking distances. On this data set is clearly displayed the predominance of short walking activities, since most walking activities (59%) are under 1 kilometre distance as displayed on the Table 1 - Walking activities'distances on the preliminary study.

Table 1 - Walking activities'distances on the preliminary study

Distance (meters)	Number of performances	% of performances
0 - 99	24	21%
100 - 999	45	38%
1000 - 1999	19	16%
2000 - 2999	7	6%
3000 - 3999	3	3%
4000 - 4999	5	4%
+5000	14	12%

Taken the input from the individuals, we were able to identify 27 distinct walking activities. As in Staurateapp (Sillito, 2013), we created a pool of walking activities and assigned them context (time of the day, place, reason for performing the walking) so we could understand the motivation behind walking activities. Mainly, we found that a huge part of individuals (61%) performed walking activities in order to improve their well-being and consequently to boost their health condition. Within this category can be included motives

like weight loss, diminish sedentary levels and burn extra calories. Besides this main reason, the activities were also performed to take advantage of situated benefits on this type of activities like boosting energy levels (13%), mood levels rising (8%) and taking breaks from professional activities (6%).

Using the same method, we were also able to filter the events that triggered the walking activity. We immediately excluded the desire to hike since that was not intrinsically present on people's daily routines. Most of the events (30%) were due to the need to go from place to place in order to perform some type of action on the destination for instance "Every Sunday, me and my three children walk to church from home." and "I live nearby to my office and my habit is walking daily to work…". The second highest event noticed (24%) on the statements was the choice of the stairs over the elevator. Other reasons like parking far away (17%), shopping (16%) and performing chores (10%) were also a big motive to perform walking.

3.4 *Findings/implications for design*

Overall, we concluded that shorter activities are more likely to be performed and thus be achieved daily which increases the odds of that activity to be constantly repeated until they are performed almost as an automatic task that becomes difficult to not be performed by habit.

We also found that, most of the walking activities were tightly connected to chores or tasks people had to perform so they ultimately were combining "business with pleasure". This reinforces our thesis about how there is a huge potential on providing contextual and location based walking challenges.

4 The Application

CrowdWalk final prototype is a result of many design iterations, all can be found in the Appendix section CrowdWalk prototyping.

The way all the prototype screens are connected and the app navigation is explained on Figure 11 - CrowdWalk sitemap. The user journey begins on the Splashcreen where he stands until all the data is loaded into the app. If this is the first app launch, the system will ask for him to set a daily goal. After, the user lands on the Home screen where he can browse through challenges (and perform them) or different time frames where past activities can be consulted. Furthermore, one can also add walking activities into the system (automatically available to everyone, through Crowdsourcing) or change the previously set settings.

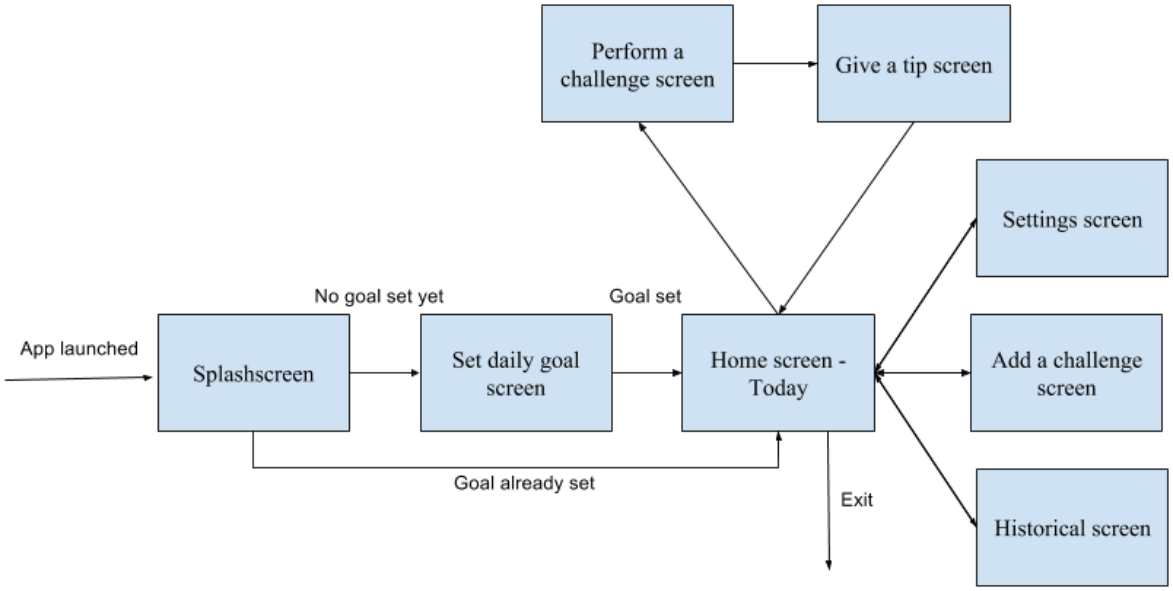

Figure 11 - CrowdWalk sitemap

4.1 *System overview*

CrowdWalk was developed as an Android application using the Android Studio 2.1 IDE(“Android Studio,” n.d.). The minimum OS version supported is 4.0.3. Although this

application runs on tablets, the design is only optimized for mobile phones, on portrait orientation.

The application relies on the GPS sensor to determine what is the user's current location as well as the gyroscope sensor in order to measure (an approximation of) the number of steps walked by him.

4.1.1 Architecture

The application itself depends on two external entities in order to be fully functional: Parse database(Bernstam, Sukhar, Yu, & Lacker, 2011) and Foursquare API("Foursquare API," n.d.). The first one allows the existence of the CrowdWalk repository that is constituted by walking challenges, challenge performance and user tips. Every time the app is started, this data is fetched from Parse according to the venue and challenge selected. The second entity is Foursquare API, that provide the app with nearby venues based on the provided GPS coordinates of the user. The location can be retrieved by Wi-Fi but it is way more accurate if the location services of the phone (GPS) are enabled.

Apart from that, the user data is stored locally on the device using SQLite database technology (in data tables show on **Error! Reference source not found.**) since there is no login on CrowdWalk there was no way to store user data online.

The Facebook API("Facebook API," 2007) is not a mandatory component. If the Facebook app is present on the device where CrowdWalk is being used, it is possible to share the activity on the user feed, if not, the app will continue to run normally.

Once CrowdWalk is installed on a device, there are two services (tasks) constantly running in background of the phone, this means that, even if CrowdWalk is not opened, these two tasks are running anyway:

- Step counter service
- Notification service

The first one, the step counter service, is responsible for retrieving and analysing the data from the device's accelerometer and, at the same time, updating the user walking distances on the local database. If the user is performing a walking challenge, the steps registered are saved as a walking challenge performance. If that is not the case, the non-challenge walking values are updated.

The notification service, is the notification manager of the app. This service is always listening to the amount of steps registered by the other service and, given some time interval, if the user has not been moving much, a notification will be triggered to present on the device. On CrowdWalk's case, the user must walk 50 steps in 40 minutes in order to prevent the notification to be shown. Also, the notification system is disable between 10 p.m. and 10 a.m. due to resting time and charging purposes.

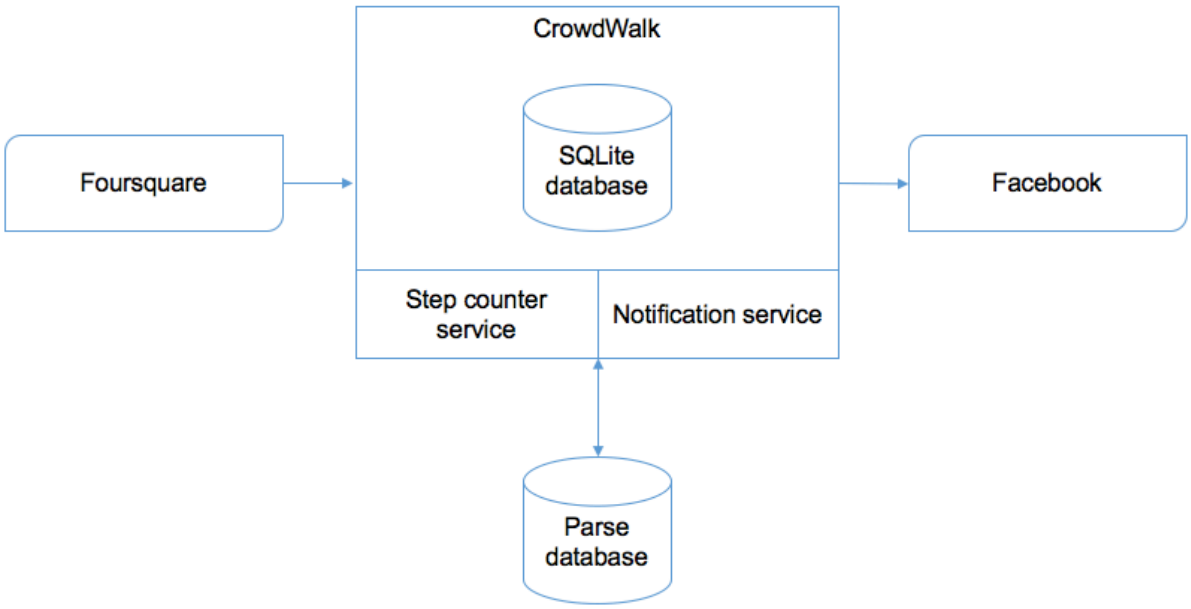

Figure 12 - CrowdWalk's system architecture

4.1.2 External libraries

Besides the Android SDK that is natively integrated, and the three previously mentioned technologies (Facebook, Parse and Foursquare) SDKs, there was a need to use three other external, open source libraries in order to fulfil the intended design:

- ViewPagerIndicator
- MPAndroidChart
- Calligraphy

ViewPagerIndicator library(Wharton, 2011) allows to give feedback to the user regarding the current item selected on a ViewPager widget (that is the horizontal slider/carousel that contains the challenges). On the CrowdWalk app this was used on the bottom of the challenges carousel. This is particularly useful so that the user can automatically know how many challenges there are on the previously selected venue.

The use of MPAndroidChart("MPAndroidChart," n.d.) was crucial so that the app could display the circles that represent the walking challenges on the Home screen, the venues on the Historical screen and the walking challenge progress on the Perform a challenge screen. Unfortunately, the Android SDK does not allow to create these complex graphical widgets up to now.

The Calligraphy library(Jenkins, 2014) makes possible for the app to have another font on all the text simply by setting the TrueType Format (.ttf) file on the app start-up. Again, the Android SDK is limited on this issue since this mentioned effect is only possible by setting the font manually text label by text label.

4.1.3 Data scheme

On the **Error! Reference source not found.** is represented the Enhanced Entity-Relationship model of CrowdWalk's database. Venues, locations and challenges are provided by the online database whereas the performances are stored on the device's local memory (SQLite database)

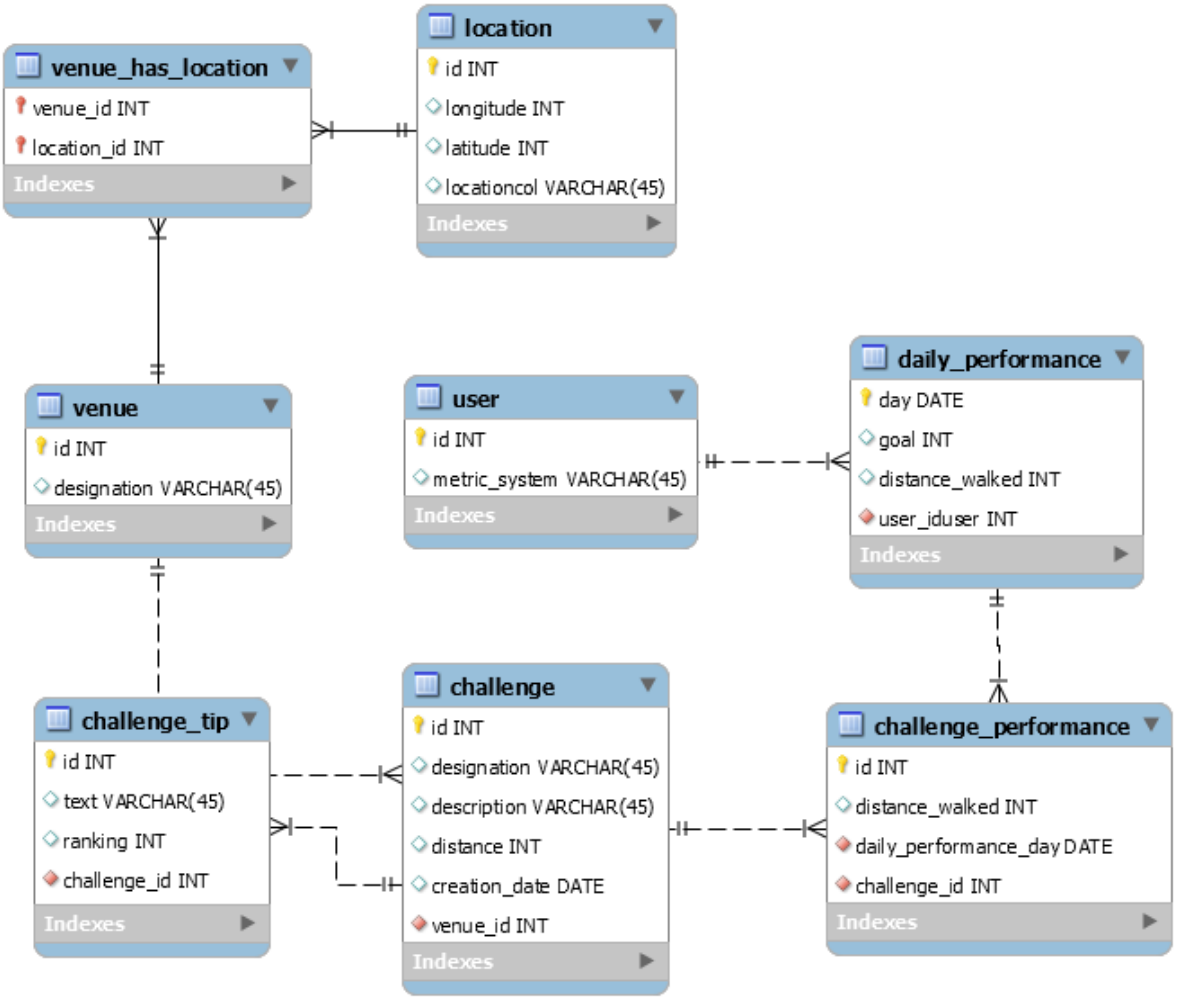

Figure 13 - CrowdWalk database scheme

4.2 *Application description*

CrowdWalk was developed as an android app, as a result of the preliminary study conclusions. The first time the user opens the app, its asked to him to set a daily walking goal value as shown on Figure 12. This value and the metric system scale can be altered at any time inside the app, by clicking the settings button as described on **Error! Reference source not found.**.

Similarly to *Fitbit* and further activity trackers, CrowdWalk proposes a daily walking goal to first-time or unacquainted users, indicating the distance recommended and challenging them to attain it(Mercer, K., Li, M., Giangregorio, L., Burns, C., & Grindrod, 2016).

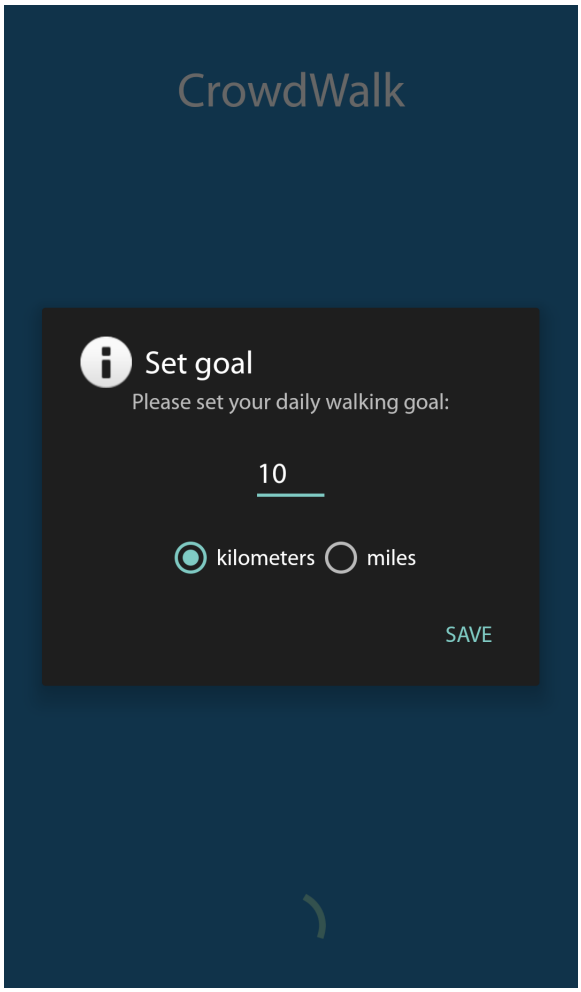

Figure 14 - Splash screen, daily goal input popup

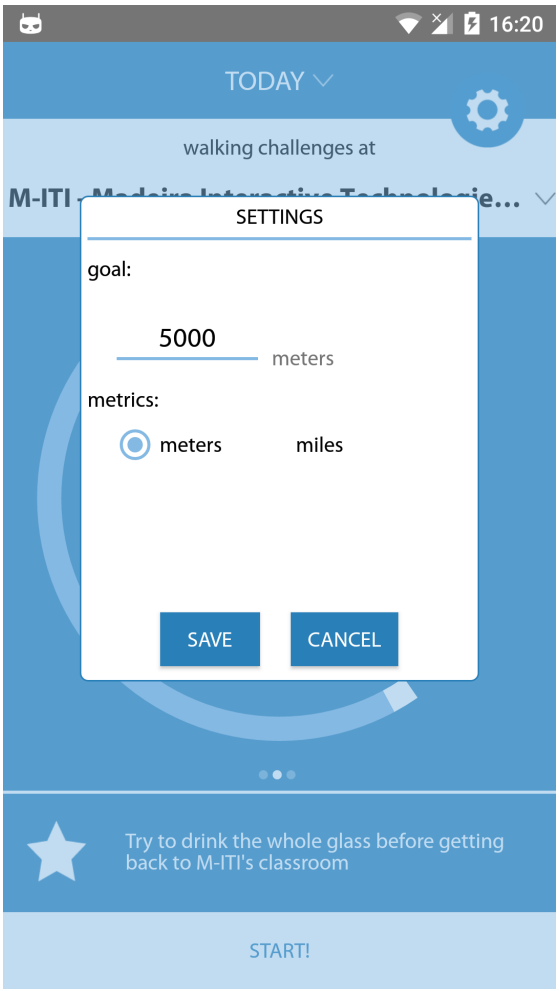

Figure 15 - Settings popup

The top section of the app consists in two selector elements that allow user s to filter the content of the app. The first one (**Error! Reference source not found.**) is a dropdown on which the user can navigate between the *Home Screen* and the *Historical Screen* – the time frame selector. By default, on this selector, "Today" is the value selected as the user opens the app. The past periods that can be selected are "Last week", "Last month" and "Last Year".

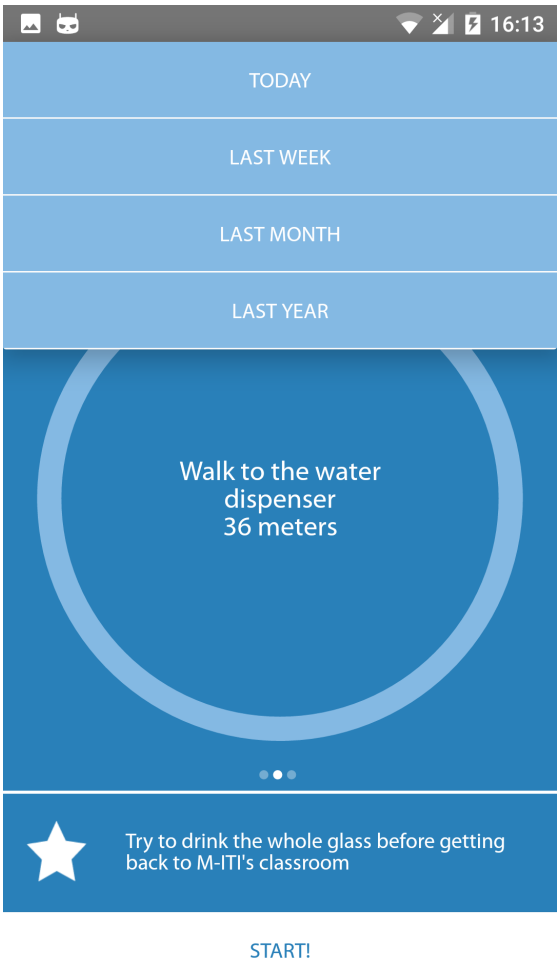

Figure 16 - Home screen time selector dropdown

The second element (**Error! Reference source not found.**), is another dropdown on which the user can select the venues on that he wants to consult data – the venue selector. Below the top section, on the middle of the app screen, its positioned the content container, where the data is presented according to the top section filter values (time frame and venue). On the bottom, there is always a button with different possible actions, according to the context of the content that is being presented.

Figure 17 - Home screen venue selector dropdown

All in all, while navigation the app, the user can be presented with four different screens: *Home, Historical, Create a challenge* and *Perform a challenge*.

4.2.1 Home screen

This is the landing page of CrowdWalk and, in order for this screen to be presented, the time frame selector must be set with "Today". When the user opens the app, this option is selected by default and the loaded content is as shown on **Error! Reference source not found.**.

Based on user selected venue, the central container is populated with challenges on that same venue. Browsing through venues is made by horizontal scrolling on this area on

which challenges are ordered from the most performed to the least one. The first item of the list is always a shortcut to add a new challenge on the current location although by default, the first available challenge on the venue is present first on venue selection. Each challenge is contextualized to the user regarding: what the user goal is, how much have he walked on the day so far and how much does the challenge represents of the user daily goal. That representation is made by a circular ring constituted by three sections: the amount of walking done so far on the day, the challenge distance and the remaining distance to achieve the goal. The first component is represented by how much is missing on the ring. The challenge distance is represented in white and the remaining distance in light blue. By clicking one of these sections, the user has feedback on how much that section represents (in percentage) within the circle ring. On the middle of the circle there is the walking challenge designation as well as its duration and, when clicking that area, a popup with the walking challenge description is presented.

Each time a challenge is selected, the slider on the bottom updates its content to display the user tips regarding that challenge. Those are hints given by users that have already performed that challenge. Each one of them can be marked as favourite and the navigation through them is made by scrolling horizontally.

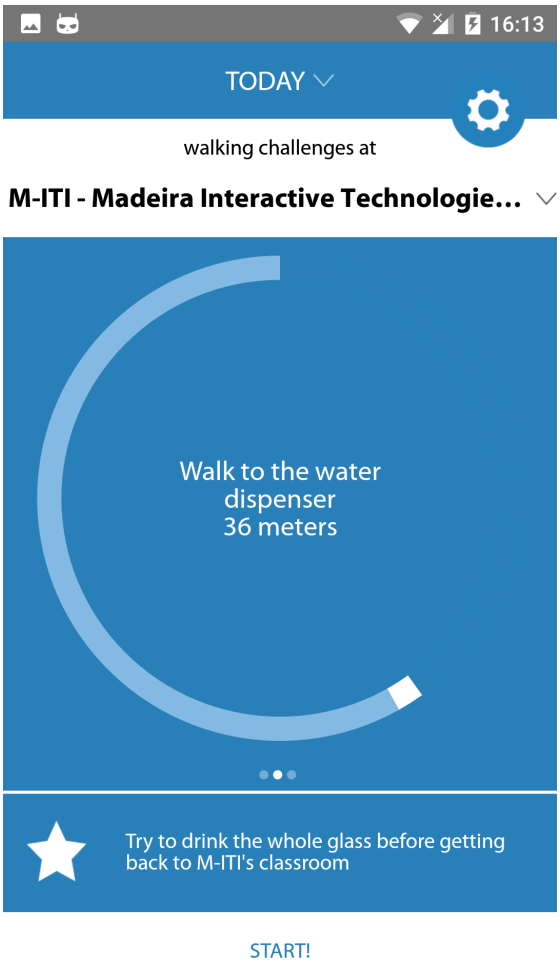

Figure 18 - Home screen

The bottom action button changes accordingly with the selected item on the challenges area: if the it is a walking challenge, by clicking the button the user can start performing the challenge. If the selected item is the shortcut to add a challenge, the button can also be used to perform such an action.

4.2.2 Historical screen

While on the *Home Screen* and pressing any of the past time frame options (Last week, Last month or Last year), the user is taken to the *Historical Screen*, see Figure 19 - Historical screen, last week's view. This screen purpose is to present the user his walking performance over the selected time interval, helping the user visualize and identify progresses

towards his goal. On the top, is state the average walking distance walked within that interval.

Once again, the central area contains a circle ring that represent the total amount of walking during that period. It is mainly divided in:

- Distance remaining to achieve the goal
- Non-challenge walking
- Challenge walking

The distance remaining to achieve the goal is calculated based on the sum of the daily goals the user had for the selected time period. The non-challenge walking refers to the walking distance the step counter sensed, while the user was not performing any challenge whereas the challenge walking section refers exactly to the opposite. Non-walking challenges percentage is presented to acknowledge all the physical activity performed when it was not submitted as a challenge so he does not feel penalized. This last section can be represented by one or more ring sections being that, each one of them represents a venue where the challenges were performed.

If the user clicks in one of the venues where walking challenges were performed and the press de centre of the circle, the content of the circle changes so that each ring sections represent a walking challenge performed within the previous selected venue. On this state, by pressing the circle sections, the bottom message slider content is updated with statistics regarding the performance of that challenge. If the user swipes the message, the system will retrieve another message related to the challenges performed in that venue. If the user wants to get back to the previous form of the circle, the venues section, the native back button must be pressed.

The message slider has the same scrolling behavior of the tips slides on the *Home Screen*.

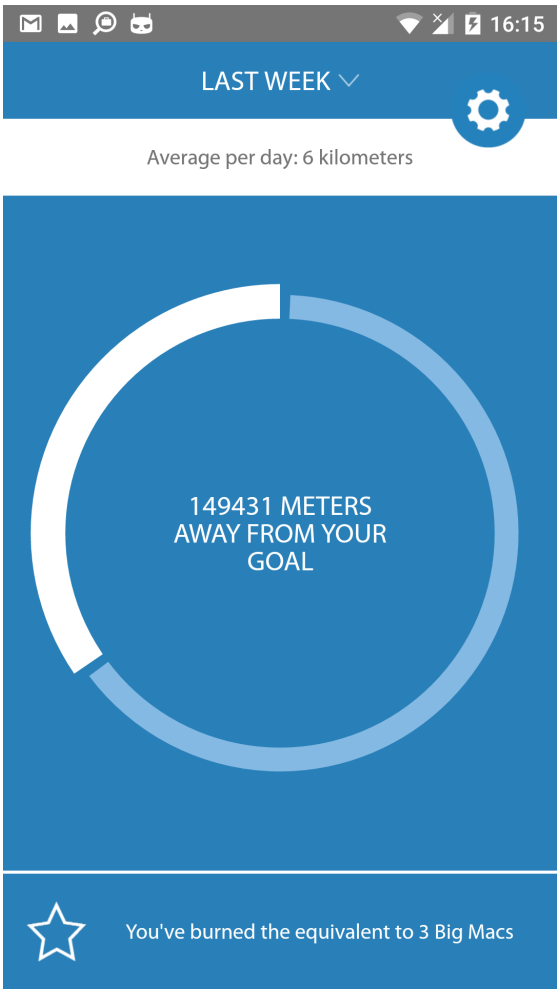

Figure 19 - Historical screen, last week's view

4.2.3 Add a challenge screen

The user is taken to this screen whenever he clicks on “Add a challenge” button (Figure 20 - Add a challenge screen). Here he can fill in the form to submit a new challenge in the CrowdWalk challenge repository. In order to successfully add a new challenge, one must provide:

- Challenge title
- Estimated challenge distance
- Challenge description

The challenge then will be added to the venue selected on the previous screen, being that explicit on the top location of this screen. The challenge distance estimation value is constantly updated based on other user's performances so that the system can provide a more accurate walking distance on each walking challenge.

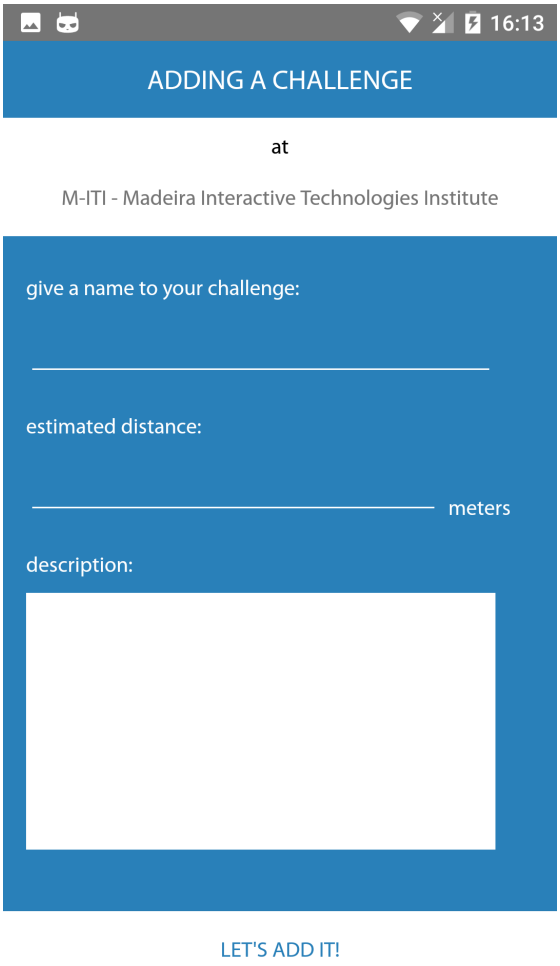

Figure 20 - Add a challenge screen

4.2.4 Perform a challenge screen

After a challenge is selected, the user can start performing it and thus is taken to the *Perform a Challenge Screen*. The step counter starts to count the user steps right away and that is visible on the distance achieved label. Once again, the user is contextualized about the current venue he is in on the top section of this screen.

On the central container of this screen, circular ring logic is reused and as the user progresses within the challenge, the white section (challenge distance) will start diminishing. If, by any chance the user walking exceeds the challenge distance, the remaining section (light blue) will start to be consumed as well. On the centre of the ring, the app provides the user with the duration of the challenge, as well as its designation (Figure 21- Performing walking activity screen). At any time, the challenge performance can be cancelled by clicking the native back button of the device. When the user finishes performing the challenge, he then clicks on "Complete challenge" in order to register this performance on his historical data. Optionally, he can provide a tip to other users that later would like to perform the same challenge. At the end of this process, it is possible to share this achievement on Facebook("Facebook," 2004) as can be seen on Figure 20.

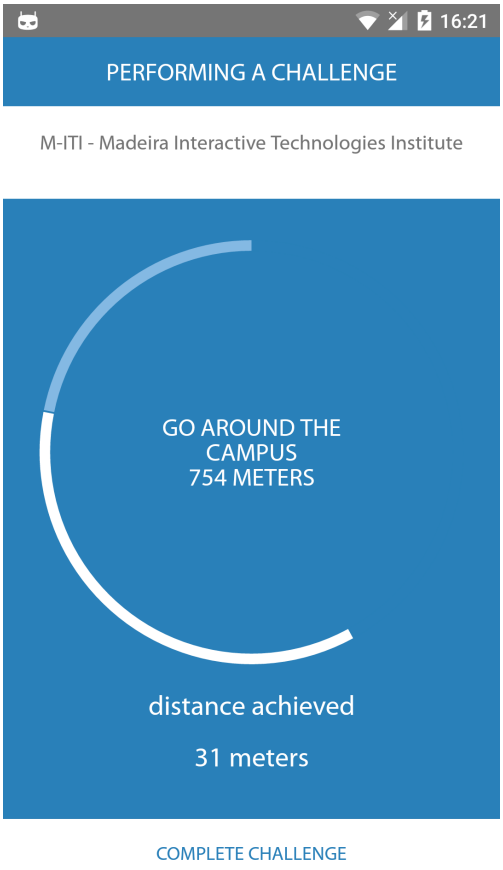

Figure 21- Performing walking activity screen

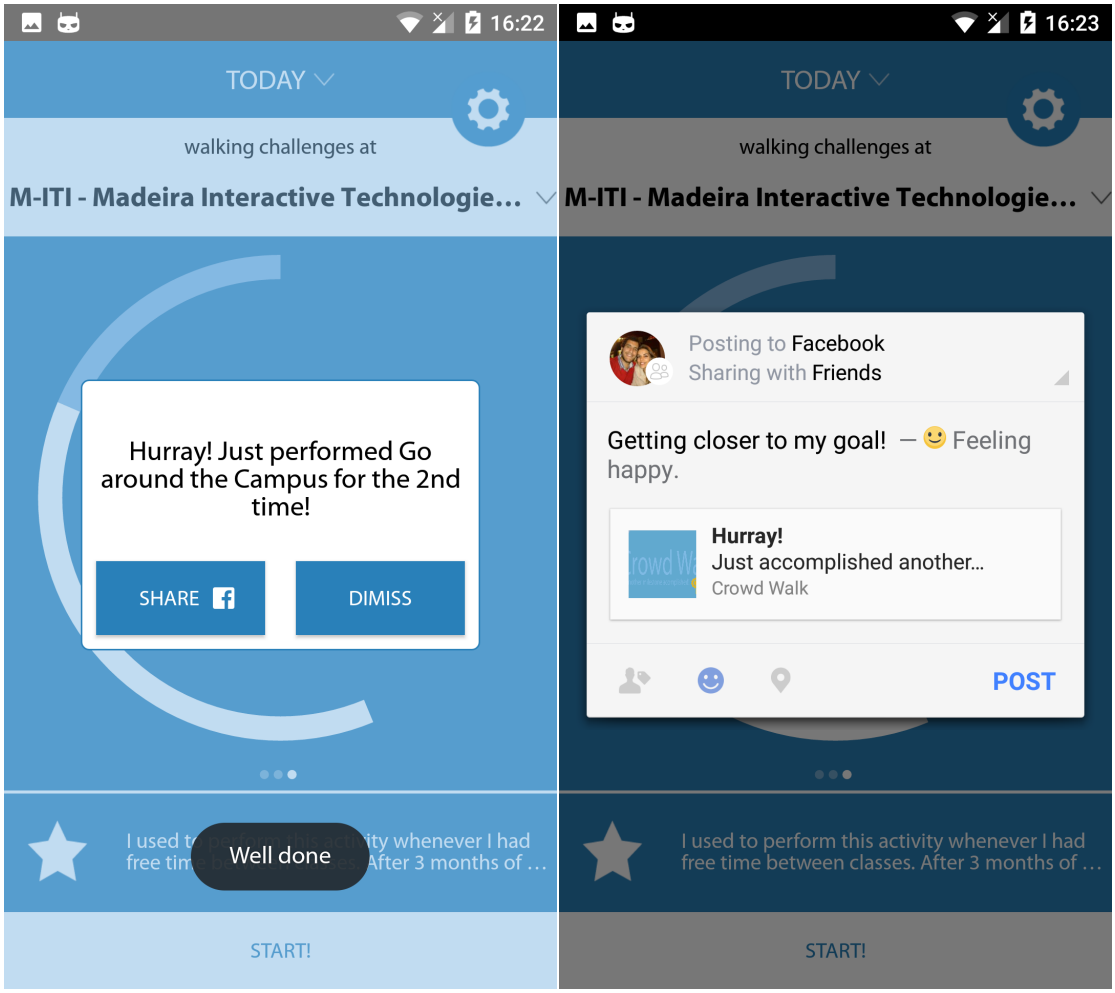

Figure 20 - Share performed activity Facebook popup

4.3 *Feedback strategies*

Measuring apart, another CrowdWalk's mission is to deliver the results to the user and that is one of the most crucial and sensitive pieces of the app. The way we deliver the news can decide whether the user will feel motivated to perform more physical activity and feel pleased with the results or if he feels that he is underperforming and decides to quit the app. Taking that into consideration, the following feedback strategies were adopted:

As mentioned before, when entering the home screen (that is the landing page of the app), the user will see the daily progress circle that indicates how much the user walked on

that day. The subliminal message we want to pass in there is that the day's clock is running out of time (physical activity moves toward the clockwise direction) and that by performing activity the user is moving on the direction of completion/finish line. The circular graphic figure is also a handy approach to demonstrate how much the selected walking challenge would contribute to the daily goal distance if completed. By presenting first the ones that would make the user achieve the goal, we hope that he feels more tempted to perform and get it done for the day.

Figure 21 - CrowdWalk inactive notification displays another way CrowdWalk provides feedback to the user is through notifications. When a user reaches a certain level of inactivity, a notification is sent to the user warning him he has been inactive for too long. This nudging feedback strategy keeps reminding the user that he has compromised to fulfil a certain goal he set. Also, reinforcement strategies operate on the availability heuristic and it has been conceived as a strong predictor of behavior. According to theory, information that is readily accessible, it is judged with a higher weight probability and ascribed as more important (Thaler & Sunstein, 2008). Hence, reinforcing a behavior or recapping a user of a problem they face, helps retaining the behavior on top of their mind, increasing the chances of being consider as a problem worth solving.

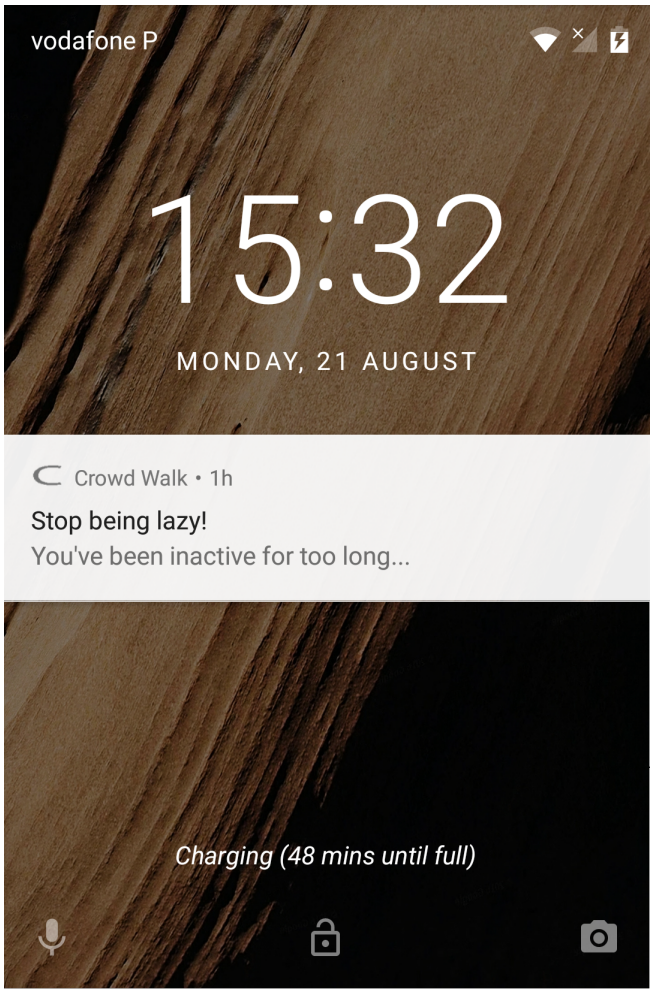

Figure 21 - CrowdWalk inactive notification

On the historical screen, for each walking activity selected, the user is presented with contextual messages generated by the app itself taking into consideration the walking activity the user did. This messages' goal is to make the user realize his improvements as time goes by. By assimilating the distances walked with other real world distances (for example, "You walked the equivalent to the Eiffel Tower's height!") or by stating how healthy they were ("You've burn the number of calories existing on 10 Big Macs) we expect that the user keeps performing more physical activity so he can get back to the app and be surprised with novel, original and personalized messages.

5 UI study

5.1 *Study proposal*

The main goal of this study was to perform a summative test (Sauro, Lewis, 2012) which consists on describing the usability of a software using metrics. Specifically, we wanted to test the interface consistency and how good the Human Centred Design principles(Norman, 2013) were applied on CrowdWalk.

5.1.1 Schedule, participants, sessions and location

To determine how many participants the sample should contain, we applied the most commonly used formula on this type on User Interface studies (Nielsen.Landauer, 1993):

$$n = \frac{\ln(1 - p(x \geq 1))}{\ln(1 - p)}$$

Figure 22–Number of users for testing, calculation formula(Nielsen & Landauer, 1993)

Assuming we wanted to have a 75% chance of observing at least once problems that have a 10% chance of happening, that gives an *n* of 13,16(13) participants. These participants were recruited through social networks using convenience sampling (Facebook groups and email). Each test session took about 30 minutes and were made on closed and isolated rooms to minimize the odds of distractions. In order to secure the quality of the data, we restricted the testing to users who were used to an android device in their routines. This way, the study sample will represent the behavior of target users.

5.1.2 Scenarios

In order to obtain the most precise results on these types of studies, the tasks have to be directly related to the main tasks of the software (Goodman, Kuniavsky, Moed, 2003). These are the tasks we will ask the users to perform:

1. Browse through nearby venues
2. Browse through challenges
3. Create a walking challenge
4. Search for a specific challenge to perform
5. Check how much does a challenge represents (%) related to the user's goal
6. Perform a walking challenge
7. Browse through other user's tips on a challenge
8. Update the daily walking goal
9. Update the distance metrics
10. Consult the last week/month/year performance
11. Browse through system messages (statistics on performance)

5.1.3 Metrics and expected results

To test the system Human Centred Design principles of the app, the metrics collected during the testing procedure were:

- Successful task completion
- Task duration

Since CrowdWalk is meant to be a daily usage app, and assuming the user is performing these tasks for the first time, we targeted:

- Task-completion rate higher than 90%
- Each task (excluding performing a challenge) should not take more than 30 seconds to perform.

In order to test the app overall usability, we have chosen Post-Study System Usability Questionnaire method (PSSUQ) (Lewis,1990a, 1992). The choice was made based on its global reliability score of 0.94 and on the fact that it does not require any licensing fee. See Appendix The Post-Study Usability Questionnaire Version 3. When analysing the PSSUQ, we used its four scores (Sauro, Lewis, 2012), one representing overall and the other three being subscales:

- Overall: Average the responses for Items 1 through 16 (all the items)
- System Quality (SysQual): Average Items 1 through 6
- Information Quality (InfoQual): Average Items 7 through 12
- Interface Quality (IntQual): Average Items 13 through 15

5.2 *Results*

5.2.1 Task performance

The test results referred on the Appendix UI study -tasks performance results demonstrate how the test users performed the proposed tasks in terms of time taken to complete them. Note that some of the tasks were not complete due to user's lack of ability to figure out how to. Table 2 - Task completion time and rate per task displays the successful completion rate and the average time to completion of each task.

Table 2 - Task completion time and rate per task

Task	Successful completion rate	Average time to completion (seconds)
Browse through nearby venues	92,31%	11,3
Browse through challenges	100,00%	16,1
Create a walking challenge	100,00%	21,8
Search for a specific challenge to perform	92,31%	21,5

Check how much does a challenge represents (%) related to the user's goal	69,23%	16,4
Perform a walking challenge	92,31%	7,0
Browse through other user's tips on a challenge	53,85%	16,7
Update the daily walking goal	100,00%	14,8
Update the distance metrics	100,00%	3,2
Consult the last week/month/year performance	100,00%	10,8
Browse through system messages (statistics on performance)	84,62%	13,8

We were not surprised to verify that the top four fastest tasks performed (Tasks 9, 6, 10 and 1) have more than 90% of completion rate meaning that, those are straightforward tasks, the ones users can perform easily and effectively. Task 9 ("Update the distance metrics") highlights as the one performed faster and always successfully. One of the reasons why we think this task had outstanding results is because it is preceded by Task 8 ("Update the daily walking goal") which is performed on the same screen as Task 9. Since the users already had knowledge about the settings screen (how to access it, how to interact with it and how to update the values), this task had high odds of being performed successfully.

Table 3 – Task completion time and completion rate average expected and actual results

Expected average time to completion (seconds)	Actual average time to completion (seconds)	Expected average completion rate	Actual average completion rate
30	14,0	90%	89,51%

The average time to complete a task was 14 seconds and it is way below the 30 seconds expected as referred on the previous chapter which means that the system is very responsive to user's actions and, the steps needed to perform a task are well suitable to sustainable performance levels.

Our evaluation revealed a task-completion rate of 89.51%, slightly lower than the threshold initially defined (90%). We identified the tasks with lower competition-rate: Task 5 with 69,23%*(Check how much does a challenge represents - %)*, Task 7 with 53,85%(*Browse to other user's tips on a challenge*) and Task 11 with 84,62%(*Browse through system messages)*. See Table 3 – Task completion time and completion rate average expected and actual results.

Task 5 – *"Check how much does a challenge represents (%) related to the user's goal"*. In order to obtain this information, the user should navigate to the Home screen, choose a venue that has walking challenges in it and, on the circular ring click the white section of the circle. The system automatically display the message "This challenge is about x% of your daily goal", as described on Figure 23 - Challenge percentage within the daily goal feedback.

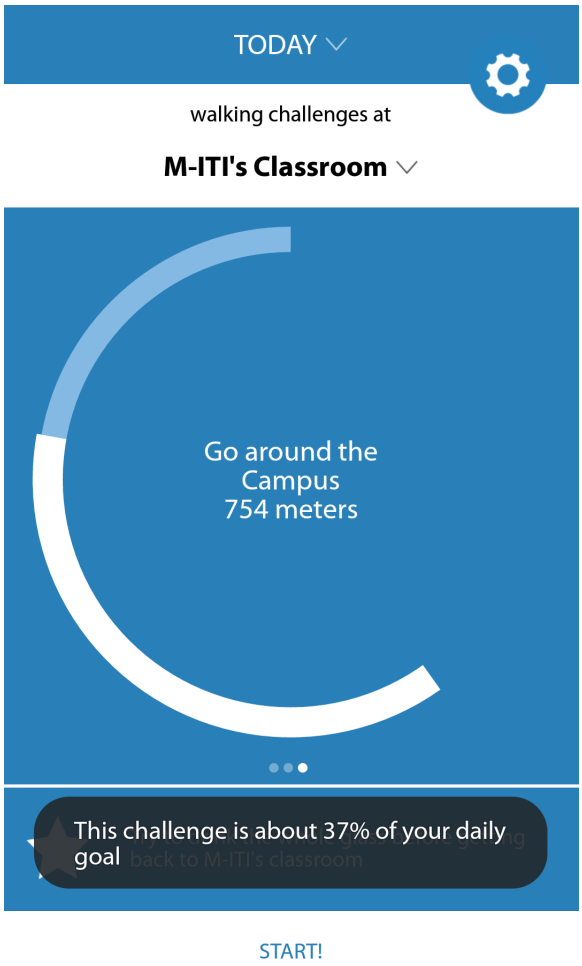

Figure 23 - Challenge percentage within the daily goal feedback

We believe the reason why more than 30,77%of users may have struggled with this task could be because there is no hint signifier on the circular ring that indicates that the user can click on the circle slices so he can get what that slice represents in terms of percentage when compared to the daily goal. Users reported that they were not able to understand that the circle was clickable. We believe that these results were compromised by the fact that the circular shape approach is novel on the activity trackers implementation and although it leverages the graphical representation of walking activity, it compromises the interaction with it by not being a common UI component of most apps. A possible solution to this case could be, providing the walked values (in percentage) next to the corresponding circle slices by for of text or by adding an icon. Additionally, another way to solve this would be to

present a brief User Interface tutorial the first time the user opens the app explaining how to interact with certain components of it.

Task 7 – *"Browse to other user's tips on a challenge"*. Ideally, users would perform the following steps to complete the task: Select the home screen, choose a venue with challenges in it, swipe challenges until finding one with user tips and finally swipe the tips slider (from right to left) to browse through the different tips. Figure 24 - Navigation on user tips, through swipe demonstrates how the tips slider behaves when scrolled.

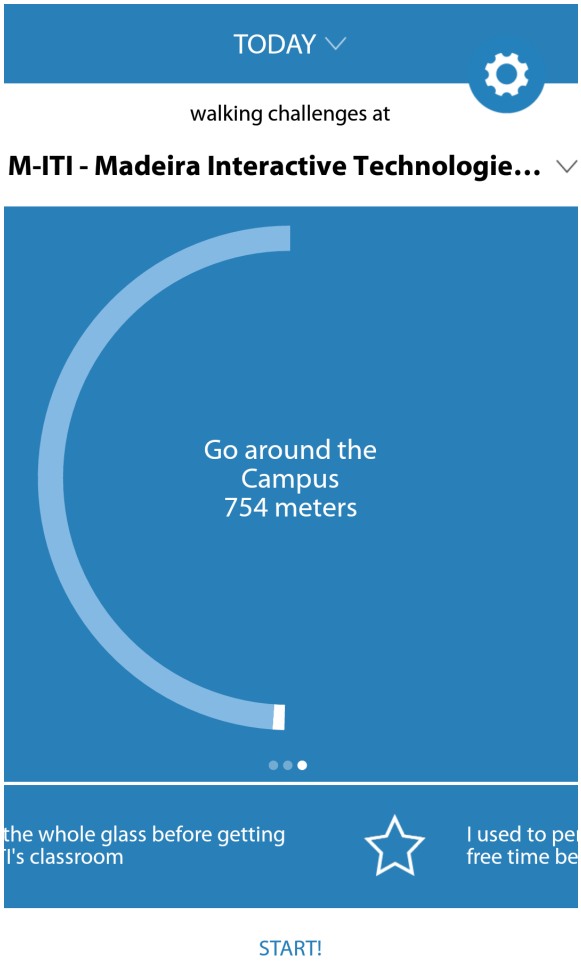

Figure 24 - Navigation on user tips, through swipe

This task was the one with the lowest completion rate (53,85%). As designers, we took for granted that the user would intuitively swipe on that section to browse through the tips but two scenarios that deceived the users:

- First challenge the user consults has only one tip – If the first challenge on which the user tries to swipe on the tips only has one tip, the swipe action will have no behavior at all. If this happens, the perceptual model of the user regarding the tips slider would be that there is no swipe action at all on the tips slider and so, he will never try again this action. One possible solution to this problem would be providing feedback on this scenario. When the user tries to swipe on a challenge with only on tip, the system could present a message with something like "There are no more user tips for this challenge".
- The tip container fills in the screen width – There is no way to know that there are more elements than the one visible if there is no indication of that at all. Contrary to the challenges slider that contains the circular dots as an indicator of the browsing state within the challenges, the tips slider lacks any feedback so, one of the solutions would be to add these visual cues on the tips slider as well. Other solution would be to decrease the tip container width so that the user can preview the previous and following tip, as represented on Figure 25 - Navigation on user tips, next and previous tip preview

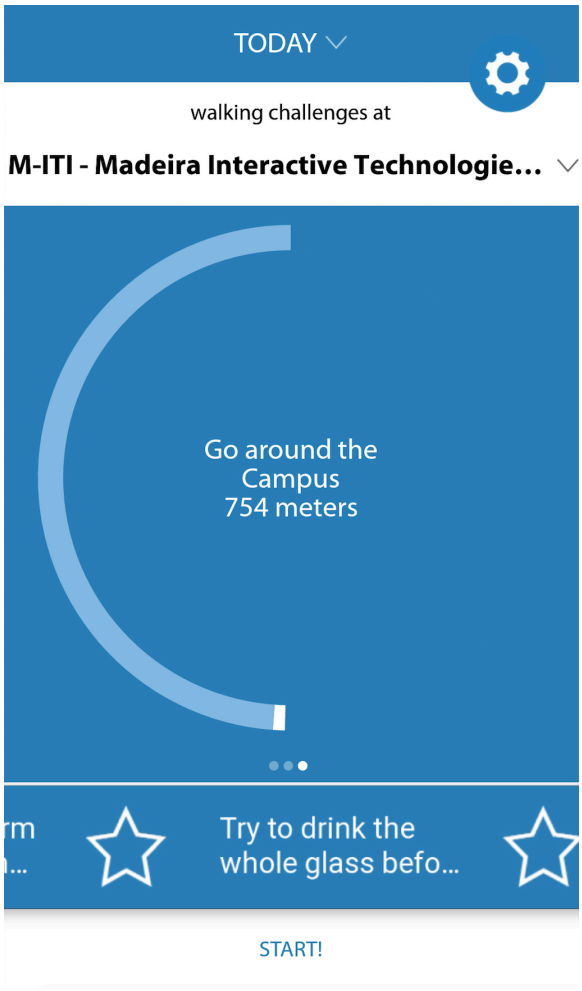

Figure 25 - Navigation on user tips, next and previous tip preview

Task 11 – *"Browse through system messages (statistics on performance)"*. In order to obtain this information, the user should: Select the historical screen through the top dropdown (select either "Last week", "Last Month" or "Last Year"), and browse through the system messages slider. One factor that lead users to not perform this task successfully was the lack of contextualization about the app's structure. As we introduced the app to the users, we should have had referred key concepts about the app, including that system messages stands for statistical messages automatically provided by the app when the historical performance is consulted.

All in all, our evaluation allowed us to identified design errors that compromised the interaction of the user and that disguised some remarkable features of our app. These errors identified, will be considered in the next design interaction to enhance the usability of the app

(future work). Further, the usability evaluation allowed us also to observe that the insights obtained in the preliminary study were important and reflected the high competition score of the remaining tasks.

5.2.2 PSSUQ evaluation

The results of the PSSU Questionnaire can be found on the appendix UI study – Post-Study System Usability Questionnaire results. Table 4 - SysQual, InfoQual, IntQual and Overall scores of CrowdWalk displays the calculated scores according to this method's scales.

Table 4 - SysQual, InfoQual, IntQual and Overall scores of CrowdWalk where 1 being the highest level of satisfaction and 7 the lowest

Scale	Scale scoring rule	Score
System Quality	Average items 1 - 6	2,6
Information Quality	Average items 7 - 12	2,9
Interface Quality	Average items 13 - 15	1,8
Overall	Average items 1 - 16	2,5

The scores can take values between 1 and 7, with lower scores indicating a higher degree of satisfaction (Sauro & Lewis, 2012).Our interpretation of the results indicates that the most pleasant part of the application was the interface, which reflects a pleasant experience while using it. We believe that the colour scheme consistency across the app is one of the reasons why the Information Quality had the highest score. On the circular ring,

we represent the transparent section as walked distances, the white section as what a challenge represents and the blue section as the remaining distance for the goal. All main action buttons (star challenge, stop challenge or add challenge) are always presented as white buttons on the bottom of the screen so it represents the main action within the current screen.

The second-best Quality score was the System Quality (2,6). This section evaluates how easily the user can navigate and perform tasks on the app (interaction). We believe that the CrowdWalk's top-down hierarchy (time, place, challenges, information) across all screens helped users to have a better perception on how to perform the requested tasks.

The lowest Quality score was from the Information Quality. This section represents how the system interacted with the user either by providing error messages upon wrong action or by how clearly the information needed is presented on the screen. Additionally, in some specific scenarios it is not very clear how the user can undo (sometimes is not even possible) a wrongful action. Recovering from incorrect actions was an insight distinguished for further investigation.

Overall, the app scored a 2,5 out of 7, which means that the final prototype proves once again to meet our expectations regarding the overall use of the system.

6 Conclusion

To begin with, we did not manage to compare CrowdWalk with other similar applications due to the fact that, there are almost none. The innovation CrowdWalk brings into the field of activity tracking applications would not allowed us to properly measure the same functionalities across applications.

We believe the goals and the identified requirements were met. By brining novel components like contextual information and Crowdsourcing into CrowdWalk, we contribute to boost the levels of the daily amount of walking and thus, create habit formation. The system messages, comparisons with real life facts, improves the odds of users sustaining engagement with these application for longer periods of time than usual.

The preliminary study supported the initial thoughts about what would a system like this should behave and, provided interesting implications for the design. It was verified that daily walking activities are most likely to be performed in small distances and on locations the users spent a lot of their routines. The motivations behind these walking activities also show evidence that the main goal is to maintain or boost the current activity levels and hence the well-being.

The prototype allows user to share their insights about their experiences while performing walking activities in such a way that other users can feel inspired to perform novel activities that never crossed their minds and which have potential to be performed on daily routines. The ability to define a goal can encourage the user to perform walking challenges in order to accomplish the challenge. CrowdWalk also leverages public commitment. By providing Facebook share option, Crowdwalk supports public commitment by making goals visible to a group of friends and allowing them to keep track of their activity level and progress towards a pre-set goal. Research has shown that announcing our plans to others increases the likelihood of them being completed. According to theory of cognitive dissonance (Festinger, 1962), our need for a sense of consistency and identity pressures us to behave consistently to our commitments and avoid the mental discomfort that the contraction could cause.

The user interface study revealed to be positive in task execution evaluation by achieving an 89,51% task completion rate, almost reaching to the expected goal of 90%. Regarding the PSSUQ score evaluation, the 2,5 Overall score demonstrates that, the users felt a pleasant experience during their interactions with the CrowdWalk.

Overall, the prototype complies with the initial requirements and was able to perform all the necessary tasks in order to accomplish the goals of this thesis.

6.1 *Limitations*

Despite all the data is being stored (either locally or on the server) as explained on 4.1.1, it would be ideal that all that information uploaded to the server instead of being on the device. This would prevent the user to lose all the data in case the device memory is erased by any reason. This would require an authentication system to be built within the app so the data could be securely accessed multiple times. On the other hand, the user could cheat the system if the same account was logged in at the same time on more than one device since the step counting would be heavily adulterated.

A common issue that personal tracker apps present is the measurement of the steps taken, since it relies on the gyroscope of the device whose precision may vary depending on the manufacturer. CrowdWalk was tested on different devices and there were some misleading data being collected due to the different accuracy levels of the accelerometers. Most sports trackers use the GPS to complement the step measurement but, on this particular case, that would prove to be useless since considerable amount of challenges are located indoors, where the GPS accuracy almost completely fails.

Currently, CrowdWalk fetches the nearby venues using the Foursquare API and, whenever the app performs this task, it asks the user to turn on the location services on the phone (GPS). If the user chooses to not enable this service, the GPS coordinates that the app receives most likely to be inaccurate since the location is made via WIFI.

As previously mentioned, the nearby venues are fetched via APIs and, for that reason, internet connection is mandatory. If the user does not have internet connection available, the

venues will not be fetched and, consequently, the challenges on them will not be fetched either. A possible solution to this could be implementing a caching system on the mobile device that would store the challenges of the venues the user was already in so they could be used on offline mode. Later this data would have to be sent to the server. In addition, the same implementation could be followed to the process of creating a challenge.

6.2 *Future work*

Based on the feedback we got from the current implementation of CrowdWalk, future work could be implemented by taking advantage of some of the features existing and the already consumed inputs of the app.

First, the algorithm to present the challenges could be refactored so that it takes in consideration the time of the day (day time, night time, working hours, weekend). The notification module could be improved to present users with novel challenge suggestions at different times of the day depending on what the user's availability is. For example, on the weekends, the system should be aware that the user is most likely to perform activities during day time since he probably will not be on his workplace. Also, the long-distance challenges should be presented first assuming there is more free time during the weekend.

In addition, the algorithm to present challenges could take into consideration the goal completion status by presenting first the challenges that will make the user complete the daily goal.

Regarding the venue selection, instead of presenting the closest one, the system should be able to pick one that is still close to the user but has higher rated walking challenges so that it improves the odds of performance. Another improvement could also be, using indoor localization tools to provide users with context within a venue by providing specific orders to perform a challenge (like "Turn left, then right for 100 meters") instead of just naming the challenge. This could reveal to be a difficult task for someone who is not familiar with the venue itself.

On the social component of the app, the existing Facebook challenge completion sharing makes it hard for the user to be aware of others that use the app. For that reason, we propose adding a social module into CrowdWalk that allows user to consult and compare walking performance with other users of the app. This would introduce the gamification concept into the app, which could boost the long-term adoption. Also related with the social component of the app, we believe that one way of turning walking activities more entertaining would be to notify the user that there are friends nearby and suggest him to meet them by creating a walking activity on that context: “Peter is 2 miles away from you, near the cafeteria. Go meet him!”.

Notification wise, we think that the app could be improved so that the system messages regarding the historical performance could be delivered as a phone notification instead of the user having to open the app and consult them. We also believe that developing a smartwatch app that pairs with the phone app would be a much better way of delivering this type of feedback through notifications. In addition, the user could consult his walking statistics and goal completion status directly on the smartwatch.

Finally, one aspect that may be needing some improvement is app configuration in terms of settings options. As referred before, the user sedentary threshold is statically set on the app to 50 steps in 40 minutes. This could be configurable in a certain way so that the user can set a bigger or smaller time interval. Also, the system should be able to suggest goal increase if it detects that the user’s activity is often exceeding the daily goal set.

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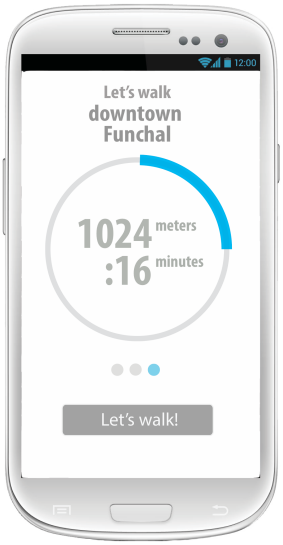
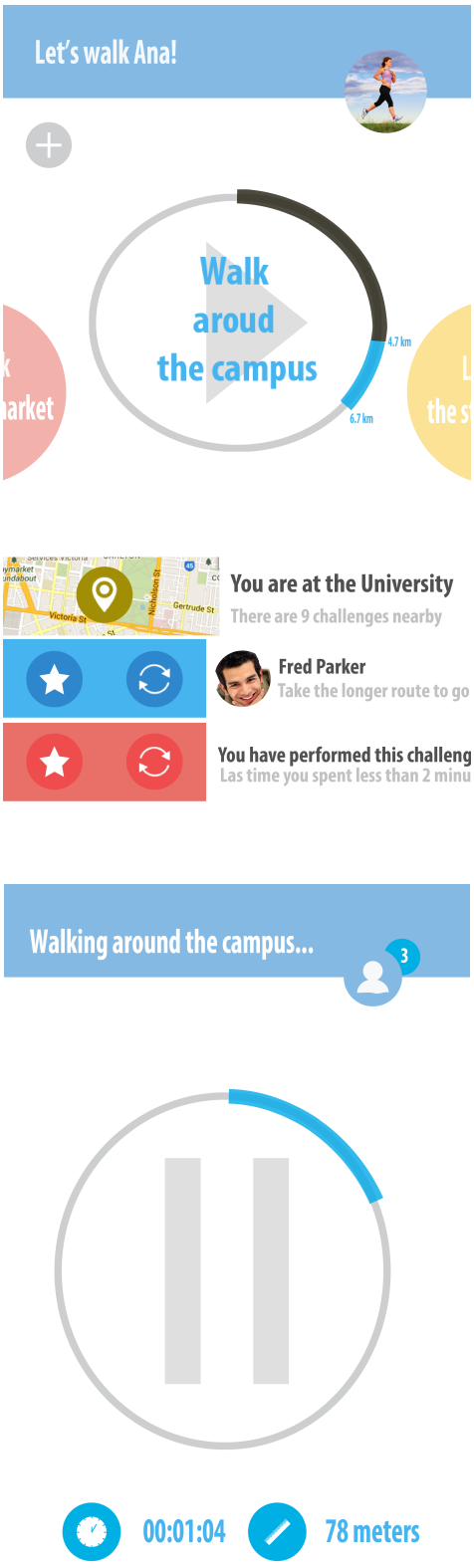
Appendices

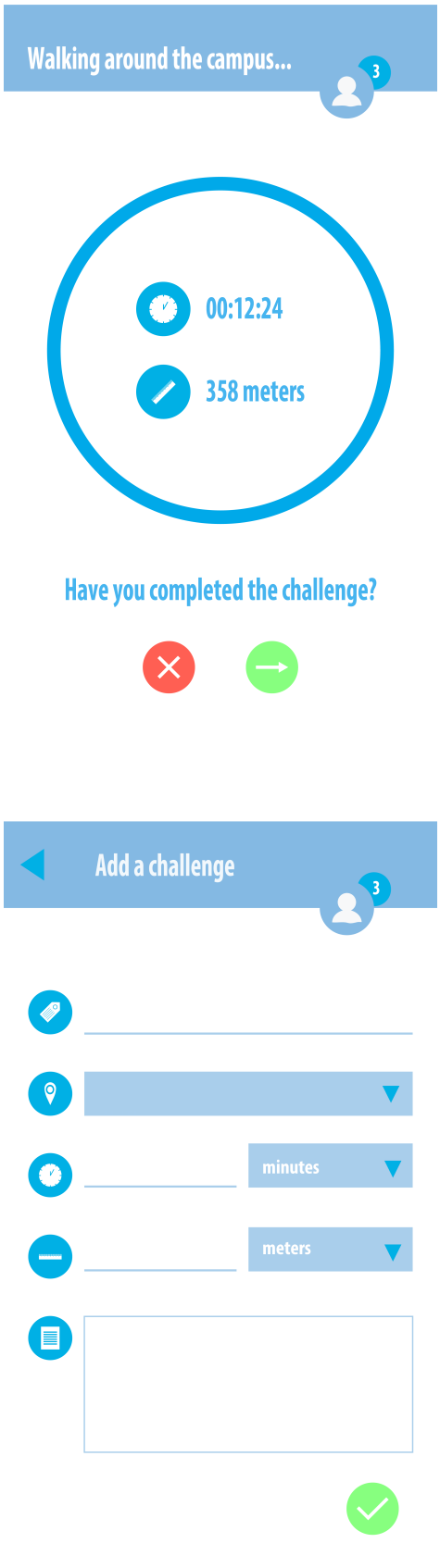
Preliminary study questionnaire

#	**Question**
1	What is your gender?
2	How old are you?
3	What is your country of residence?
4	Walking activity #1 - Can you think of a habit or practice you embedded (at some point
5	How much do you typically walk within this habit? (meters)
6	How often do you perform this activity? (Rate from: Exclusively once - Daily)
7	Walking activity #2 - Can you think of a habit or practice you embedded (at some point
8	How much do you typically walk within this habit? (meters)
9	How often do you perform this activity? (Rate from: Exclusively once - Daily)
10	Walking activity #3 - Can you think of a habit or practice you embedded (at some point
11	How much do you typically walk within this habit? (meters)
12	How often do you perform this activity? (Rate from: Exclusively once - Daily)

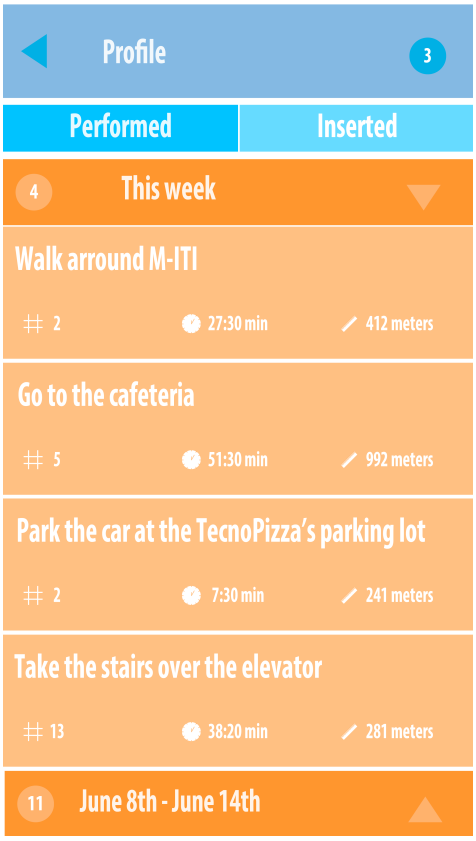
CrowdWalk prototyping

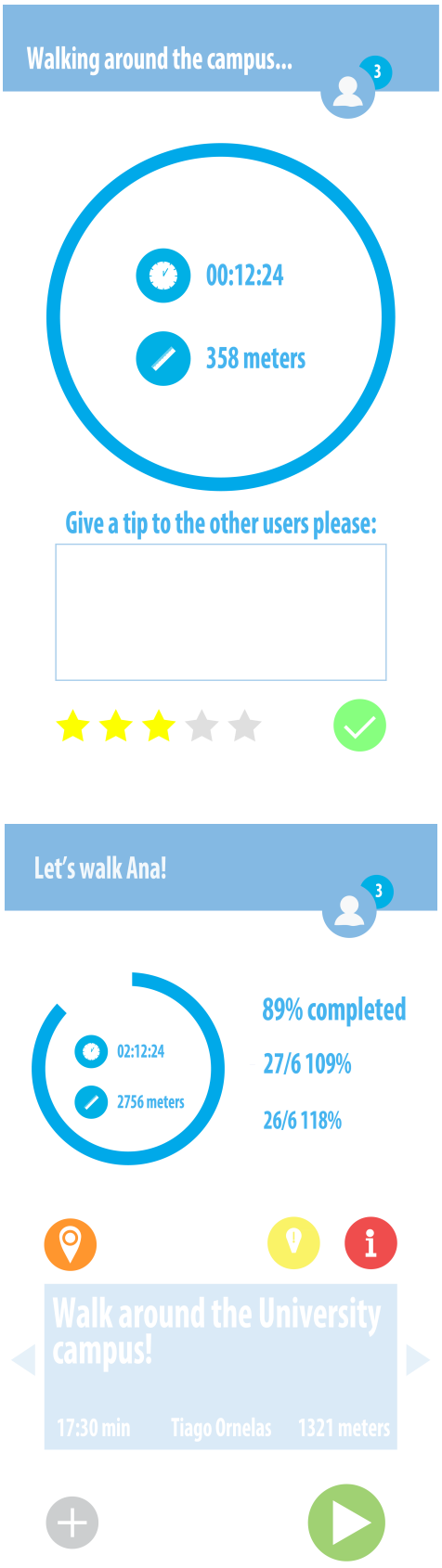


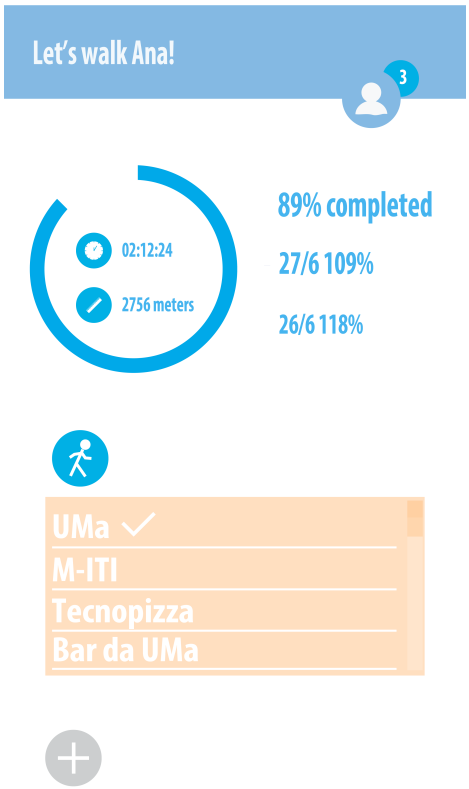

Let's walk Ana!
Walk
aroud
the campus
4.7 km
6.7 km
You are at the University
There are 9 challenges nearby
Fred Parker
Take the longer route to go
You have performed this challeng
Las time you spent less than 2 minu
Walking around the campus...
3
00:01:04
78 meters

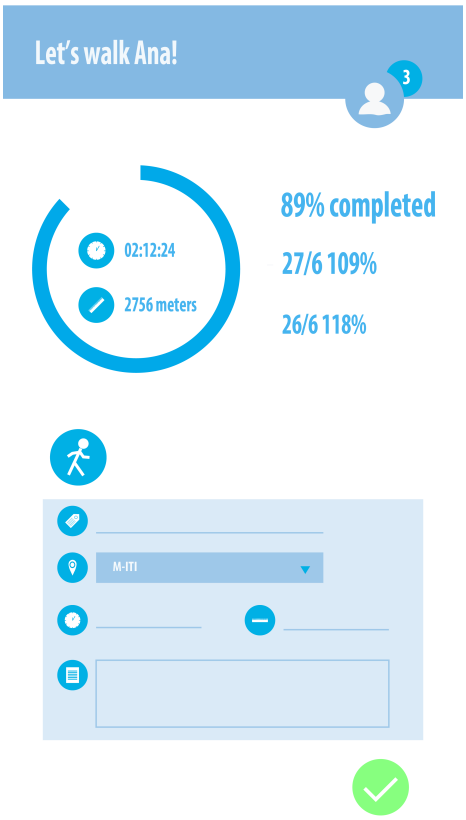

Walking around the campus...
3
00:12:24
358 meters
Have you completed the challenge?
Add a challenge
3
minutes
meters

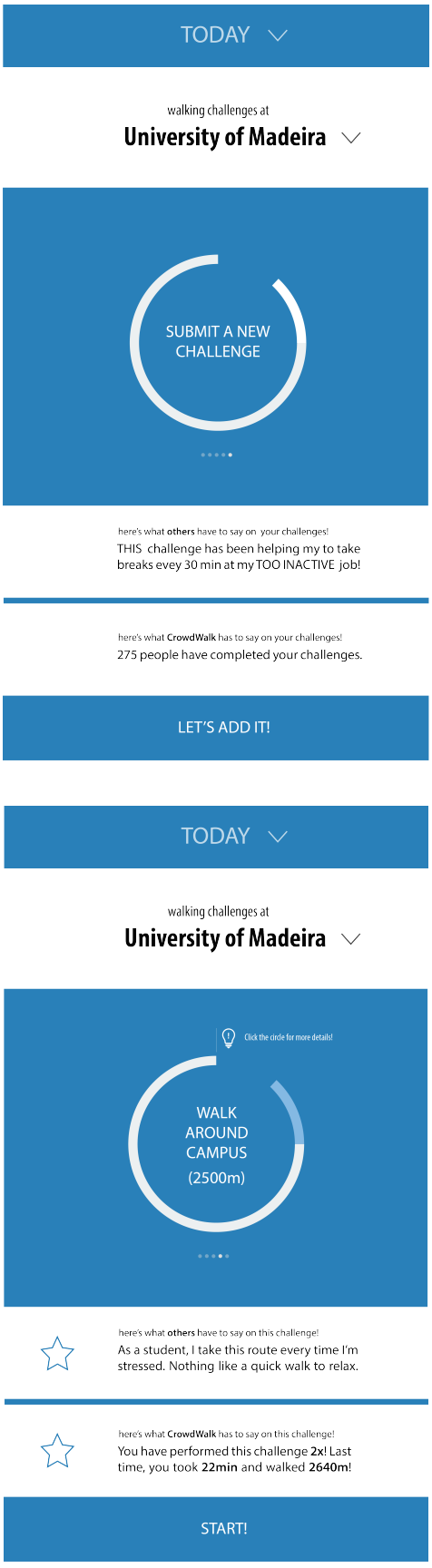

Profile
Performed
Inserted
97
Pick grosseries with the cart still
88%
18:21 min
412 meters
Fred Parker
Try to get one item at a time! You maximize the exercise this way.
Tiago Ornelas
I allways leave my shopping cart at the last aisle!
Rúben Gouveia
Be careful with this technique. I allways end up buying more than I need!
8
Waiting for the bus? Walk to the next station.
8
Park far away
3
Leave a bus stop early
2
Check your mailbox


Profile
3
Performed
Inserted
4
This week
Walk arround M-ITI
2
27:30 min
412 meters
Go to the cafeteria
5
51:30 min
992 meters
Park the car at the TecnoPizza's parking lot
2
7:30 min
241 meters
Take the stairs over the elevator
13
38:20 min
281 meters
11
June 8th - June 14th


Walking around the campus...
3
00:12:24
358 meters
Give a tip to the other users please:
Let's walk Ana!
3
02:12:24
2756 meters
89% completed
27/6 109%
26/6 118%
Walk around the University campus!
17:30 min
Tiago Ornelas
1321 meters


Let's walk Ana!
3
02:12:24
2756 meters
89% completed
27/6 109%
26/6 118%
UMa
M-ITI
Tecnopizza
Bar da UMa


Let's walk Ana!
3
02:12:24
2756 meters
89% completed
27/6 109%
26/6 118%
M-ITI


TODAY
walking challenges at
University of Madeira
SUBMIT A NEW CHALLENGE
here's what others have to say on your challenges!
THIS challenge has been helping my to take breaks evey 30 min at my TOO INACTIVE job!
here's what CrowdWalk has to say on your challenges!
275 people have completed your challenges.
LET'S ADD IT!
TODAY
walking challenges at
University of Madeira
Click the circle for more details!
WALK AROUND CAMPUS
(2500m)
here's what others have to say on this challenge!
As a student, I take this route every time I'm stressed. Nothing like a quick walk to relax.
here's what CrowdWalk has to say on this challenge!
You have performed this challenge 2x! Last time, you took 22min and walked 2640m!
START!

The Post-Study Usability Questionnaire Version 3

	The Post-Study Usability Questionnaire Version 3		Strongly agree						Strongly disagree		NA
			1	2	3	4	5	6	7		
1	Overall, I am satisfied with how easy it is to use this system.		O	O	O	O	O	O	O		O
2	It was simple to use this system.		O	O	O	O	O	O	O		O
3	I was able to complete the tasks and scenarios quickly using this system.		O	O	O	O	O	O	O		O
4	I felt comfortable using this system.		O	O	O	O	O	O	O		O
5	It was easy to learn to use this system.		O	O	O	O	O	O	O		O
6	I believe I could become productive quickly using this system.		O	O	O	O	O	O	O		O
7	The system gave error messages that clearly told me how to fix problems.		O	O	O	O	O	O	O		O
8	Whenever I made a mistake using the system, I could recover easily and quickly.		O	O	O	O	O	O	O		O
9	The information (such as online help, on-screen messages and other documentation) provided with this system was clear.		O	O	O	O	O	O	O		O
10	It was easy to find the information I needed.		O	O	O	O	O	O	O		O
11	The information was effective in helping me complete the tasks and scenarios.		O	O	O	O	O	O	O		O
12	The organization of information on the system screens was clear.		O	O	O	O	O	O	O		O
13	The interface* of this system was pleasant.		O	O	O	O	O	O	O		O
14	I liked using the interface of this system.		O	O	O	O	O	O	O		O
15	This system has all the functions and capabilities I expect it to have.		O	O	O	O	O	O	O		O
16	Overall, I am satisfied with this system.		O	O	O	O	O	O	O		O

UI study -tasks performance results

Subject ID	Task	Success?	Time(seconds)
1	1	N	-
	2	Y	3
	3	Y	2
	4	N	-
	5	Y	24
	6	Y	1

Subject ID	Task	Success?	Time(seconds)
	7	N	-
	8	Y	1
	9	Y	3
	10	Y	39
	11	N	-
2	1	Y	1
	2	Y	1
	3	Y	17
	4	Y	4
	5	Y	8
	6	Y	14
	7	N	-
	8	Y	11
	9	Y	5
	10	Y	9
	11	Y	10
3	1	Y	1
	2	Y	14
	3	Y	21
	4	Y	24

Subject ID	Task	Success?	Time(seconds)
	5	Y	11
	6	Y	22
	7	N	-
	8	Y	3
	9	Y	4
	10	Y	10
	11	Y	13
4	1	Y	5
	2	Y	8
	3	Y	20
	4	Y	10
	5	Y	11
	6	N	-
	7	Y	23
	8	Y	26
	9	Y	6
	10	Y	6
	11	Y	6
5	1	Y	5
	2	Y	18

Subject ID	Task	Success?	Time(seconds)
	3	Y	24
	4	Y	29
	5	Y	48
	6	Y	1
	7	Y	47
	8	Y	11
	9	Y	5
	10	Y	9
	11	Y	5
6	1	Y	23
	2	Y	6
	3	Y	35
	4	Y	78
	5	N	-
	6	Y	2
	7	Y	37
	8	Y	54
	9	Y	2
	10	Y	7
	11	Y	12

Subject ID	Task	Success?	Time(seconds)
7	1	Y	28
	2	Y	28
	3	Y	19
	4	Y	4
	5	N	-
	6	Y	12
	7	Y	28
	8	Y	3
	9	Y	1
	10	Y	2
	11	Y	20
8	1	Y	10
	2	Y	16
	3	Y	11
	4	Y	18
	5	Y	3
	6	Y	3
	7	Y	13
	8	Y	13
	9	Y	2

Subject ID	Task	Success?	Time(seconds)
	10	Y	4
	11	Y	26
9	1	Y	6
	2	Y	47
	3	Y	21
	4	Y	40
	5	Y	6
	6	Y	7
	7	Y	23
	8	Y	28
	9	Y	5
	10	Y	26
	11	Y	31
10	1	Y	30
	2	Y	32
	3	Y	29
	4	Y	2
	5	N	-
	6	Y	9
	7	Y	46

Subject ID	Task	Success?	Time(seconds)
	8	Y	11
	9	Y	2
	10	Y	11
	11	Y	8
11	1	Y	5
	2	Y	18
	3	Y	31
	4	Y	8
	5	N	-
	6	Y	14
	7	N	-
	8	Y	11
	9	Y	2
	10	Y	4
	11	N	-
12	1	Y	23
	2	Y	7
	3	Y	18
	4	Y	22
	5	Y	20

Subject ID	Task	Success?	Time(seconds)
	6	Y	5
	7	N	-
	8	Y	12
	9	Y	2
	10	Y	7
	11	Y	29
13	1	Y	10
	2	Y	11
	3	Y	35
	4	Y	41
	5	Y	82
	6	Y	1
	7	N	-
	8	Y	9
	9	Y	2
	10	Y	7
	11	Y	20

UI study – Post-Study System Usability Questionnaire results

Subject ID	PSSUQ Question #	Answer
1	1	5
	2	2
	3	7
	4	5
	5	6
	6	4
	7	7
	8	NA
	9	4
	10	4
	11	4
	12	4
	13	1
	14	1
	15	1
	16	1
2	1	2

Subject ID	PSSUQ Question #	Answer
	2	2
	3	3
	4	3
	5	2
	6	2
	7	NA
	8	4
	9	2
	10	3
	11	2
	12	3
	13	1
	14	1
	15	3
	16	1
3	1	3
	2	3
	3	3
	4	4

Subject ID	PSSUQ Question #	Answer
	5	2
	6	3
	7	NA
	8	NA
	9	NA
	10	3
	11	NA
	12	1
	13	1
	14	1
	15	3
	16	2
4	1	3
	2	3
	3	2
	4	2
	5	1
	6	1
	7	7

Subject ID	PSSUQ Question #	Answer
	8	NA
	9	1
	10	2
	11	1
	12	2
	13	2
	14	2
	15	1
	16	1
5	1	3
	2	3
	3	3
	4	3
	5	2
	6	2
	7	5
	8	4
	9	4
	10	4

Subject ID	PSSUQ Question #	Answer
	11	4
	12	2
	13	3
	14	3
	15	4
	16	3
6	1	2
	2	3
	3	5
	4	2
	5	1
	6	1
	7	NA
	8	4
	9	NA
	10	3
	11	3
	12	5
	13	2

Subject ID	PSSUQ Question #	Answer
	14	2
	15	NA
	16	2
7	1	3
	2	2
	3	3
	4	2
	5	1
	6	2
	7	3
	8	2
	9	3
	10	2
	11	2
	12	2
	13	2
	14	2
	15	2
	16	2

Subject ID	PSSUQ Question #	Answer
8	1	3
	2	3
	3	2
	4	3
	5	3
	6	2
	7	7
	8	1
	9	3
	10	3
	11	2
	12	3
	13	3
	14	3
	15	2
	16	2
9	1	1
	2	1
	3	2

Subject ID	PSSUQ Question #	Answer
	4	1
	5	1
	6	1
	7	N/A
	8	1
	9	1
	10	2
	11	1
	12	1
	13	1
	14	1
	15	1
	16	1
10	1	2
	2	3
	3	2
	4	2
	5	1
	6	3

Subject ID	PSSUQ Question #	Answer
	7	N/A
	8	2
	9	2
	10	2
	11	2
	12	1
	13	1
	14	1
	15	2
	16	2
11	1	5
	2	4
	3	6
	4	2
	5	2
	6	5
	7	7
	8	3
	9	NA

Subject ID	PSSUQ Question #	Answer
	10	6
	11	2
	12	4
	13	2
	14	2
	15	3
	16	4
12	1	4
	2	4
	3	4
	4	4
	5	4
	6	1
	7	7
	8	1
	9	NA
	10	4
	11	2
	12	2

Subject ID	PSSUQ Question #	Answer
	13	1
	14	1
	15	4
	16	1
13	1	1
	2	1
	3	2
	4	1
	5	1
	6	1
	7	NA
	8	1
	9	1
	10	1
	11	1
	12	1
	13	1
	14	1
	15	1

Subject ID	PSSUQ Question #	Answer
	16	1