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WalkNRide
Contextualising feedback in physical activity trackers

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WalkNRide: Contextualising Feedback in Physical Activity Trackers

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ABSTRACT

Increasing levels of sedentarism and obesity, along with advances in sensor technologies have instigated a market for *wearable activity trackers*, electronic devices that sense users' physical activity levels with the goals of self-monitoring and behaviour change. Nowadays, activity trackers are one of the most desirable technologies, making up for a market of over $230 million in 2013. However, despite the spike of users' interest, activity trackers have been shown to lose their appeal over time, with a recent survey suggesting that one out of three users discard the tracker in the course of the first six months of use.

The question we pose is: how can we design activity tracker so that users' interests is sustained over the long term? Our design approach focuses on *contextualising physical activity*. We do this through sensing users' locations and activities (such as being still, walking or commuting through a car, bus or other means) and thus providing innovative ways of presenting feedback on users.

This thesis presents the design and evaluation of *WalkNRide*, a physical activity tracker for Google Android. Through a longitudinal field study of WalkNRide, we attempt to inquire into the factors that drive the adoption (or non-adoption) of the tool as well as the ways in which the use of the tool contributes towards habit formation.

Keywords: Sedentarism, Obesity, Personal Informatics, Activity trackers, Textual feedback, Behaviour Change.

RESUMO

O aumento dos níveis de sedentarismo e obesidade, assim como os avanços em tecnologias de sensores têm motivado o recente interesse no desenvolvimento de *wearable activity trackers*, dispositivos electrónicos que detectam os níveis de actividade física dos utilizadores, que têm como objectivos providenciar uma maneira dos mesmos se monitorizarem a si próprios, assim como motivar uma mudança de comportamento. Hoje em dia, os *activity trackers* são uma das tecnologias que mais gera interesse, ocupando um mercado estimado acima de $230 milhões em 2013. Contudo, apesar do elevado interesse por parte dos utilizadores, os *activity trackers* têm em comum o problema de que os utilizadores começam a perder o interesse pelos mesmos ao longo do tempo, com um inquérito recente a mostrar que um em cada três utilizadores descarta o dispositivo durante os primeiros seis meses de uso.

A questão que se põe é: como podemos desenvolver um *activity tracker* em que o interesse dos utilizadores se sustém por longo termo? A nossa abordagem foca-se em contextualizar a actividade física. Isto é conseguido recorrendo a sensores que detectam a localização e actividades dos utilizadores (como estando parados, a andar, ou num transporte como um carro, autocarro ou outros) e assim conseguindo formas inovadoras de apresentar feedback aos utilizadores.

Esta tese apresenta o desenvolvimento e avaliação de *WalkNRide*, um *physical activity tracker* desenvolvido para o Google Android. Através da elaboração de um estudo à volta do WalkNRide, tentamos perceber os factores que levam à adopção (ou não adopção) da aplicação, assim como das formas em que o uso desta contribui para a formação de hábitos.

Palavras-chave: Sedentarismo, Obesidade, *Personal Informatics*, *Activity trackers*, Feedback Textual, Mudanças de comportamento.

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1. INTRODUCTION

1.1. Motivation

Obesity is one of the most dominant problems in today's society, resulting in one of the main catalysers of diseases such as type 2 diabetes and various cardiovascular diseases, which can lead to early death, especially in the case of children and adolescents [1]. It has also been shown that it may also aggravate symptoms such as depression and anxiety [2].

Another problem that obesity can also bring are the high costs associated to it: not only for the government and health organisations, but also for the person himself, who will, for example, deal with high costs for a health insurance. In fact, it is estimated that obesity costs more than 200 billion dollars a year to the U.S. government [3].

In Portugal, on the year of 1996, the direct costs of obesity were estimated as being 46.2 billion escudos [4] (just over 230 million euros). This corresponded to 3.5% of the total healthcare costs, with costs with drugs carrying the largest amount of expenses. However, the total healthcare costs were estimated at just below 400 million euros. Later on, on the year of 2002, the costs of obesity were estimated as being higher than in 1996 [5]: the total healthcare costs were estimated at just below 500 million euros, with direct costs counting for 59.8% of the total, and the indirect costs counting for 40.2% of the total healthcare costs for that year.

In 1994, Seidell and Deerenberg [6] estimated that, in The Netherlands, the healthcare costs associated with overweight and obesity (body mass index higher than 25kg/m^2) were approximately 1 billion Dutch guilders, which corresponded to around 4% of the total healthcare costs in the country. In Australia, Segal et al. [7] estimated the cost associated with obesity (body mass index higher than 30kg/m^2) for the year of 1989 – including costs for the management of obesity, non-insulin-dependent diabetes mellitus, gallstones, hypertension, coronary heart disease, breast cancer and colon cancer -, as being amounted to 394.7 million Australian dollars. In France, Lévy et al. [8] studied the direct costs related with obesity in that country, and concluded that these (with body mass index equal or higher than 27kg/m^2) were around 11.89 French Francs, which represented 2% of the total expenses in healthcare. Hypertension represented 33% of those costs, and cancer 2.5%. Indirect costs were calculated in 0.6 billion French Francs. Moreover, these values were underestimated, since not all costs were included, due to the lack of information.

One of the main causes of these problems with obesity have to do with the lack of exercise and sedentary lifestyles. It has been studied that watching TV has a bad effect on people's health [9], since food advertising leads to increased food intake (therefore, increased calories intake). Increasing levels of obesity seem to be occurring in parallel with the reduction of physical activity and increase of sedentarism [10], which was justified by the authors with the increase in the use of motorised transport and physically-inactive activities such as TV viewing and computer work. The World Health Organization mentions several examples of energy-saving activity patterns in modern societies [11]:

- **Transport**: increases in car ownership;
- **At home**: ready-prepared meals/ingredients, washing machines and vacuum cleaners make meal preparation and cleaning easier;

- **At the workplace**: mechanisation and robotics have reduced the need to expend energy;
- **Public places**: lifts, escalators and automatic doors make people save time and energy;
- **Sedentary pursuits**: television viewing is responsible for a lot of inactivity, due to the reasons stated above;
- **Urban residence**: some urbanised areas of affluent countries are often dangerous for children, women and older people to go out alone or at night, and congested roads prevent children from playing on the streets.

But governments and health organisations are shifting their overall paradigm, which was based on curing, instead of preventing [12]. Common diseases are referred as having their roots in lifestyle, social factors and the environment, and that successful health promotion depends on a strategy of prevention [13]. Therefore, as one of the main causes of obesity relies on sedentary pursuits such as TV viewing, reducing children's TV viewing and video game usage proved to be a very promising approach to prevent childhood obesity [14]. Khan et al. [15] have built some community strategies and measurements to prevent obesity in the United States, such as requiring physical education in schools, improving access to outdoor recreational facilities, enhancing infrastructure supporting bicycling and walking, locating schools within easy walking distance of residential areas, etc. Globally, organisations are also trying to tackle this problem with their employees, by preventing, and therefore reducing the costs associated with health problems from their workforce. For example, the University of Pittsburgh Medical Center (UPMC) has won several awards for its innovative programs, which promoted a healthy workplace [16]. As a result of these programs, UPMC's total health care costs have dropped to 1.1%, while national and regional averages are near 7%; there has been a 38% reduction in tobacco use by employees (within 6 years); more than 9000 employees participated in a "weight race", and lost a combined 16.5 tons over 12 weeks.

And normally, people have no access to information on how much they are sedentary, or how much do they normally walk at a given place. This is why we have been witnessing a boom of wearable devices, which is proven by the fact that 1 in 10 Americans own an activity tracker [17].

1.2. Activity tracking

Activity tracking consists on the sensing and monitoring one's daily physical activities. This can be simply achieved through the use of a pedometer (Figure 1), which may be a small wearable device that counts the users' steps, or even in the format of a mobile application, that does the same job, by using the device's sensors, such as the accelerometer.

Figure 1 - The Omron HJ-112 pedometer, used in Houston [18].

However, with the recent years' development of more ubiquitous technologies and devices, other alternatives have arisen. These have the ability to track more details than just the users' steps, like other wearable devices such as Fitbit [19], Jawbone Up [20] and Nike+ Fuelband [21] (all three displayed in Figure 2), or even other mobile applications such as Moves [22] (displayed in Figure 3). These other details normally include sleep tracking and users' daily activities, which, in most cases, are classified into:

- Idle - when the user is stopped somewhere;
- Walking;
- Cycling;
- In a vehicle - which can include buses, cars and trains;

Figure 2 - Fitbit, Jawbone Up and Nike+ Fuelband, from left to right, respectively.

These devices and applications are able to monitor a wide range of factors that affect our lives. Therefore, they have the power to inform us about our own behaviours, increasing our self-awareness.

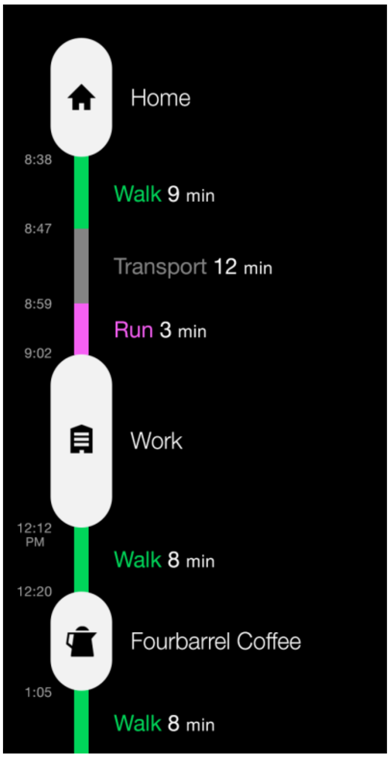

Figure 3 - The course of the day on Moves application [22].

The accuracy of the details on our daily lives, present on Moves, highlight the amount of information that activity trackers are now able to monitor, due to the advances on ubiquitous technologies.

1.2.1. How do activity trackers help towards behaviour change?

People consider activity trackers important because they facilitate the collection of where they have been to, how much time they have spent in a place, how much they have walked, etc. A lot of users claim that they start using an activity tracker to optimise their fitness levels [17]. Nowadays, this is probably the usage that most people give to activity trackers, given the details present on these. And by having the possibility to go back and look into the course of the day, we are able to understand, for example, in which situations we walk the most – if after work, or in the evening when we go shopping, etc.

In fact, activity trackers have been used to increase users' physical activity [23], as an exercise advisor [24], and also for retrospective interpretation of activities [25]. Nowadays, as already stated, activity trackers are also used to track and monitor users' sleep.

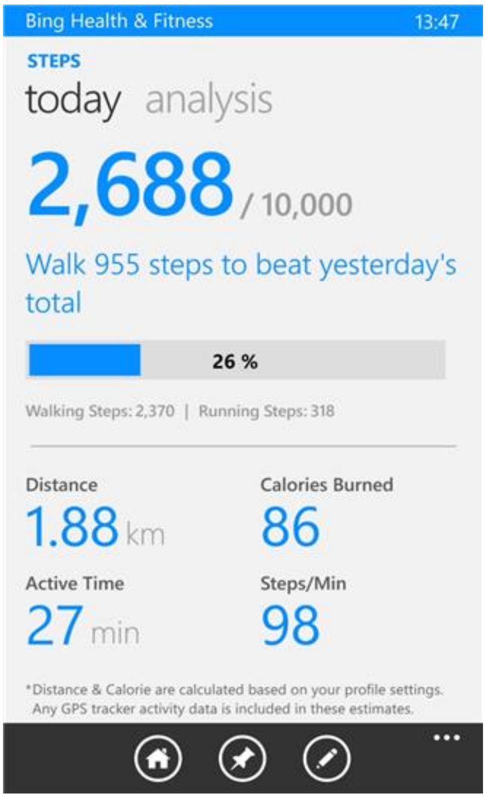

Figure 4 - Bing Health & Fitness application [26] day summary.

Bing Health & Fitness [26] (illustrated on Figure 4) is more focused on exercise than, for example, Moves. Therefore, the feedback given by the application will be more focused on motivating the user to exercise more, whereas Moves is more dedicated to recording our daily lives, being able to track the current context (such as locations). Bing Health & Fitness tries to motivate users to walk more by having:

- **Daily goal – together with a progress bar**: it motivates the user to try and reach that mark every day;
- **Text-based message**: it tries to motivate the user to walk more than he did on the previous day;
- **Daily statistics**: make the user aware of his current state, and just by presenting users with the calories they have burned may have a positive effect on them;

1.2.2. Decreasing users' engagement over time

Activity trackers have the goal of changing people's behaviours (by improving them), which is already a difficult task, since people's behaviours and routines are not easily changeable. Moreover, keeping users motivated after having used the system for a long time is an even harder task.

Consolvo [27] states that one of the causes for decrease of motivation over time when using activity trackers has to do with the feedback that systems present to users. For example, users who perform the desired behaviour must be rewarded, but when users do not perform as well

as they should (which may happen because of unplanned events, or because of an injury, etc.), they should not be punished, nor rewarded, but their interest should be sustained. Also, problems with the technology may occur: not giving the user proper credit for performing a healthy activity - for example, lifting weights, but using a system that does not have the necessary technology to acknowledge that - will make users upset; and giving users credit for something that they have not done is also something that makes users decrease their usage of the system over time. These are issues that are still difficult to solve with the technology existent nowadays, which is always prone to error. For example, data gathered from a device's accelerometer and then translated into a physical activity requires a lot of study in order to create patterns, and these may not always be correct.

Ian Li's vision [28] tackles another factor: the context. He mentions that activity trackers should take into account the context with which the user is involved, at every moment. For example, being able to count steps taking into account the user's location should have a positive effect, since people have different patterns of sedentarism and physical activity at different places.

1.3. Objectives of this thesis

1.3.1. Can we prolong users' engagement?

Given the already presented fact that users start losing their interest on activity trackers over time, one of the goals of this dissertation is to determine if we can prolong users' engagement with activity trackers by enhancing users' activity data with:

a) **Contextual information**: how will people react if they can understand how much physical activity they perform at different locations? Will this translate to more physical activity? What can context offer that numbers cannot alone? What are the benefits of contextual information in terms of awareness of one's physical activity behaviours over time?
b) **Actionable and evolving feedback strategies**: does the presentation of inferences about users' behaviours help them change their behaviours? And does the constant use of novelty on feedback motivate behaviour change? Additionally, how do different forms of feedback contribute towards prolonged engagement and behaviour changes?

1.3.2. Understanding users' engagement loops with activity trackers

Our second goal is to develop a richer understanding of the micro-usages of activity trackers, more precisely, users' engagement loops with these tools.

With the increase in functionality and diversity of use, mobile phones are accessed frequently for different uses [29]. Yan et al. [30] reported that most mobile device usage is characterised by brief interactions (50% of mobile engagement lasts less than 30 seconds) and tend to be repetitive. Oulasvirta [31] further built upon this concept, defining it as habit-forming, characterised by brief, repetitive inspections of dynamic content quickly accessible on a device.

Most literature on activity tracking consists on how different behaviour change strategies (goal setting, rewards, etc.) can encourage physical activity. However, there is limited knowledge in

terms of how usage is characterised over prolonged interactions with these tools. Our main focus will be to understand if participants' usage is characterised by micro-usages - short bursts of interaction with applications -, how time affects these and the reasons why participants engage, disengage and re-engage with these tools. This will possibly shed some light on how people adapt these tools in their life, and how time affects their usage of these tools. We will try to address questions such as: is the usage of activity trackers characterised by micro-usage/habit formation? How often (and for how long) do users engage with these applications? Why do they disengage?

1.4. Document structure

This chapter has introduced the problems with obesity and sedentary lifestyles we are trying to solve, and it has also provided some awareness about the basics of physical activity trackers.

On the next chapter, entitled "Literature Review", some actual activity trackers will be discussed, against some theories around the design of personal informatics systems - which will also be introduced – and, more specifically, some theories around the design for behaviour change.

The third chapter is named "System Overview", and this is where we will turn theories into functionalities, by introducing WalkNRide, which is a physical activity tracker, developed as an Android application. These functionalities, or, more specifically, feedback strategies, will be highlighted and discussed, focusing on the users' point of view. Other implementation-related information will also be presented in this chapter.

In order to achieve the goals/objectives proposed in this first chapter, we conducted a field study, which will be introduced, together with our approaches to achieve each of those proposed goals. The results and findings will also be presented, always with the focus on these goals.

The fifth chapter, termed "Discussion", will be used, as the name suggests, to discuss the results and findings of the previous chapter.

And finally, the last chapter, entitled "Conclusion", will state the contributions of this work to the area of physical activity trackers and personal informatics systems, and also give some suggestions in terms of future work.

2. LITERATURE REVIEW

2.1. What are personal informatics systems?

We spend a lot of time searching and getting to know the world around us, but what about knowing more about ourselves and our daily lives? Self-knowledge can be achieved manually, by taking notes of everything that goes through our lives, like keeping track of what we eat every day. However, advances in technology allow us to use sensors that track almost everything, and to have access to loads of information gathered from the Internet, forming some conclusions about ourselves and our behaviours.

Systems that automate this process of tracking ourselves belong to a class of systems known as personal informatics [32], and can range from a lot of fields: since physical activity trackers, to finance trackers, etc. These systems help people collect relevant data about themselves, allowing them to self-reflect, and achieving what is called self-knowledge. This data would be really difficult for a human to track, since we cannot memorise everything that happened, and also because of our lack of ability to track everything that for example sensors can track.

2.2. Related work

HealthVault [33] is a website and a mobile application that helps people manage their health information. Users have a profile, which include information such as allergies, current medications/supplements, family history and emergency contacts, and it also allows users to manage factors such as their weight, height, blood pressure, cholesterol and exercise. Other services and applications such as Moves [22] and Fitbit [19] can be used as an extension of HealthVault, by tracking and adding exercise and activities performed to this system.

In terms of activity trackers, which are gradually being adopted by a lot of people over time [17], a wealth of research prototypes have been developed within HCI: Houston [18], Fish'n'Steps [34] and UbiFit Garden [2] are some examples that will be described on the next sub-chapter.

But while significant advances have taken place within Human Computer Interaction with respect to the development of novel personal informatics systems, there has been limited conceptual advancement as to the kinds of questions that people ask when interacting with these systems. So, how can we induce behaviour change?

Ian Li [32] mentions a model with 5 stages (Figure 5) present on the use of personal informatics (which is composed by a description and the barriers for each stage):

- **Preparation**: occurs before people start collecting information, deciding what information they will record, and how they will record it;
    - Barriers: a barrier at this stage can be to determine what information to collect, and which tool to use;
- **Collection**: the collection of data through the observation of the actual context;
    - Barriers: some problems may occur if the tool is not the correct one for what the user actually needed, or simply because he forgot to collect the information.

Other problems like the lack of information or the use of subjective estimations may also represent a barrier to users;

- **Integration**: this stage consists of transforming all the collected data into its final format, and may be a long process (for example, inserting annotated data into an Excel spreadsheet or even another software), or a short one (for example, what nowadays' systems do - displaying the data in a "visible" format);
    - Barriers: barriers at the integration stage consist on the difficulty of organising data that comes from multiple inputs, and also when the integration takes a long time (forcing users to have a lot of work to do at this stage);
- **Reflection**: happens when the user reflects on his personal information, which may consist of lists of collected information, or even exploring information visualizations. This may be a "short-term" or a "long-term" reflection. Short-term reflections are useful for making the user aware of his current status (for example, pedometers which show users the step count). Long-term reflections are useful for making users compare their personal information between different times, revealing patterns and trends (for example, devices that have no screen, forcing the user to check the information only after synchronising with the desktop software;
    - Barriers: lack of time or difficulties retrieving, exploring or understanding information are some of the barriers at this stage;
- **Action**: this final stage is the stage when people choose what to do with their new understanding about themselves;
    - Barriers: some systems encourage users to take action, but some do not, making this a barrier to users, who will have some more difficulty on the understanding of their personal information.

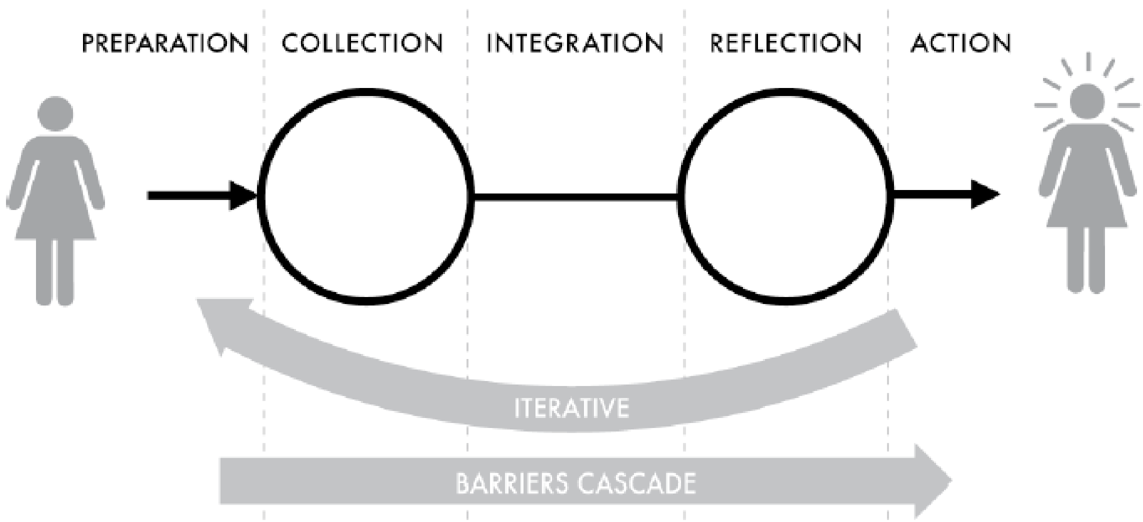

Figure 5 - Ian Li's [32] stage-based model of personal informatics.

These stages have 4 properties:

- **Cascading barriers**: problems in earlier stages affect the later ones, so, systems have to be designed for all stages, not being focused on only one;
- **Iteration**: users keep introducing new data, new tools and/or processes as they progress through the stages. Therefore, personal informatics systems have to be flexible, by supporting imports and exports of data to and from other systems, as well as supporting different kinds of information;
- **User-driven vs system-driven**: each stage may be user-driven, system-driven, or a combination of both. User-driven stages are those where the user always has to do everything (for example, at the Integration stage, the user has to manually transcribe the collected information, so that it can then be reflected on, at the Reflection stage), and system-driven stages are those where the system takes the responsibility of performing the tasks for that stage (for example, at the Collection stage, the system may use sensors to collect the data);
- **Uni-faceted vs multi-faceted information**: uni-faceted systems only show one facet of people's lives (for example, a system that tracks users' physical activity), while multi-faceted systems show various facets of people's lives (for example, diabetes management systems may associate more than one parameter, such as blood sugar level and food consumption). Uni-faceted systems are simpler, however, only focus on a specific facet, while multi-faceted systems may be much more complicated (having to collect a lot of data), but offer a lot more meaning to people's lives when the information of all facets can be merged together (instead of presenting information separately for each facet).

This model represents the stages of the use of (mainly) "manual" personal informatics systems, but it still helps on the design of "automatic" personal informatics systems, since almost all of these stages are also present on these systems, except from the preparation stage, which is mainly a user decision on which tool he should use for his goals. For example, the integration stage is one of the main stages on these automatic systems, since on the manual ones everything has to be dealt by a human, which, apart from tiring, can be prone to errors (which is actually another barrier on this stage). On automatic personal informatics systems, this integration is done with no effort from the user, and lots of inputs no longer face a problem to him. The properties of these stages are also important to personal informatics systems, like for example, the cascading barriers, since that if a user is facing difficulties on integrating the data, his reflections and actions will be affected, and this has a great impact, which may lead the user to abandon the system.

2.3. Promotion of behaviour change

Behaviours can be observable (for example, actions) or unobservable (for example, feelings or intentions), states Ian Li [28], and the change on these highly depend on the user's motivation for change (Ryan and Deci [35] refer to it as "the why of behaviour"). The author states that multi-faceted personal informatics systems have a higher possibility of changing users' behaviours, like tracking context (for example, users' locations throughout the day). Consolvo

et al's [18] study participants also claimed that inclement weather conditions negatively affected their routines of physical activity.

A wealth of theoretically informed strategies to behaviour change exist. One of the most prominent strategies is self-monitoring. For instance, Seligman and Delay [36] did a study where they monitored the electricity usage of two groups of residential homes, on which both groups consumed the same amount of electricity. One of those groups was being given feedback for four times a week, while the other group was not. During the study, the group to whom was given feedback used 10.5% less electricity.

In the following sections we review some of the most prominent theories and their related design strategies.

2.3.1. Behaviour change theories

2.3.1.1. Goal-Setting Theory

The goal-setting theory has long been used on activity trackers, being now almost mandatorily part of these systems. This is because it has already been proven that the fact of having a step goal increased users' likeliness to change their behaviour in terms of their physical activity [23].

Houston [18] was composed of two pieces of hardware: a wearable pedometer and a mobile phone (Nokia 6600). The phone application would provide users the ability to insert and view their step counts, to have a daily goal, add comments to a step count, share their results with others, etc. Compared to the existing systems nowadays, this was a very simple system. However, it already had a daily goal, which made a difference to the users, who would check it, and if the goal was far from achieved, some would have some unplanned physical activity, in order to meet their goal. Recognising users for meeting their goals certainly also helped for these behaviour changes.

Fish'n'Steps [34] also consisted on using a pedometer, but it did not consist on also using a mobile phone. Instead, it worked like a game (Figure 6), on which users would go to a public kiosk to upload their daily step count, and there they would find their virtual pet (a fish in a tank), which emotional and growth state depended on how much steps his owner did, in relation to his daily goal. As a game, in one of the versions, four users shared a fish tank, and all four users had to walk every day, or else the tank's water would get darker and the tank's decorations (plants, small animals, etc.) would start to disappear. Therefore, it had to be a team work, and for that reason, people could see the others' progress (as long as in the same team), and they could also chat with each other, by leaving a message on the application for the rest of the team.

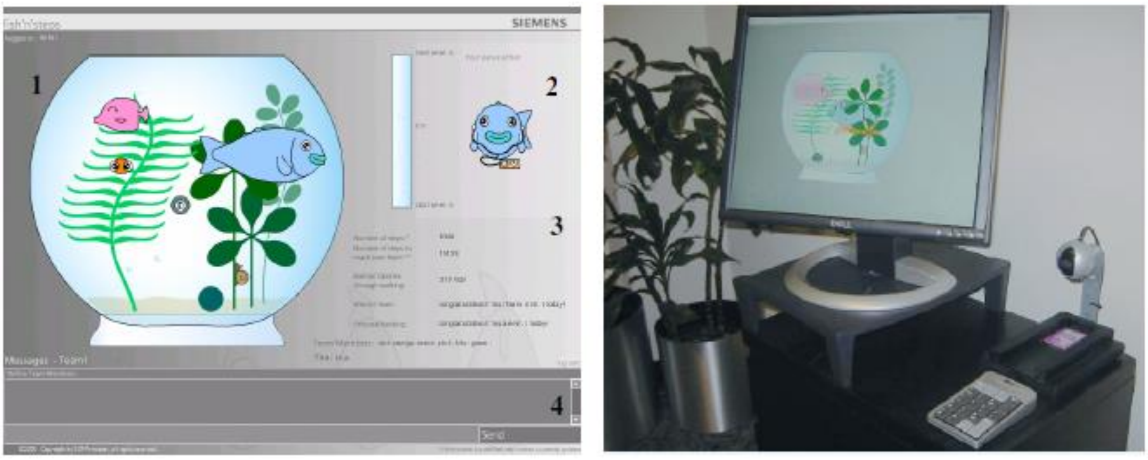

Figure 6 - Fish’n’Steps [34] system components, which include: 1) Fish tank – the fish tank contains the virtual pets belong to the participant and his/her team members, 2) Virtual Pet – the participant’s own fish in a frontal view on the right side next to the fish tank, 3) Calculations and feedback – improvement, burned calories, progress bar, personal and team ranking, etc., 4) Chat windows for communicating with team members.

2.3.1.2. Presentation of Self in Everyday Life

Goffman built a theory called Presentation of Self in Everyday Life [37], which is about people trying to make a good impression to others. The author describes this theory as someone performing at a stage, by also comparing the audience on that stage to those who observe the “actor’s” performance. For example, the actor can be used to refer to a person who is using a social network, and the audience as the people who follow him (i.e. his friends/followers on that social network).

Overall, people always try to show their best side to others. This theory has been widely used, given the existence of social networks, which are the best example within this theory. Nowadays, almost all activity trackers have social features, such as sharing users’ records and achievements. Normally, people would not want to share their negative achievements, so, systems shall allow users to have their own “backstage”. However, if this backstage strategy is not used, users may not like having their negative records showing up to everyone, and this may even lead to them abandoning the system.

This factor is well tackled at UbiFit Garden [2], which is a mobile application, developed on a mobile phone that already had an accelerometer, so, running and walking were already able to be detected within the phone, unlike what happened with Houston and Fish’n’Steps. But its best feature was quite similar to the one in Fish’n’Steps (however, the fact that all of this happened on the phone made it look much better): it changed the phone wallpaper (Figure 7) according to the user’s physical activity. Therefore, if the phone detected activity, flowers would start to grow and butterflies would also start to appear on the wallpaper, but if no activity was detected, the wallpaper would consist on an empty garden, which does not punish users (the sky would still be blue and the grass would still be green and healthy).

Figure 7 - UbiFit Garden's [2] wallpaper example on a phone.

The theory is well reflected on this system, since the wallpaper reflects the user's behaviour, which may be seen by other people. However, this is not as likely to happen as in social networks, which have an even bigger importance here. As already stated, most activity trackers give users the ability to share their achievements on social networks. For example, Endomondo Sports Tracker [38] (Figure 8) is a mobile application that tracks a wide range of sports, from climbing to playing football, or even just walking.

Figure 8 - Endomondo Sports Tracker [38], during a running activity.

Like many other activity trackers, Endomondo provides users with the ability to share their activities. For example, if the user has been playing cricket, he may want to share it with his friends. However, if his friends have been running long distances, and if he ran a lot less than them, he may decide not to share that run, leaving it at his “backstage”.

2.3.1.3. Transtheoretical Model of Behaviour Change

The Transtheoretical Model (TTM) of Behaviour Change [39] is a model that describes people’s motivation towards change. It argues that different stages occur in behaviour change, each requiring a different intervention strategy. Those stages are:

1. **Precontemplation**: no intention to take action within the next 6 months. Systems that target people at this stage should focus on educating, since those people are not well informed about the consequences of their behaviour;
2. **Contemplation**: intends to take action within the next 6 months. At this stage, systems should try to overcome these people’s barriers, and reward them when they have the correct behaviour;
3. **Preparation**: intends to take action within the next 30 days and has taken some behavioural steps in this direction. In preparation, systems should be even more focused on rewarding people for their good behaviour;
4. **Action**: changed overt behaviour for less than 6 months. Systems here should focus on tracking people’s progress, to help them maintain consistency;
5. **Maintenance**: changed overt behaviour for more than 6 months. In maintenance, systems should try to find strategies to solve each person’s previous problems, and keeping them motivated, since people might still suffer a relapse;
6. **Termination**: no temptation to relapse and 100% confidence.

Activity trackers should be available to be used by any person in any of these stages. Therefore, these systems have to be designed for every stage, with the same focus for each one. People that do not have an intention to take action will have to be informed about the consequences of their behaviour, as well as people who have already changed their behaviour and have no temptation to relapse have to be motivated to keep going.

Shakra [40] was an activity tracker in the form of a mobile application, which, like UbiFit Garden, did not need additional equipment to sense users’ activities, doing it without direct manual input. However, the activities are not tracked through the use of an accelerometer, unlike UbiFit Garden. Instead, it senses the activities through the fluctuation in GSM signal strength and changes to the IDs of detected cells. The application shows the user’s current activity – stationary, walking, or driving (which includes travelling in a car, bus or train) -, and also the minutes of activity per day, with a historical view through the past week. The user’s current activity is shown through the use of cartoon visualisations, as seen in Figure 9.

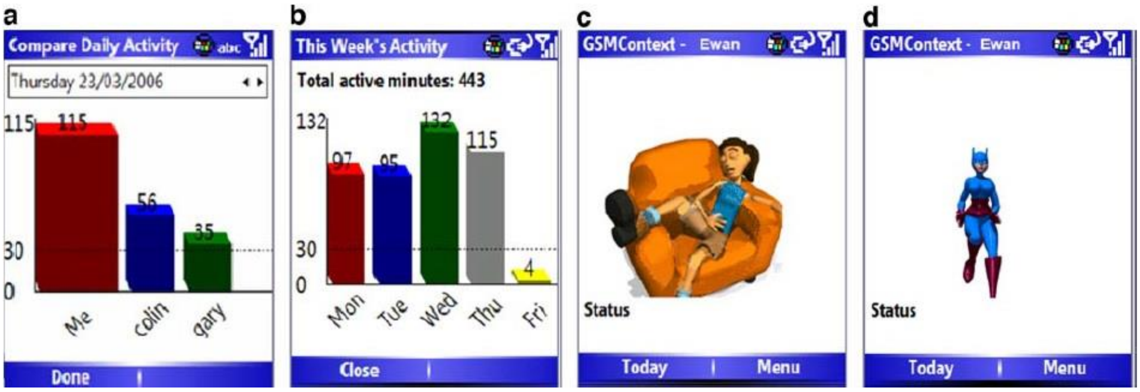

Figure 9 - Shakra's [40] interface; **a** and **b** show screens for examining relative and individual activity levels: compare Daily Activity and This Week's Activity Images; **c** and **d** show two of the screens showing the estimated current activity level: Stationary and Walking.

2.3.1.4. Theory of Cognitive Dissonance

The Theory of Cognitive Dissonance [41] happens when a person believes their attitudes and behaviours are inconsistent. Depending on how important their beliefs or behaviours are, the user will feel motivated to change his behaviour or knowledge, to reduce the importance of that matter to him, or even to avoid information or situations that cause the dissonance. For example:

- **Change behaviour**: start exercising more;
- **Change knowledge**: stop believing that the lack of exercise is bad for his health;
- **Reduce the importance**: start eating healthier;
- **Avoid information or situations that cause the dissonance**: not listening to people's advices on how the lack of exercise is bad for his health.

This theory informs us that, in order to change a person's behaviour (which is what is intended), the implications of not changing it have to be really stressed, in order to pass the message to that person, and to motivate that behaviour change. Comparing this theory with the stages on the Transtheoretical Model of Behaviour Change, we see it is more focused on the Precontemplation stage, since it tries to educate people on having a positive behaviour, so that positive behaviour changes may occur.

UbiFit Garden [2] implements the Theory of Cognitive Dissonance in its design, since it alerts people when "their garden" is not as nice looking as it should be. This motivates people to change their behaviour, starting to walk more than they have, recently.

2.3.1.5. Social Cognitive Theory

The Social Cognitive Theory [42] matters about people enjoying having a positive behaviour (for example, enjoying being healthy), instead of relying on incentives such as rewards. It focuses on increasing users' self-efficacy, by also increasing the likelihood of people creating routines [43].

Therefore, people have to feel good about having a positive behaviour, which, in terms of activity trackers, is about feeling good about exercising.

Shakra [40] was mostly designed using the Social Cognitive Theory, since it only informs users about their activity, not focusing on rewarding them with points or badges. This way, people who change their behaviour, change it by themselves, which is called self-reflectiveness [42].

2.3.1.6. Fogg's Behaviour Model

Fogg's Behaviour Model (FBM) [44] suggests that behaviour change happens when all three factors are present: motivation, ability, and triggers.

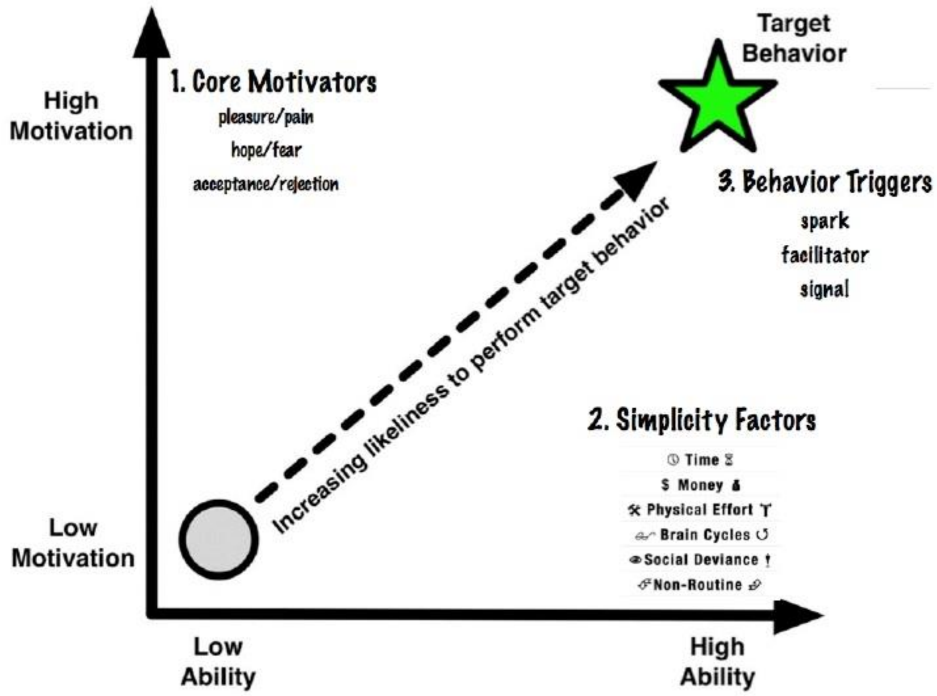

Figure 10 - Fogg's Behaviour Model (FBM) [44].

This model, presented on the previous figure, is a conceptual one, so, units are not present. The star (target behaviour) is placed on the circumstances where behaviour change is highly likely – high motivation and high ability. The trigger is placed close to the target, suggesting that there has to be a trigger for the target behaviour to take place. Subcomponents/factors are also suggested to achieve the desired behaviour. For example, to achieve high motivation, factors such as pleasure, hope and acceptance have to be present. To achieve high ability, time, money and physical effort are normally involved.

This model is present on UbiFit Garden [2], given the use of the wallpaper, which induces pleasure on people, who enjoy having their phone looking good, and their physical effort is not felt as big as if a feature like this one was not present, therefore, people also achieve high ability, leading to behaviour change.

2.3.1.7. Consolvo's Design Strategies for Lifestyle Behaviour Change Technologies

Consolvo's Design Strategies [27] were based on four design goals established by Breakaway [45], an ambient display that encourages people to take breaks more often. These four design goals were [45]:

- **Abstract**: We wanted to use data abstraction, rather than raw sensor data collected from the user, to display information to encourage people to be more active, and to draw attention to the harm that is done to the body by sitting for long stretches of time;
- **Non-intrusive**: We wanted to present data in an non-obtrusive manner and to make it available at all times during the work day without interrupting work;
- **Public**: We wanted to present data in a way that people would willingly display it in a public place like the office. We needed to present the data, which is personal by nature, in a way that is appropriate to be presented in a public environment;
- **Aesthetic**: Since the display would function as a personal object within the office space, it would need to be inquisitive and sustaining interest over time.

These goals were specific to the Breakaway Project, therefore, Consolvo transformed these goals into general design strategies, plus, adding four other [27]:

- **Abstract & Reflective**: Use data abstraction, rather than raw or explicit data collected from the user and any technologies, to display information to encourage the user to reflect on his/her behaviors by showing the user what s/he has done and how those behaviors relate to his/her goal;
- **Unobtrusive**: Present and collect data in an unobtrusive manner, and make it available when and where the user needs it, without unnecessarily interrupting his/her everyday life or calling attention to him/her;
- **Public**: Present and collect the data, which is personal in nature, such that the user is comfortable in the event that others may intentionally or otherwise become aware of it. Because the data needs to be available whenever and wherever the user needs it, it is likely to be something that s/he wears/carries, resides in a shared/common space, or uses while in the presence of others. The technology should not make the user uncomfortable in those situations;
- **Aesthetic**: If the display and any accompanying devices function as a personal object(s) that may be used over time, they need to be inquisitive and sustain interest. The physical and virtual aspects of the technology must be comfortable and attractive to support the user's personal style;
- **Positive**: Use positive reinforcement to encourage change. Reward the user for performing the desired behavior and attaining his/her goal. When the desired behavior is not performed, the user should not receive a reward nor a punishment, but his/her interest should be sustained;
- **Controllable**: When appropriate, permit the user to add to, edit, delete, and otherwise manipulate data so that it reflects the behaviors that s/he deems suitable. The user should be in control of who has access to what aspects of his/her data;
- **Trending/Historical**: Provide reasonable and accessible information about the user's past behaviour as it relates to his/her goals. Historical data should accommodate changes in lifestyle goals over time and provide for the portability of data across devices;

- **Comprehensive**: Account for the range of behaviors that contribute to the user's desired lifestyle; do not artificially limit data collection and representation to the specific behaviors that the technology can sense or monitor.

The best example of a system that uses most of these strategies is certainly the Breakaway Project [45], since these were based on its goals. As already stated, Breakaway is an ambient display that helps people whose jobs require them to be sitting for long periods of time, to take breaks more frequently. Therefore, sensors that detect whether the person is sit on the chair or not, are placed on the chair. After being sit for one hour, the sculpture moves to its first slouching pose. Then, the more time the person remains sit, the sculpture keeps moving to more slouching poses. But after ten minutes absence from the chair, the sculpture moves to its upright position. These positions are reflected on Figure 11.

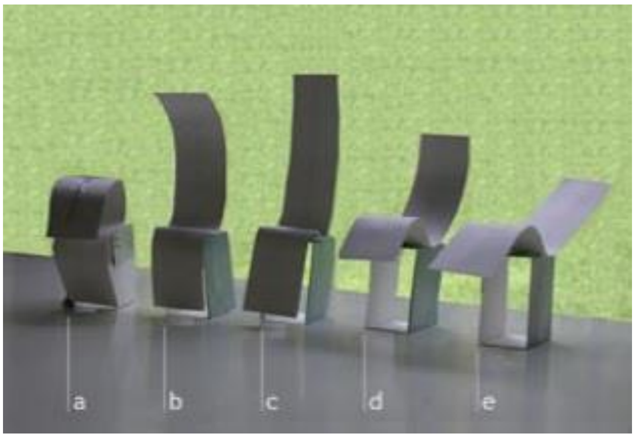

Figure 11 - Breakaway's [45] sculpture positions.

The theories stated above will be a precious help on building a prototype of an activity tracker, by providing some extra knowledge about facts that were already designed and tested with the help of some prototypes and systems. The goal-setting theory will certainly be applied, since these are not already a complement to an activity tracker, but are already part of these systems. User's privacy will be taken into account, given the review made about the presentation of self in everyday life. The stages presented on the Transtheoretical Model of Behaviour Change will be respected, since not every user is at the same level. An activity tracker focused on behaviour change certainly needs to educate its users, so, the Theory of Cognitive Dissonance will be followed. The Social Cognitive Theory will help on trying to motivate people to have healthy and positive behaviours. Fogg's Behaviour Model will support our knowledge on trying to build something with which the user can be proud of. And finally, Consolvo's Design Strategies for Lifestyle Behaviour Change Technologies will provide additional knowledge on, for example, trying to use data abstraction, instead of just informing the user about the sensors' detected information.

3. SYSTEM OVERVIEW

3.1. Motivation

Our first research question is: can we design an activity tracker so that it prolongs users' engagement with it? The application developed (which will be detailed on the next sub-chapters) will try to achieve that goal by providing users with context, and giving feedback on users' behaviours.

3.1.1. Providing users with context

Providing context makes an application more dynamic, motivating its use, and, we believe, consists in one of the ways to avoid users dropping their motivation about using an activity tracker over time. Li et al. also share this vision [28], and, in the case of activity trackers, by tracking the location, for example, we believe that people can have a better view of the places where they exercise the most.

By taking the information above into account, users' visited locations (Figure 12) will be added to the basic information already present on activity trackers, like the distance walked, goal achievement status, etc. This will turn the system into a multi-faceted one (suggested by Li's model [32] as having a greater impact on users), which will, in other words, retrieve more than one type of data from the user's behaviour.

Figure 12 - Using context as a way to show where users are active, and also as a way to log users' days.

By providing users with a way to view where they have been, together with how active they are at each place, we believe that this will lead to a better understanding of their activity lifestyle around the places they have visited, and also about their life in general. This can be seen as a way to track physical activity, and also as a lifelogging application, which adds a lot more information to the physical activity detected.

Following Consolvo's Design Strategies for Lifestyle Behaviour Change Technologies [27], this feature reflects the strategy "Abstract & Reflective": abstract because instead of displaying the latitude and longitude to the user (which is what is retrieved – raw data), that latitude and longitude is used to display the user where he is (locality, city or country), and then the user is able to exactly select where he is, by choosing from a range of Foursquare venues near him; and reflective because it allows users to review which places did they visit in a specific day, and also understand at which places they have been more active/less sedentary.

Moves [22] has been successful in using context, by also allowing users to choose from a range of Foursquare venues near them – illustrated on the next figure.

Figure 13 - Moves' approach to display context – using Foursquare venues.

However, Moves' approach has a small, but, from what we believe, important difference: it does not tell users how active/sedentary they are at different locations. By using colours, we can give more feedback to users, which will be discussed on the next sub-chapter.

3.1.2. Giving feedback on users' behaviours

Users' behaviours will be analysed, and feedback will be given, in a way to motivate behaviour change (by improving it), or trying to keep users motivated when they are performing well.

The discussion on the previous chapter consisted on informing users about how active/sedentary they are at a given location. Moves' approach does not tackle this very important factor, given the fact that obesity seems to be growing in parallel to sedentarism [10]. This is important because activity trackers have the goal to tackle obesity, and by not tackling sedentarism, they are losing "one branch of the tree" of obesity's leading behaviours.

The small row shown in Figure 12 (and also given the size of a smartphone's screen) cannot have more information than it already has. But this problem was tackled with the use of colours, not crowding the smartphone screen with information. The colours used, colour codes and other information will be discussed on the next chapters.

Another type of feedback that will be given will be by using messages (example shown in Figure 14). These messages will help users understand their behaviours, and some will also suggest changes that can be made, as a way to improve their behaviours.

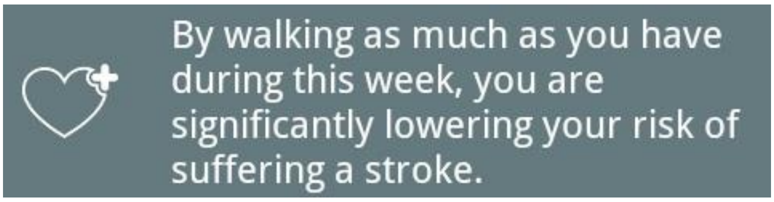

Figure 14 - Example of a message that helps users understand their behaviours. In this case, as noted by the message, the user has been active.

Other approaches have been taken into showing messages to users, such as Health Mashup [46], which collects a wide range of health and wellness data. When correlations are found within the data, messages are presented to the user, which explain these correlations in an everyday language. For example: "You walk 80% further on weekends vs. weekdays (1500 vs. 8300 steps)" [46].

Jawbone Up [20] also presents textual feedback, trying to make more sense of the data that is gathered from the user. For example: "You got from 500,000 steps to 1 Million steps in 56 days averaging 9,259 steps per day along the way. (…)" [20].

Houston [18] used simple textual messages, informing the user about how many steps did he miss until his daily goal, while entering his step count. A congratulations message was also shown when the goal was met.

The main advantages of this type of feedback [47] are:

- **Providing users with information that would not have been discovered**: machine learning algorithms, or even just algorithms that check correlations have the power to detect correlations and patterns that would be difficult to spot in the point of view of a user. This type of feedback allows applications to provide user-friendly information to users about these patterns, and also the possibility of providing suggestions for behaviour change;
- **Overcome the problem of self-monitoring to users with low-numeracy**: manual self-monitoring sometimes requires users to do some calculations and involves a lot of work, and applications which have this ability of providing feedback from users patterns are a great help, since users do not have to do any calculations or have any work with gathering or integrating multiple sources of data;
- **Make changes in the detected activity more salient**: increases or decreases in activity within a day or a week are not always spotted by users, and messages have the power to provide this information, by warning the user that he is getting behind, or even congratulating him if he is doing better.

The presentation of feedback as textual messages is relatively recent, so, limitations and disadvantages are not yet well known. Consolvo et al. [47] mention framing, frequency, length and how uncertainty is presented as properties that may affect the effectiveness of textual feedback.

3.2. Description of WalkNRide

WalkNRide (illustrated in Figure 15) is a mobile application developed for Android, as an activity tracking application, with a focus on trying to encourage users to walk more and sit for less time, by having a personal and detailed approach. It tracks users' everyday activities, including:

- Idle;
- Walking;
- In a vehicle (represented by car or bus).

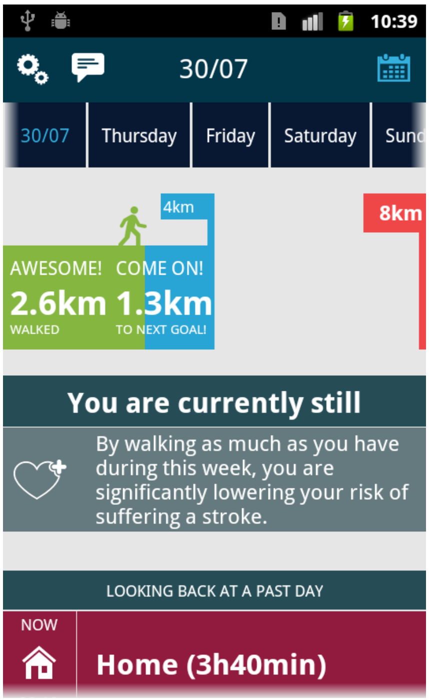

Figure 15 – An example of WalkNRide's interface.

Each activity is represented by a row, with the activities within a location being always filled with red, orange or green. These colours tell the user how sedentary he is being at the moment, at that given place, and they change whether the user has been walking (which can be subtended as a break) on the last hour or not. These walking activities, if inside that same location, are not displayed as a separate row, but are hidden "inside" the location/idle activity row, being part of that same row. The name of each place is picked from the Foursquare venues existent nearby, with the exception of "Home" and "Work", which are there by default from WalkNRide.

The application is also powered by a (software) pedometer, which is a precious help to tell the user how much he has walked. The user's covered distance is calculated taking into account his genre, height, and of course the steps he took. "In vehicle" distances were not as straightforward to calculate as the walking ones, since the accelerometer would not give us all the information we needed, so, the distance is calculated taking into account the user's previous and next location, and also how much he walked between those two locations (which is subtracted from the total distance between those locations).

The upper part of the application allows users to navigate to previous days, for the user to acknowledge how he did on each day. Below the date navigation, we have the user's goal achievement status, which, as stated on the literature review [23], is another factor that influences individuals' physical activity. This is a goal that can be defined every single day, and, for each day, it is divided into 4 sub-goals, which we also believe helps users stay motivated.

A very personal feature that was introduced were the messages. On the middle of the screen, there are always messages to present to the user (with a maximum of 3 at each time – one for each category, which will be explained later), taking into account his own data – activities, goal achievement status, etc. Added to this, each activity also has its own messages, which are accessible by swipe gestures. The 3 categories that were mentioned are:

- Facts;
- Low-level feedback;
- High-level feedback.

The facts are simple messages that advise the user, but do not take his data into account; low-level feedback messages use the user's data, and provide him with an advice, while high-level feedback messages provide him with a curiosity, also taking into account his data.

WalkNRide does not have any traditional way of sharing data, but it still has a social focus, which is believed to be developed in an innovative way. The messages provide users with data from other users, both in a broader, and also in a direct way. The broader way is when the application provides users with messages that compare the user's locality (or city, or even country), with other users' locations. For example: it can compare how much people from a user's city walk, with people from the other user's city. The direct way happens when, for example, the user has been to a place, and it tells the user that he is the second most active person at that place, just behind "John". We believe this introduces an interesting way of competing with others, both knowing, or not knowing that person in question.

3.3. Feedback strategies

3.3.1. Goal completion

This strategy, as already stated, is already part of all activity trackers, given its importance [23]. Therefore, it had to be implemented in WalkNRide. An example follows in Figure 16.

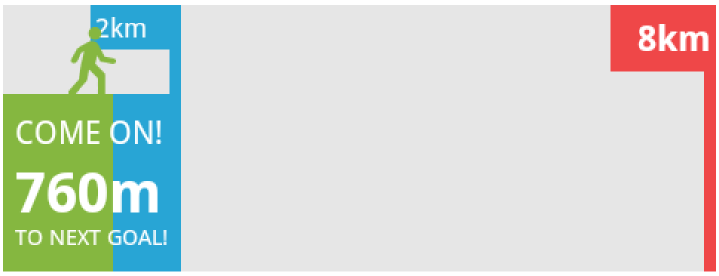

Figure 16 - Goal completion in WalkNRide.

The design of this goal completion was focused on trying to motivate users to reach it, obviously, but it did not only consist on a single goal. Our strategy to motivate users was to divide their goal into 4 "mini goals". On this example, the user's goal is 8km and he has walked a bit more than 1 km. By dividing the 8km into 4 sub-goals, we know that we will have the sub-goals 2km, 4km, 6km and 8km (which is the only one that was defined by the user: the final goal). This way, we can motivate users to reach their sub-goals, so that they can reach their final goal with less effort. This can also be seen as a strategy of divide and conquer.

The user's goal is set on the settings screen (Figure 17), and he can define whatever goal he wants, and still have this strategy remaining the same, by dividing the goal into 4 sub-goals.

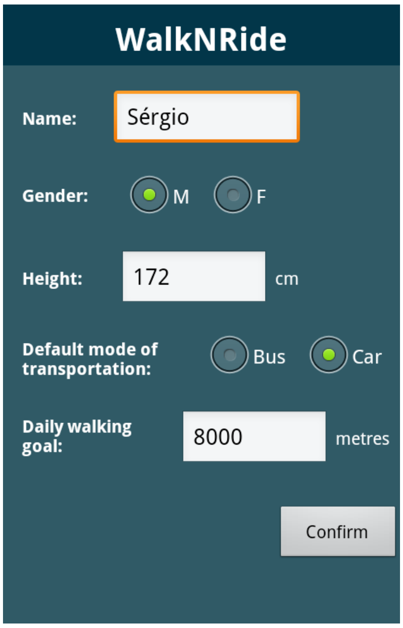

Figure 17 - Settings screen, where the user can set his daily goal, together with other settings.

3.3.2. Messages

The feedback messages were built with the primary goals of motivating a positive behaviour change in users and prolonging their usage of WalkNRide. As a secondary goal, feedback messages would provide users with some information about their own day-to-day behaviours, as a way to reach self-knowledge.

There is a total of 91 distinct textual feedback messages. Of these, 28 (31%) are shown on the "Idle" activity (within a location), 22 (24%) belong to the "Walking" activity, 15 (16%) to the "In a vehicle" activities, and 26 (29%) exclusively to the messages shown within the application itself (52 if we account for repetitions) – not referring to any activity in particular -, which we called "just-in-time", since most of them are in a form of advice given to the user at the time that he can listen to that advice and take an action.

The messages were categorised using a traditional affinity diagram technique. Overall, as already stated, 3 groups were identified:

- **Facts**: these are composed by factual information related to each category and presented to users independently of their performance/use of the application, i.e. they are not data-driven (e.g. "*Simple movements such as fidgeting, which includes knee shaking or pen tapping can burn up to 3,600 calories per day.*");
- **Low-level feedback**: these provide explicit recommendations about how to change or improve specific behaviours based on users' performance (e.g. "*You have been sitting for 45 minutes, try taking breaks every 30 minutes.*");
- **High-level feedback**: these portray users' behaviours and trends, however, they do not provide additional suggestions based on this information (e.g. "*This week you walked 2000 meters.*").

Two researchers independently mapped all messages into the three previous categories (the summary of this categorisation can be seen in Table 1). Iterator agreement was almost perfect (Cohen's K=0.84). Cases of disagreement were resolved jointly by both researchers. Results of this categorisation can be found in Appendix A.

	Facts	Low-level	High-level	TOTAL
Idle	10	8	10	28
Walking	12	5	5	22
In a vehicle	7	4	4	15
Just in time (exclusive)	0	13	13	26
Just in time (total)	17	18	17	52

Table 1 – summary of messages categorisation.

At each interface responsible to show the messages – both at the "just-in-time" and at the level of each activity – a maximum of three messages are displayed, one for each category. If there are not messages to be displayed in one of the categories (for example when the user is just starting to use the application, there is not any data to be analysed), only the messages applicable to the other two categories are showed. At least one message is always displayed, which belongs to the facts, since these do not take into account users' data, and can be shown even if the user is just starting to use WalkNRide. These messages can be accessed through swipes to the left or right.

The idea of having these feedback messages as a way to prolong the usage of WalkNRide was to always have different messages popping up to the user. This way, users would not always be seeing the same messages, which would, in theory, make them always want to see new messages. This was achieved by showing the messages that the user had seen less times (or had not seen at all), but still following the strategy of showing a message for each category. This could even be improved if different messages could be created within the web service (detailed on chapter 3.6), and shown on each user's application, but this strategy was not followed.

As already stated, these messages were also built to help bring positive behaviour changes to users, and this was achieved through each message content. For example, WalkNRide has access to users' calls, and, by having that information, together with the user's activity during each call, we could build a message that would congratulate the user if he had been walking during his last call, or, giving him the advice to try and walk while talking on the phone if he had not been (Figure 18) – this, we believe, would motivate a positive behaviour change to users, since this is normally a small change to a person's behaviour, and can end up being a very healthy one, especially on long calls.

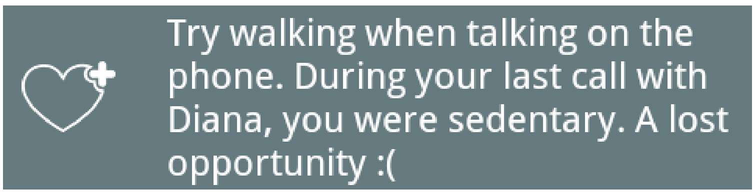

Figure 18 - Message that tries to motivate users to walk while talking on the phone.

WalkNRide's social feature – which is achieved through these messages – was also believed to motivate positive behaviour changes, since it compares different localities, cities and countries, as well as different people. There was the assumption that if we compare, for example, the activity in the user's locality with the activity in another locality (where WalkNRide is present with at least one user), each of these users will try to make their locality the leader on the ranking. The same was believed to happen when comparing different people: if the user is within, for example, a university, and if there is another WalkNRide user in that same university (both would have to have "checked-in" there before, but do not have to be there at the same time), we believed that, by comparing these two people's activity, just by informing each one the other's nickname (which is defined by each user), even if they do not know each other, this would start a competition between them, motivating a positive behaviour change in each one of them. And the more the people within a given venue, the better the competition would get, since each user's activity would be ranked, and compared with the person on the position below or above on the ranking.

It should also be noted that these messages respect users at different stages (as seen on the Transtheoretical Model of Behaviour Change [39]), by trying to motivate behaviour change, and also by motivating those who have changed their behaviour (Figure 19).

Figure 19 – Congratulating a user about his behaviour. In this case, at a given place, where he was active.

3.3.2.1. Just-in-time messages

These just-in-time messages were initially thought as being used as "just-in-time recommendations", which is the purpose of the name. These just-in-time recommendations (an example can be seen in Figure 20), as the name suggests, would help users at the time they see the message, so, related to their current behaviour and activity. They were believed as being really important to the application, given the importance of immediate feedback. An example of this would be a message telling the user to take a break, since he has been sitting for too long. But general messages, not related to any activity in particular were also included in this part of the application.

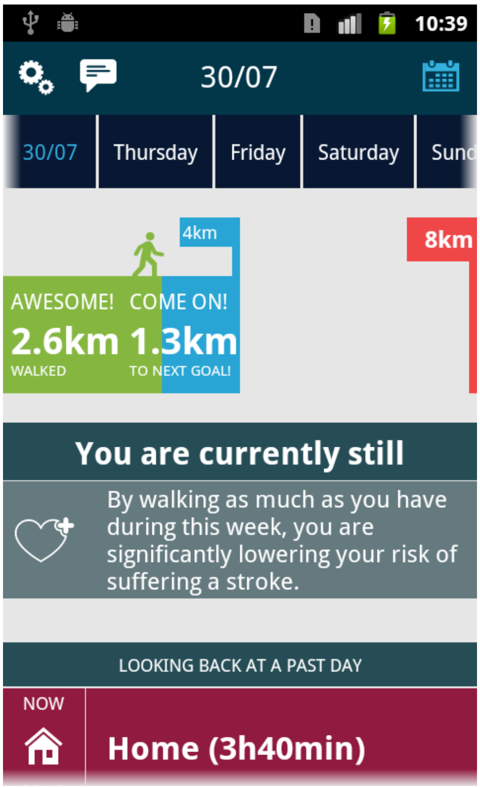

Figure 20 - An example of the just-in-time messages interface, situated on the centre of the screen. In this case, the message is informing the user about his recent behaviours.

3.3.3. Activity ordering

The ordering of the activity rows was designed to be in a descendant way, instead of ascendant, in terms of time. It was decided to be designed in this way since the focus is on the current activity (the last one performed), and not the one on the beginning of the day. If an ascendant order was followed, users would always see the first activity of the day on the beginning of the list, which would not bring anything new, and several application consultations would always show the same activities – starting from the beginning of the day -, forcing the user to scroll down the list of activities just to check his last activity/activities.

By choosing to display the activities in a descendant order, the user is always aware of his most recent activity (as shown in Figure 21), and the activities before that one are easily accessible, without needing to scroll through the whole list. This way, we believe that the activities are ordered from the most important (the current one), to the least important (how did the day start).

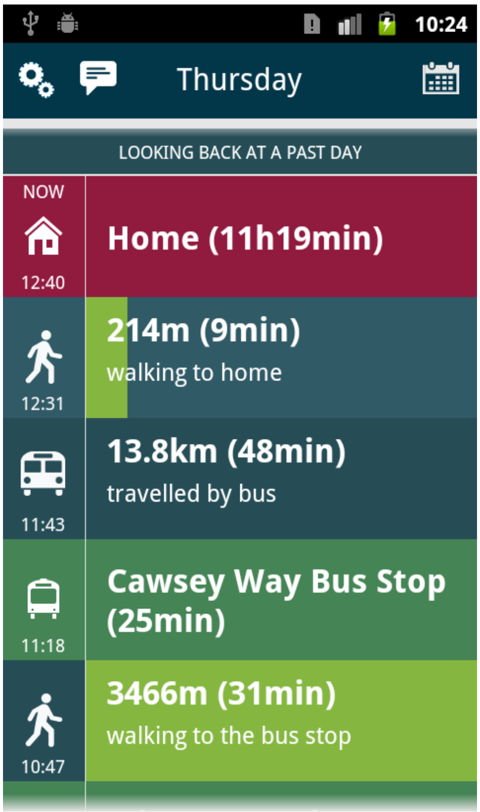

Figure 21 - Example of the descendant order on the activities list, ordered by the starting time of each activity.

3.3.4. Colours on locations

Each activity row within a location (walking or idle) is not represented separately, but instead, is treated as being part of that same location, therefore, only one row represents all those activities. Besides helping with context, it prevents the user from seeing a lot of activities within the same location, which we believe only makes sense if together in one row. This is possible since the application recognises walking activities inside a location, which happens if the user's phone is always connected to the same Wi-Fi hotspot, or if he is within 100 metres of that location (no matter how the location is gathered – GPS, Wi-Fi or by using mobile data). The colours used were red, orange and green, and they change whether the user has been taking breaks or not. For example: if the user is stopped at a place, for more than 1 hour, the row will be red (Figure 22). However, if he starts to walk, the row turns into green, telling him that he is doing great, since he is taking a break (Figure 19). But after he is stopped again for more than half an hour, the row turns orange, before going red again, after 1 hour idle. We think that by using these colour codes, the user is aware of the places he is most sedentary at, so, if he wants to walk, why not go to the shopping centre, where he always has a green row? Again, this strategy was used to promote a positive behaviour change.

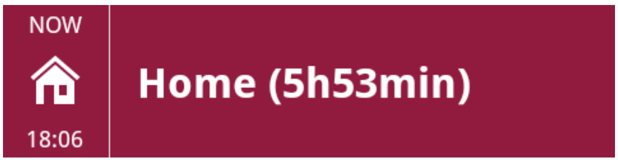

Figure 22 - User's sedentary behaviour at a location, which happens to be at home.

3.3.5. Current activity inference

It was also decided to include on the app a small row with textual feedback about the user's current detected activity (Figure 23). For example, "You are currently walking". This supports seamfulness and informs the user about the correctness of the activity inference.

Figure 23 - Activity inference, which is displayed on the centre of the screen.

3.4. Activity detection algorithm

An API and an algorithm were used to detect users' activities:

- An activity detection API, developed by Google, for Android [48, 49];
- An algorithm included in an open source pedometer application for Android [50];

The activity detection API sends updates about the current activity to WalkNRide (around every 30 seconds), and the information provided is a list of the most probable activities, taking into account the patterns of movement on the accelerometer. This list not only contains the types of activities themselves, but also the confidence that that activity is the correct one. Therefore, the most probable activity is easily gathered, by going through the list and selecting the one that has a greater confidence. In this case, only most probable activities with confidence higher than 50% are considered.

Each activity row was created with the feedback from the activity detection API. But there was a problem: too many "Idle" activities were being detected. For example, when walking through stores on the street, if the user would sometimes stop just to take a look at the storefronts, a lot of "Idle" activities were created, as well as "Walking", since the walk had been interrupted, and then started again. Therefore, it was decided that "Idle" activities were only going to be created as long as the user had been stopped for 10 minutes, with consecutive "Idle" activities detections. This way, the daily lists of activities were drastically shortened, and were now more meaningful to the user.

Since we had access to a pedometer, running in parallel, and also because the activity detection was not immediate, walking activities were not always detected, if performed by just a few seconds, or just a few steps. Therefore, we tried using the pedometer to quicker detect walking activities. It consisted on detecting 10 steps in less than 10 seconds, and if this was achieved, a walking row was created. At first, it was seen as a great improvement, since walking activities were now detected much faster. But we then realised it was prone to errors, such as when using a phone with a very sensitive accelerometer, and being on a sloppy road, causing the accelerometer to move a lot, and the algorithm to detect inexistent steps. Therefore, the activity detection algorithm was kept as the primary one, as it was on the beginning.

After using the application for some time, an issue was detected. When using an elevator, the algorithm happened to detect an "In vehicle" activity. Therefore, the algorithm used to create

an “Idle” row was used for this problem as well (but not the time variable), causing “In vehicle” activities to be detected within 1 minute of consecutive “In vehicle” detections. This also improved vehicle detections, lowering the case of “false alarms”.

But then, when going to, for example, a shopping centre, it is expected that people walk a lot, and not to be stopped for 10 minutes consecutively, so, only walking activities would be detected, even if the user had been there for a long time. The solution was to rely not only on the activity detection API, but also on the location capabilities of the phone. Therefore, when the user spent 10 minutes (purposely similar to detecting “Idle” activities) within 100 metres, or if always connected to the same Wi-Fi hotspot, an “Idle” activity would be created, with his current location. This allowed locations like shopping centres or other places where we do not usually stop, but stay there for some time, to be detected as a location, not only relying on the fact that the user will be stopped for 10 minutes at that given place.

However, the algorithm had to be dynamic, to fit bigger spaces like airports as well, and those 100 metres were not flexible or dynamic, and there was not another way to detect the size of certain spaces. Therefore, we gave that task to the user: if he spent some time in a part of the airport, but then walked for more than 100 metres away from that place (but still in the airport), the location would be detected as another one. But if the user repeated the process of registering that location as the airport as well, the range of detected places as being the airport would increase, accepting locations within 100 metres of his first location, and also within 100 metres of his second location. This, we believe, was a dynamic way of tackling this problem, giving the user the chance to correct his location.

The algorithm was finished, but there was still another issue: the battery usage. The application was draining the phones’ batteries, and the solution was simple: not to run the 2 algorithms in parallel. The pedometer was not being used, but was still running in parallel, so, we made the decision to only start it when a walking activity was being detected, so that information about steps taken would be retrieved from it.

3.5. Prototyping

Initially, the application would also help users save money with their trips, so, if a trip by car was chosen, instead of walking or going by public transportation, the user would not save money, while if the reverse happened, there was a money saving algorithm which allowed the user to save money on his everyday trips. This would also account into a daily goal (daily savings goal), and it was another focus of the application. First designs (Figure 24) were rather simplistic, but already had the main ideas for the application: feedback and just-in-time recommendations (messages), goal achievement (both for walked distance and also for money saving), tracking of everyday activities (already with location tracking, and also the goal achievement within each activity), day navigation (being able to check previous days’ information), and it also tracked calories burned (which was integrated as a feedback message on the final version of the application).

Figure 24 - WalkNRide's first version.

The images also show the text "This week", "This month" and "This year", since there was also the idea that the day view ("Today" or previous days – for example: "Thursday"), would show users' goal achievement and activities for that day (what is shown on the first 2 images), and that the other views (week, month and year view), would show messages summarising the days within that week/month/year.

The next iteration already brought the general aesthetics of the final version of the application (Figure 25) – except for some details -, and also maintained the ideas of the previous one, not present on the final version – money saving's goal achievement and week/month/year views.

Figure 25 - Day view on the second version.

However, these week, month and year views were changed, and now there was a custom view (Figure 26), instead of just showing messages summarising those days.

Figure 26 - Month view on walking goal achievement (first image), year view on walking goal achievement (second image), and week view on money saving goal achievement (third image).

It is also worth noting that, as these were previous weeks, months and years, the goal achievement could not be changed, so, instead of having the “Keep it up” blue bar, the remaining distance (and money, in the case of this version) was filled with red, informing the user of how much he missed to reach his goal.

Another factor worth noting is the goal calculation for these views. There was only the possibility to choose the goal (walking and money saving) for each day, therefore, the goal for the year view, for instance, would be the sum of all the goals for each day within that year.

On the day view (Figure 25), the messages were being shown only for the current activity, and instead of having a separate row for those messages, they were being integrated within the row that contained the current activity, making it a bit larger than others. However, a small improvement was made (Figure 27), and the interface for showing the messages was already becoming almost the same (aesthetically) as the one present in the last version of the application.

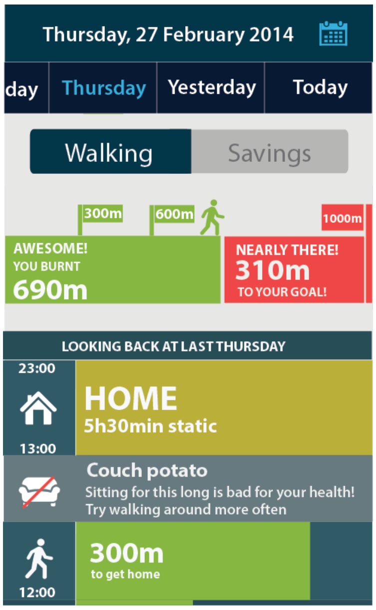

Figure 27 - Message shown as an expansion of an activity.

The next iterations resulted in the final version of the application (Figure 28), with the "just-in-time" messages being placed on the centre of the screen, as well as presenting the user his current activity ("You are currently still"). The interface for showing the messages within each activity (expanding each activity by touching it) remained almost the same, with small improvements such as removing the title, which allowed more space to show the messages, and instead of having an icon for each message, that icon was replaced for an icon in a shape of a heart, together with a plus (+) sign, which allowed users to tell us that they liked the message. Also, the size of the row that contained the current activity remained at the same size as the other rows, with the information on how static the user is being shown through each row's colour.

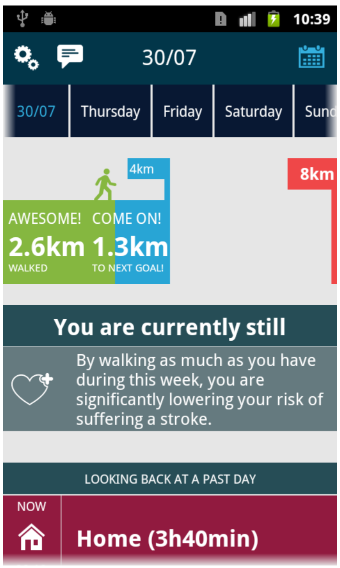

Figure 28 - WalkNRide's user interface.

3.6. Architecture

3.6.1. Mobile application

The mobile application was developed for Google Android, using the Eclipse [51] IDE, being Java the language used for the development.

The next sub-chapters will go into detail about the implementation of WalkNRide – the mobile application.

3.6.1.1. Services

There are two services/processes running in background, which are responsible for the activity recognition, which was already mentioned on the previous section. One of those services is always running in background, and is responsible for detecting which activity is the user undertaking at the moment. The other service is a pedometer, and is not running all the time, being called only when a walking activity is detected – and its function is to count users' steps. These services are also started when the user boots up his phone, leaving no need for users to open the application for it to start detecting his activities.

But one of the challenges with the activity recognition was: how to prevent the application from creating so many activities? If no treatment was done to the activity recognition, each user would have an enormous list of activities for each day. Then, it was decided that for the user to be at a place, he must have consecutive "Still" activity detections within 10 minutes. Another problem was the "In vehicle" detection: elevators and strange movements with the phone would trigger that activity type, so, it was decided that for the user to be in a vehicle, he must have consecutive "In vehicle" activity detections within 1 minute.

The solution for the problem with the change of the day was to set an "alarm" for the midnight of the following day, using a "BroadcastReceiver". At this time, the user's previous day's activities were stored, and a new list of activities was created for the new day, together with the loading of the standard interface (no distance had been walked), and the first activity of the day would be the last one from the previous day.

3.6.1.2. Getting users' location

The strategy used to get the user's location is achieved by launching a location listener when the user is still. If the phone's GPS sensor is turned on, the app tries to get the location via GPS, but if for any reason it cannot get the location (due to being inside a building, for example) for 1 minute, the location listener is re-launched, but with the location being achieved through mobile network or Wi-Fi (if at least one of those is turned on). This is achieved by running a process when the location listener is set to "listen" to the GPS sensor, and that process is used to check if the location is already known, and if it is not, for more than 1 minute, the strategy changes to the one explained above.

After using the application for some days, for most of the times, users will already have registered at least one location (for example, "Home"), so, whenever the user is within 100

metres of a saved location (or if he is connected to an already known Wi-Fi hotspot), the application automatically understands that he is at that place. This way, the user does not have to be always entering that he is at Work, at a café that he goes a lot, etc.

3.6.1.3. Storing data on the device

Users' activities, locations and other data are all stored in each user's device, by using the "SharedPreferences" class, which allows us to store and to return several types of values (String, Integer, Float, etc.). The biggest challenge was to store the user's activities, together will all the information related to it (location, distance walked, time, etc.), since we could not store these within a List. Hence, the solution was to store it in a String, separating each activity with a semicolon (";"), and each attribute of each activity with a comma (",").

The actions were another type of data that was stored. This was again developed taking into account the study, since we wanted to study how users used WalkNRide. These were the actions being recorded:

- Opening the application/Switching on the screen with the application in foreground;
- Closing the application/Switching off the screen with the application in foreground;
- Clicking in icons that lead the user to a different screen;
- Checking previous days;
- Scrolling up/down on a day's activities;
- Opening activities, that lead to showing the messages (the type of message being shown was also stored within the action);
- Swiping through messages (again, the new message being shown was also stored);
- Closing activities;
- Switching from car to bus (and the vice-versa);
- Liking/disliking messages;
- Navigating on the map;
- Scrolling up/down on the Foursquare venues;
- Choosing a Foursquare venue.

All these actions were stored together with the date and time of that occurrence.

3.6.2. Communication with web server

WalkNRide was designed in order to save both users' information (daily activities and other user related information), and also other data related with the users' usage of the application (users' actions, messages seen, etc.) in a database, stored in an online server. All this information is stored within the device, and, when there is an internet connection available, this data is automatically uploaded to the server (Figure 29).

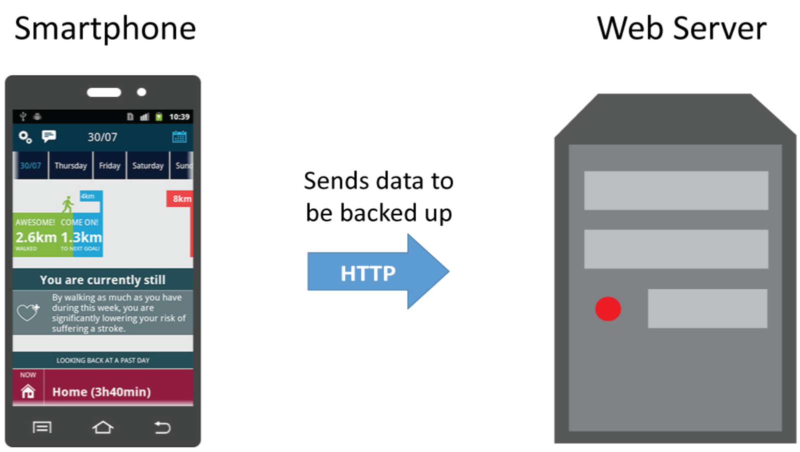

Figure 29 - Abstract Architecture (Backing up data).

However, the communication with the server is not exclusively single-sided, as when a user registers his e-mail within the application (Figure 30), if he was already registered, his data is completely restored to his phone (except if he is doing this on a different phone – the data is not restored because of privacy issues). For the study purposes, even if the user is not already registered, the web server sends information about which version of the application should be activated.

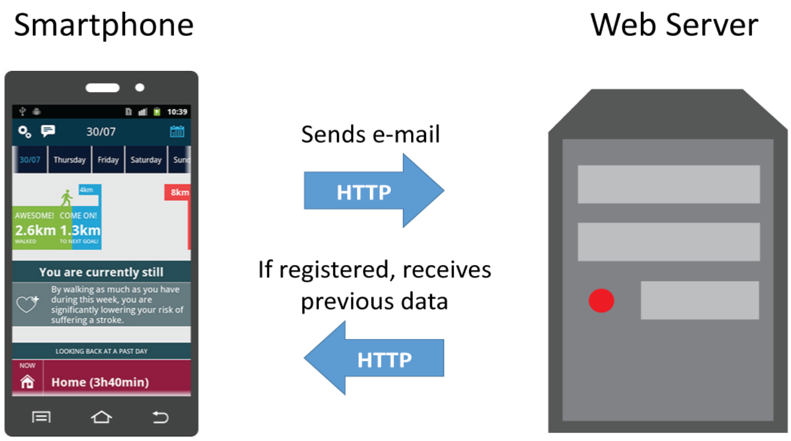

Figure 30 - Abstract Architecture (Registering e-mail).

The application also communicates with the server when displaying messages (Figure 31). For example, messages that compare the user with other users require internet access, as a way to access the database.

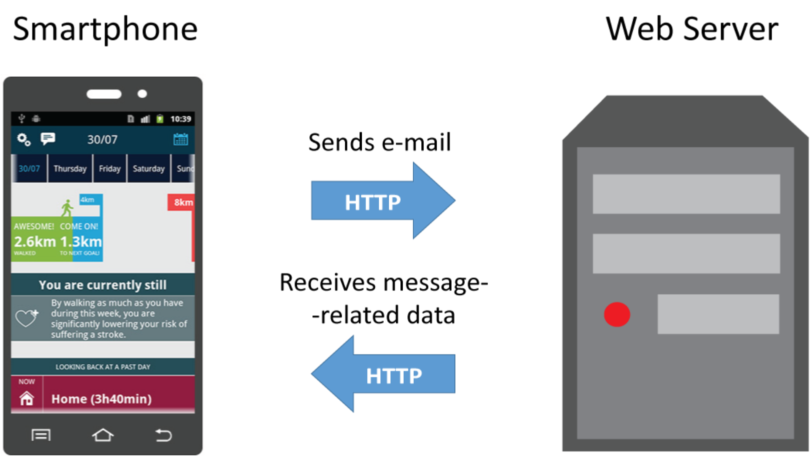

Figure 31 - Abstract Architecture (Asking for message-related data).

3.6.3. Database

The MySQL database present in the Web Server (Figure 32) was designed to save every piece of data recorded from each user, simplifying the process of gathering the data to use in the study.

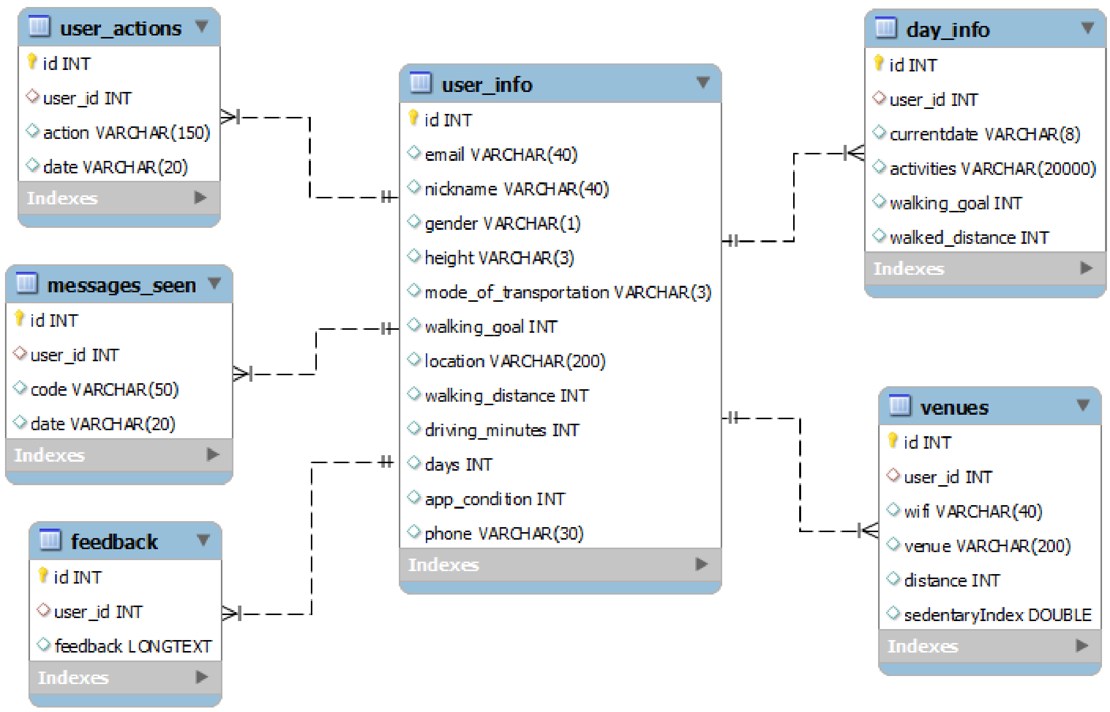

Figure 32 - EER Diagram.

4. FIELD STUDY

4.1. Research questions and method

Our study had two main goals:

1. **Can we prolong users' engagement with an activity tracker?**

In order to achieve our first goal, we split our application into three distinct versions. The first version of the application ("baseline") presented users with a minimalistic interface, containing users' goal completion and their current activity – still, walking, or in a vehicle (Figure 33). The goal of the baseline version was to provide users with an awareness of their physical activity (and respective goal completion) on the fly. The second version of our application ("context"), in addition to what the "baseline" version offered, contextualized users' physical activity by tracking (and showing) their physical activity at (and between) certain venues. The goal of this version was to allow users to look back into their days and identify patterns and opportunities to increase their physical activity. Our third version ("evolving") was the most complete one; in addition to what the "context" version offered, it added messages that analysed users' behaviours and further supported inferences based on their data. The goal of these messages was to support inferences about the impact of one's physical activity, but also to sustain information gratification over the long term, through altering the messages presented, and through this to sustain the perceived novelty among users.

By splitting up the app into three versions, we intended to understand how users would adapt to the features of each version and how this would influence their usage – e.g.: will users walk more, or engage more with the application if it provides context? If so, why?

2. **Understanding users' engagement loops with activity trackers.**

Our hypothesis is that users' engagement with activity trackers is characterised by iterative forms of engagement and disengagement – what we term *engagement loops*. At some points, the activity tracker is more present in a user's mind than others. Our goal was to understand how this takes place. To achieve this, users' actions and all application-related information were tracked and sent to an online server, for further analysis. With this information, we were then able to understand, for example, if there was a formation of habits and routines, and, if so, what triggered those habits. As discussed, the Social Cognitive Theory [42] is concerned about routine formation, therefore, levering on this theory, we had a strong focus on habit formation. Added to this, we had the ability to understand users' engagement with the application, which would provide us with some knowledge about why do people lose interest in activity trackers over time.

Interviews were also conducted with the users at the end of the study, in order to obtain feedback concerning the different versions of the application (namely usage-related questions).

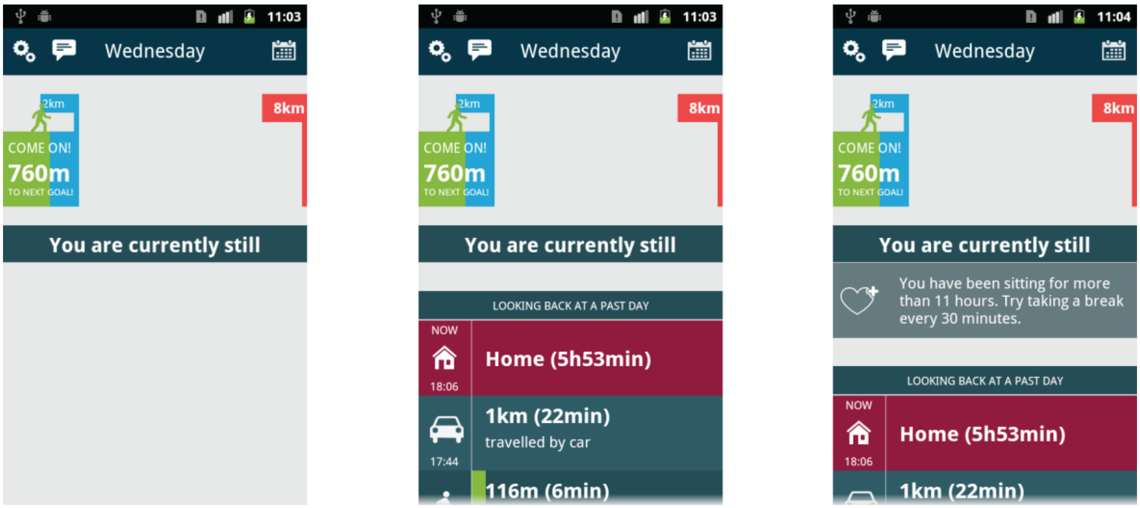

Figure 33 - Comparison between the 3 versions of the application (baseline, context and evolving).

4.1.1. Study design and procedure

Our application was placed on Google Play (play.google.com) and spread out via some forums (forum.pplware.com, forums.androidcentral.com, androidforums.com, among others), Facebook pages and through Reddit, an online social bulletin board system that allows users to share content in the form of links or text posts. We decided not to apply convenience sampling (namely by recruiting friends, relatives or acquaintances) in order to clear out potentially biased results. This is, we wanted the participants' usage of these applications to be influenced by as less external factors as possible (e.g. not using the application as a personal favour, etc.). Additionally, contrary to other authors [34], we did not search for users with a specific level of physical activity or that intended to become fitter.

4.1.2. Participants

We conducted a four-week field study. A total of 58 users installed the application from Google Play (50 male, 8 female). Of these, 19 (33%) were randomly assigned to the first version of the application, 18 (31%) to the second version, and 21 (36%) to the third version. Users freely downloaded the application from Google Play and were provided with no financial incentives. Additionally, users were informed that their data would be logged and used for research purposes. In the following section, the findings within the study are analysed.

4.2. Findings

In general, users used the application for approximately four days (M=4.29, SD=6.46; where M is the mean, and SD the standard deviation), accessing it approximately 6 times per day (M=5.79, SD=6.78), with an average usage duration of 36 seconds per day (M=00:00:36, SD=00:01:03).

4.2.1. Usage sessions among conditions

In order to develop a richer understanding of usage variations across conditions, we collected the time, frequency and duration of users' usage sessions. A single usage session is defined by the moment that the user opens the application from idle or screensaver mode and the next time the phone is idle, locked or the application is closed and is characterized by a certain duration. Then, we analysed how many of these were short interval reward based (SIRB) – one of the indicators of habit formation are occurrences of usage sessions that are rapidly executed (less than 30 seconds), separated from preceding usage sessions by at least 10 minutes and reward-based (e.g. information consumption, social networking, etc.).

Overall, participants in the "evolving" condition used the app for more days (M=5.67, SD=9.65) when compared to the "context" (M=3.89, SD=4.42, U=680.0, p<0.05; where U is the Mann-Whitney U test, and p is the level of significance) and "baseline" conditions (M=3.16, SD=2.57, U=516.0, p<0.01). Furthermore, no participants in the baseline or context condition used the application for the full four-week period of our observation (Figure 34). On the contrary, some participants from the evolving condition (9.6%, N=2, where N is the number of participants) completed at least 4-weeks of usage. Of these, 1 (4.8%) participant was still using the application to the date of our analysis (6 weeks since install).

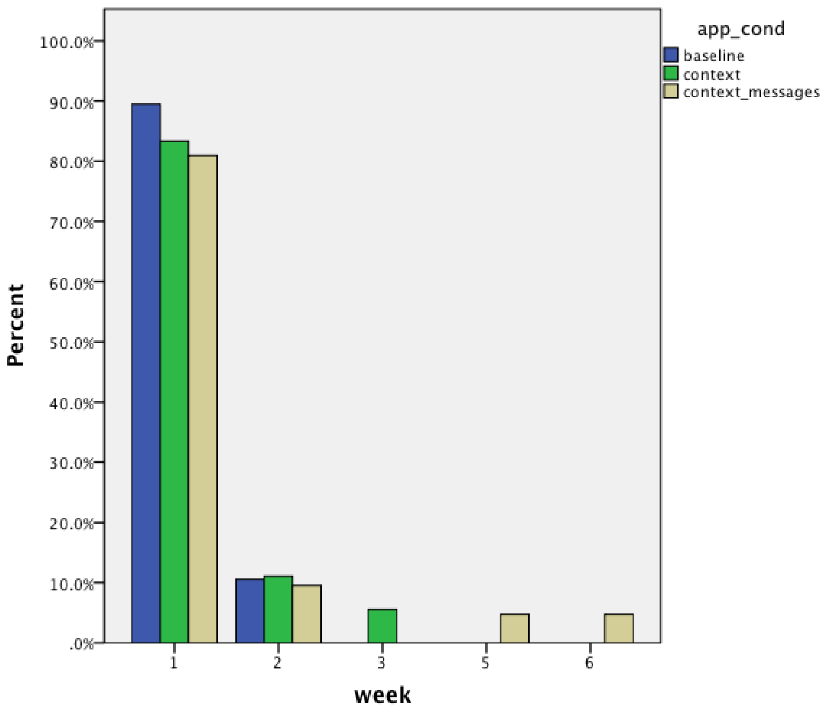

Figure 34 - Number of weeks for which users used the application.

No significant distinctions were found in terms of the average number of daily usage sessions among conditions ($\chi^2(2)=2.76$, $p=0.25$; where $\chi^2(2)$ is the Chi-square test, and p is the level of significance), however session duration was lower in the baseline condition in respect to the context (U=20292.0, p<0.01), and evolving condition (U=32368.5, p<0.05). Additionally, 49% of

the sessions in the baseline condition were defined by short interval reward based sessions (SIRB) in comparison to 28% in the context condition and 41% in the evolving condition.

Furthermore, users would come back to the application more frequently in the context condition when compared to the baseline (U=19163.0, p<0.01) and evolving conditions (U=44286.0, p<0.01). Some of these findings can be further analysed in Table 2.

	Baseline	*Context*	*Evolving*
Days of usage (SD)	3.16 (2.56)	3.89 (4.42)	5.67 (9.95)
Usage sessions per day (SD)	5.06 (5.22)	8.59 (9.79)	6.52 (7.00)
Duration sessions (SD)	00:00:21 (00:00:33)	00:00:30 (00:00:52)	00:00:28 (00:00:39)
SIRB sessions	48.8%	28.2%	40.6%

Table 2 – Mean usage values among conditions.

4.2.2. User engagement over time

Initial interactions were characterized by a higher number of usage sessions, which dropped over time in all conditions (baseline: r=-0.35, n=34, p<0.05, context: r=-0.36, n=31, p<0.05, evolving: r=-0.34, n=66, p<0.01; where r is the correlation coefficient, and p is the level of significance). We found that this was due to two main reasons: 1) Initial engagements were characterized by explorative interactions as compared to a more "focused" set of interactions in prolonged interactions – accesses were higher to check how the application could be useful/check what the app does, and 2) Participants are initially confronted with data that portrays typically invisible behaviours, but lose interest in this information over time. Mostly, participants were interested in checking their physical activity levels and how this fluctuated among visited venues: [P1] *"I used the app to see how much I walk every day",* [P2] *"I would check where I was spending my days"*.

It should also be noted that the usage in the first week is very similar between the context and the evolving conditions. This may have happened because both conditions are similar, with the difference that the evolving condition contains the messages, which probably did not still present users with good inferences, given the small amount of time since users had installed the application. However, on the second week, users with the evolving condition opened the application for some more times than the other conditions, which may be explained through the existence of the messages. More details on users' "application openings" during the study can be observed in Figure 35.

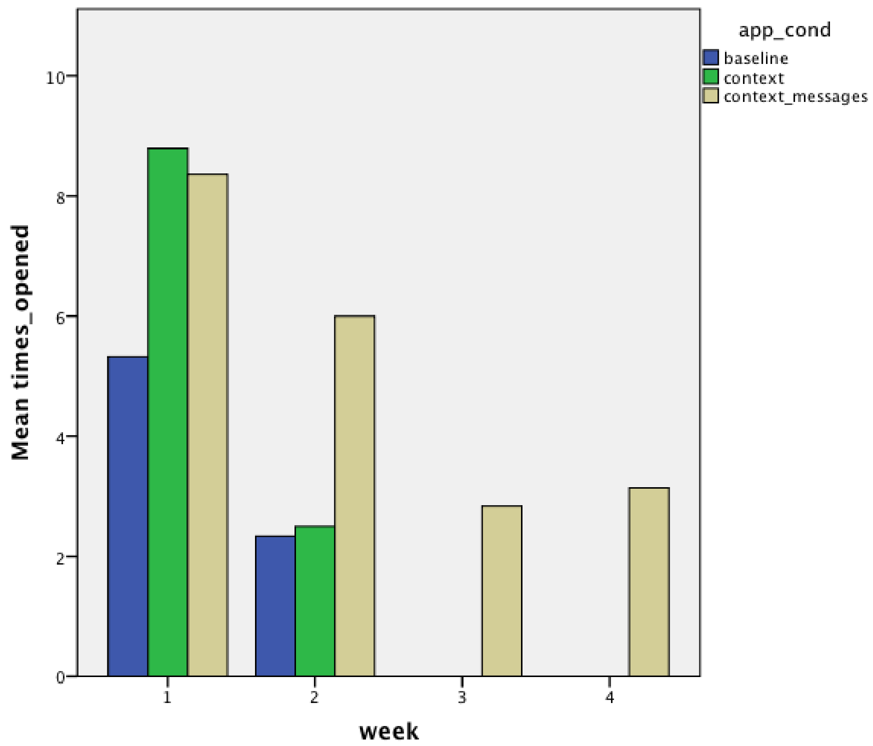

Figure 35 - Average amount of times the application was opened within the 4-week period.

The average duration of engagement was sustained over time (context: r=-0.10, n=277, p=0.08, evolving: r=-0.04, n=431, p=0.41) except in the baseline condition (r=-1.52, n=172, p<0.05). Given the features of the three conditions, we believe that the most plausible cause of this behaviour was due to the lack of information gratification on the baseline condition.

The duration of engagement on the evolving condition on the second week immediately stands out, given the comparison between that condition and the other ones. This may again be explained due to the existence of the messages, which "hold" the user, making him spend more time in the application. The duration of users' engagement can be further analysed in Figure 36.

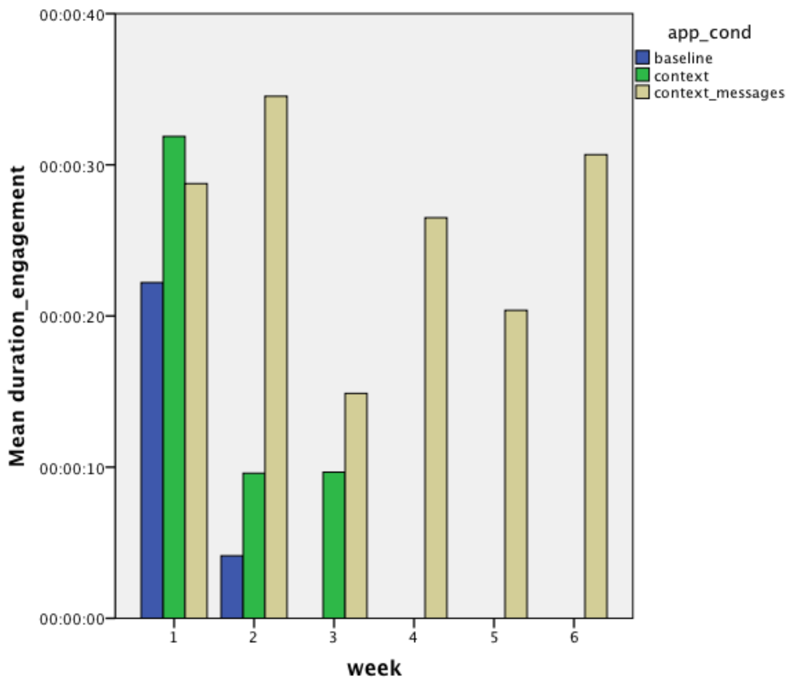

Figure 36 - Mean duration of engagement with the application.

Among the three conditions, the context in which users accessed the application was while stopped in a place. This was mostly visible on the evolving condition, which may be justified by the features present on this condition, which require the user to be at a given place to select a venue from the list of Foursquare venues, and also because messages are logically better to analyse when stopped, instead of when walking. However, we still hoped to see this when in a vehicle (particularly when using public transportation), but it was not the case, at least on the evolving condition. It should also be noted that "commute" includes car and bus activities. The contexts in which users accessed the application can be seen in Figure 37.

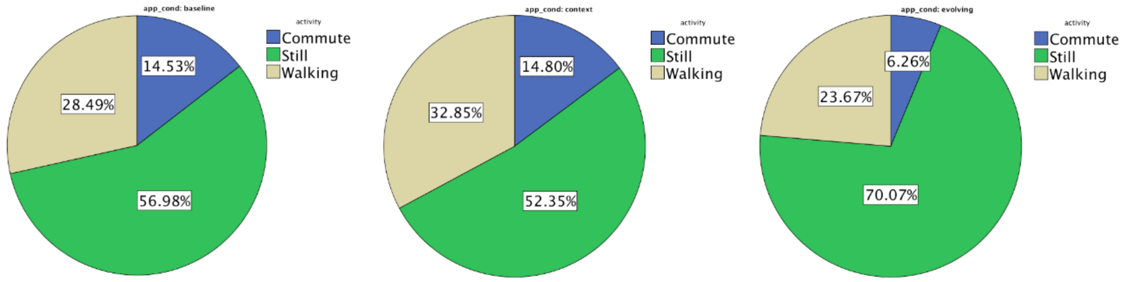

Figure 37 - Contexts (namely current activity) in which users access the application, on the baseline, context and evolving conditions, respectively.

The times of the day in which users accessed the application the most were in the afternoon and in the evening. This was already expected, since the application was focused on recording the users' day. As a result of this, application openings were more expected to happen at the end of the day. However, there were still a lot of accesses in the morning, particularly on the evolving condition, which may be justified by having users introducing their location at the time, or due to users looking at the day before, or even to their morning trip to work/school, looking into factors such as distance walked (majorly on the baseline condition) or activities during trip (context and evolving conditions). The times of the day in which users accessed the application can be observed in Figure 38.

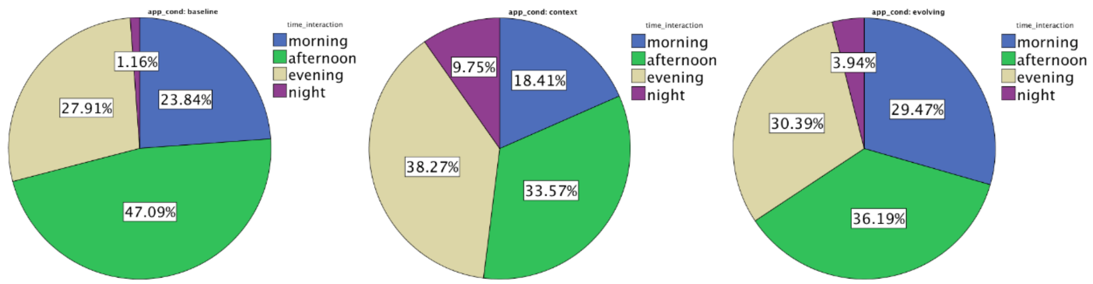

Figure 38 - Time of the day in which users access the application, on the baseline, context and evolving conditions, respectively. Morning (6am – 12pm), afternoon (12pm – 6pm), evening (6pm – 12am) and night (12am – 6am) were the times of the day considered.

4.2.3. Physical activity over time

Further tests revealed no distinctions (Figure 39) between the level of users' physical activity among conditions ($\chi^2(2)=3.42$, $p=0.67$) – even though a small improvement is observable as the number of features increase, by, for example, comparing the context condition with the evolving condition -, or in terms of the percentage of days they underachieved their goal as compared to overachieving (baseline - overachievement: 29.4%, underachievement: 70.6%; context - overachievement: 31.9%, underachievement: 68.1%; evolving - overachievement: 21.2%, underachievement: 78.8%). Additionally, users did not walk more over time in any of our conditions (baseline: r=0.15, n=34, p=0.11, context: r=-0.26, n=31, p=0.22, evolving: r=-0.32, n=66, p=0.52.

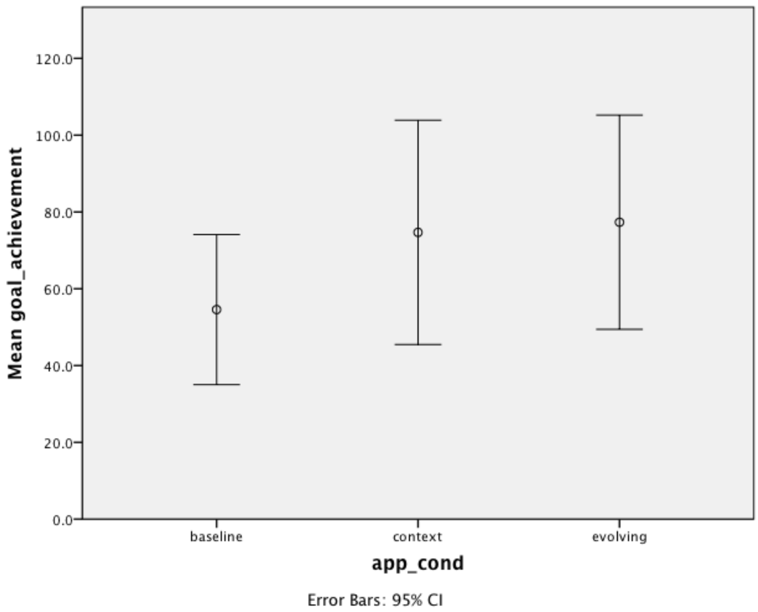

Figure 39 - Percentage of goal achievement among the three different conditions.

Overall, users walked an average of 159 meters per day (SD=77) in our baseline condition, 246 (SD=159) in the context condition and 377 in the evolving condition (SD=104).

4.2.4. Feedback

The average number of new messages discovered per session was 1 (M=0.55, SD=0.67). Discovering new messages made users come back to the application with a higher frequency (r=0.52, n=70, p<0.01), but did not influence the distance achieved by users (r=0.33, n=70, p=0.78).

The average number of messages seen per session was 2 (M=1.6, SD=1.2). There was no relationship between the total number of messages seen in a session and the frequency of coming back to the application (r=-0.35, n=70, p=0.77) or distance achieved (r=-0.69, n=70, p=0.57).

5. DISCUSSION

5.1. Implications for design

1. **People could not think of a goal for themselves.**

At first sight, it may seem that WalkNRide was a failure, given its average days of usage. However, it helped us uncover situations with which people struggled. For example, the fact that people could not think of a goal for themselves was one of the major factors that led people to stop using the application. Thus, most of them would use the default goal provided by the application, which was 1000 metres per day. Therefore, the fact of imposing a goal straight from the beginning may not have been the best choice. We found out that there was a lack of flexibility on adjusting participant's goal accomplishment to their actual performance. Curiously, users were pretty much clueless in terms of goal achievement, with many wondering how much they should walk per day: "[P3] I am not sure what my goal should be. Is 1000 metres enough?".

2. **Applications should be flexible with users' goals.**

Although a recommended walking distance, many users could not adapt to their 1000 metres goal, leading to situations of underachievement, feelings of incompetence and consequently product detachment. One of our main recommendations is that tracking applications should be flexible in terms of goal accomplishment – one idea could be an appropriation to users' daily routines and walking distances, as opposed to strict and inflexible goals.

3. **Contextualising users' information provided them with more awareness.**

We found out that contextualising users' information provided them with a better awareness of the outcomes of their actions and how their daily activities could contribute towards their goal achievement: "[P40] I would look at how much I walked during my day to try to understand how I could achieve my goal (…)".

4. **The application provided users with good insights and inferences.**

In terms of evolving messages, participants praised the fact that the application provided them with insights and inferences, lowering manual burden on data analysis and interpretations that are error prone. As one user stated, "the messages were really interesting (…) It (the app) analysed my behaviour over the last week and helped me understand how sedentary I am".

5. **Participants showed aversion towards recommendations.**

Interestingly, participants portrayed aversion towards messages that provided them recommendations based on their data. As participants stated: "[P23] Is the application acting as my mother? She is the one that typically tells me what I should do", "[P49] Well, I feel like I am losing my autonomy (…) after all, I downloaded the app to get fitter, and not for it to take control".

6. No increase in physical activity over time.

Another fact to be taken into account was the evolution on physical activity over time. Our study did not reveal any pattern that tells us that there was an increase on physical activity over time. One of the reasons was due to the fact that users used the application for an average of 4 days. This is a very small timeframe, given the fact that behaviour change takes time, according to the Transtheoretical Model of Behaviour Change [39]. Moreover, participants were not particularly looking to increase their fitness levels or to lose weight, therefore, this may have also contributed to users leaving the application without trying it for some time.

7. Complaints about battery usage.

People complained about the amount of battery that WalkNRide was draining from their phones. Given this complaint, some features were optimised so that the battery usage would decrease. This change did not lead to any further complaints about battery drainage.

6. CONCLUSION

This work has investigated people's behaviours when using activity trackers. It was focused on understanding why people lose their interest with using activity trackers over time. Therefore, there were two major goals:

1. Can we prolong users' engagement with an activity tracker?
2. Understanding users' engagement loops with activity trackers.

In order to reach these goals, WalkNRide, a physical activity tracker, was developed. It used context as a way to help users understand their daily routines, as well as understanding how was their physical activity at each of the places that they visited during their day. The use of innovative ways to present feedback (such as colour coding users' sedentarism at a given venue) was also believed to contribute to the first goal. In a way to reach the second goal, users' usage of the application was recorded and sent to an online database, giving us an insight about the features that were mostly used, as well as understanding any formation of habits.

We conducted a field study with 58 users and observed their behaviour and application usage throughout the 4-week trial. Three versions of WalkNRide were used, two of them with less features than the third one. These three versions were designed in order for us to understand which features had a greater impact on users' behaviour and use of activity trackers.

Having finished the study, our first goal was partly achieved, since users' usage of the application was not as expected. However, we were able to understand what features were more important to users, giving us a positive insight about our innovative use of context (by tracking users' activity in given locations), and also our innovative forms of feedback, such as the messages. Therefore, we conclude that both context and messages were able to "hold" users in using the application, which can be observed by comparing the results of the three versions. Our second goal was achieved, since we could understand if there was a formation of habits on the three conditions. There was a greater habit formation on the baseline condition, mainly because this version did not demand or support a lot of interaction, with users opening the application just to see how much they had been walking all day (which is typically a fast task – less than 30 seconds -, and does not happen much frequently – more than 10 minutes difference between accesses). A lower number of SIRBs was achieved on the other conditions, given the fact that choosing a venue from Foursquare (both on the context and evolving conditions) and also reading messages (on the evolving condition) was a bit more time consuming than just taking a look at the daily goal and distance walked (on the baseline condition). As a result of this, we can conclude that the habit formation was mostly observed on the baseline condition because of its lack of features, forcing users to create the habit of checking their walked distance and goal achievement throughout their days.

As already discussed, the results achieved on the field study did not go as expected, and possible justifications were also discussed. However, we believe that this thesis is a good contribution to the research field of activity trackers. These are outlined in the remainder of this chapter.

6.1. Contributions

6.1.1. Use of context

The use of context (in this case, the use of locations) was again proved to be a factor that engages users when using activity trackers - and probably also other personal informatics systems. Here, Ian Li's vision [28] was followed, and it was proved that he was correct.

The study reflects this factor by analysing (comparing the three versions) the amount of time that users remained using the application (Figure 34), users' engagement with the application (Figures 35 and 36), and also users' physical activity levels (Figure 39).

6.1.2. Sedentarism tracking

The use of context supported another feature that was the sedentarism tracking. By using colour codes (green for not sedentary, orange for warning users, and red for alerting sedentarism), an innovative way of presenting feedback to the user was achieved. We could not find any other system that tracked users' sedentary behaviour, so, we believe this was a great contribution to the field of activity trackers. Other activity trackers focus on tracking how much we walk (like Moves [22], for example), and not on tracking how many breaks we take when stopped at a given location. Distance walked inside a location was also tackled in WalkNRide, in contrary with other systems, which track users' walked distance without taking into account the context into which the user is involved.

6.1.3. Social features

By using textual feedback (the messages), an innovative way of tackling social features was achieved. Instead of using the traditional ways of sharing data (posting on social media), another way of socialising was approached. People that visited a given place were compared and presented to random users that also visited that place, without harnessing users' privacy. If users chose a nickname, they would be presented to other users with that nickname (which may only be their first name, or something else). For example, if a user is being compared to another, and both have visited Madeira Shopping, by telling one of them that "John" is ahead of him (in terms of sedentarism or walking distance within that venue) by 500 meters, we believe that no privacy is being harnessed. We also believed that by comparing people that do not even need to know each other, provided us with more chances to challenge users by informing them that they are not the person that is ahead on that venue, or that they are the ones ahead, but someone is just behind them, ready to take their place. This is also believed to be a good contribution to not only activity trackers, but also possibly to other types of systems.

6.2. Future work

The work presented within this dissertation can be further extended in several ways. The most obvious extension can consist on the development of new algorithms that can compare users'

data in innovative ways, as well as giving various different insights to users about their behaviours, by using, for example, the textual feedback already present on the application. This may include other feedback rather than textual, such as, for example, the use of charts, as a way to display more information and also to display it in a more visual point of view.

Still in terms of the messages feedback, instead of developing new algorithms, as suggested above, crowdsourcing can be used to generate new types of messages, by combining the intelligence of computing (e.g. knowing for how long a person has been working since his last break), with the intelligence of humans (e.g. taking advantage of co-workers' knowledge of what activities may be more persuasive in order to take a break from work).

Detection of more modes of transport such as cycling (which is already included in the activity detection API used for WalkNRide) can easily be developed, extending the range of detected activities (and detected exercise!) within the application. And in order to facilitate the detection of more activities, which may include playing football or going to the gym, the development of an activity tracker within a wearable device could also be one of the next steps.

As a final note, an article has been written and submitted to the workshop "Designing Systems for Health and Entertainment: what are we missing?" part of the international conference "Advances in Computer Entertainment Technology (ACE) 2014". This submission has been accepted and is currently in the process of publication in the ACM Digital Library.

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APPENDICES

Appendix A: list of messages

Category	Type	Message
Still	Facts	Reducing your sitting time can decrease the risks of cardiovascular diseases.
		About 80% of hospital admissions are the result of bad health habits such as sedentary lifestyles.
		Not walking or moving is hazardous to your health: bodies become worse at metabolizing sugars and fats.
		Less than 50% of adults exercise enough to gain significant health. Inactivity is among the top causes of preventable death in the world.
		As tempting as it is to flop on the couch, spend a couple of hours standing and walking if you can.
		Keep active. Simple movements such as fidgeting, which includes knee shaking or pen tapping can burn up to 3,600 calories per day.
		Sitting too much is unhealthy! When watching TV, stand up and move with every commercial break
		Minimize the time spent in prolonged sitting. Break up long periods of sitting as often as possible
		Sitting too much is a health hazard! Walk to a co-worker's desk instead of emailing or calling her/him
		Keeping active can reduce the risks of cardiovascular diseases
	Low-level	You have been sitting for 45 minutes. Try taking a break every 30 minutes.
		Well done! You are taking breaks every 25 minutes. A minimum recommended frequency is every 30 minutes.
		You walked 500 meters during your 8 hours stay at M-ITI. A healthy number is at least 330 meters per hour
		You have been sedentary at M-ITI for 4 days in a row, this week. Try taking breaks every 30 minutes.
		M-ITI has been your least active location of the week. Try walking every 30 minutes.
		Stand and take a break from your computer every 30 minutes.
		You still haven't taken any breaks at your current location. Try walking a bit every 30 minutes.
		Great, you have been active at M-ITI for 3 days in a row. Keep active!
	High-level	M-ITI has been your most active location of the week. On average, 400m more than other locations
		You have been at M-ITI for 9h this week.
		You are today's 2nd most active person from M-ITI, out of 50 people.
		You are the most active person when at M-ITI! You walk an extra 25% than average (1000 vs. 800 meters) of the people at that location.
		You are the most active person when at home! You walk an extra 25% than the average (1000 vs. 800 meters) people at their own home.

		You are the 2nd least sedentary person when at M-ITI! You are 5% less sedentary than Sérgio.
		You took 2 breaks with an average duration of 8 minutes.
		In your breaks, you walked an average of 50 meters.
		O'Calhau is the 2nd most physically active community in Funchal. Just 300 meters below the first (M-ITI)
		This has been your 3rd most active day of the week while at M-ITI. You were 300 meters away from the day at 2nd place.
Walking	Facts	Walking will make you healthier and will also make you feel greater!
		It doesn't hurt to sweat a bit when you walk! That means you are working out, burning calories!
		Go outside and walk! It's a good source of exercise and you'll relax at the same time!
		Walking makes the whole body move simultaneously, causing positive impact on our muscles.
		Walking helps to reduce blood pressure. If you have hypertension, walking helps you manage it better.
		Walking increases the blood flow to the brain and can increase thinking skills.
		Try walking with somebody else, especially close friends and relatives.
		Walking throughout your day in a consistent way will improve your overall fitness.
		Only 13% of children walk to school nowadays compared with 66% in 1970.
		Treat yourself after going for a walk. Treats can include going out for a meal or watching a movie.
		Lose weight by taking longer, moderately paced walks. Shorter, faster walks are better for your heart and lungs.
		Remember, walking is free. You're getting something for nothing, doesn't that make you feel good?
	Low-level	You walked for 20min. Exercising for at least 30 minutes a day enhances physical and mental wellbeing.
		Walking regularly (at least 3 times a week for 30 minutes) can help you save around €224 a year in health care costs.
		By adding just 1500 meters a day to your everyday activities, you may never gain another kg.
		You are doing great! Keep on finding opportunities to walk more!
		By walking as much as you have during this week, you are significantly lowering your risk of suffering a stroke.
	High-level	Well done! You burnt 330 calories, that's more than a slice of pepperoni pizza.
		Well done! You burnt 605 calories, that's more than 1 hour playing tennis.
		Well done! You burnt 60 calories, that's more than 30 min typing on the computer.
		Congratulations! Up to now you have walked 90 meters. You are 10 meters from covering length of a football pitch!
		This was the day of the week you walked the most between Home and Work.
Commute	Facts	If you have time, park your car further away and walk the remaining distance!
		Challenge yourself to never drive to a destination less than 1 km from your home.
		Even though over 40% of the trips taken in Europe are less than 1 km, less than 10% of all trips are made by walking or biking.
		Reducing short-distance car trips brings positive benefits for the environment and increases your physical health.
		Driving has been recognized as one of the main factors behind sedentary lifestyles.
		Driving can mean long periods of being sedentary. Try leaving the car behind if it is a short journey and walk instead.

		The cost of operating a car for one year is approximately €4,000, but walking is free!
	Low-level	Did you know that you would have burnt around 500 calories if you had walked instead of driving for these 8 km?
		You would have met 30% of your daily walking goal if you had walked this distance.
		You should have made at least 3 breaks while driving for these 3 hours!
		You could have avoided between 25 and 30g of carbon dioxide emissions if you had walked.
	High-level	This morning (/evening) you drove 30 min more (/less) than usual (15 minutes).
		You walked more and drove less than usual between Home and Madeira Shopping!
		This trip you made you spend between 4.50 and €5.
		This trip contributed to between 25 and 30g of carbon dioxide emissions.
Just-in-time	Facts	Keep active. Simple movements such as fidgeting, which includes knee shaking or pen tapping can burn up to 3,600 calories per day.
		Go outside and walk! It's a good source of exercise and you'll relax at the same time!
		Experts suggest walking 5km a day to improve health and 8km a day to lose weight.
		If you have time, park your car further away and walk the remaining distance!
		If you have time, leave the bus some stops earlier, and walk the remaining distance!
		You've been doing great! Keeping active can reduce the risks of cardiovascular diseases.
		Sitting for too long is a health hazard! When watching TV, stand up and move with every commercial break.
		Sitting for too long is a health hazard! Walk to a co-worker's desk instead of emailing or calling him/her.
		Minimize the time spent in prolonged sitting. Break up long periods of sitting as often as possible.
		Reducing your sitting time can decrease the risks of having cardiovascular diseases.
		Challenge yourself to never drive to a destination less than 1 km from your home.
		About 80% of hospital admissions are the result of bad health habits such as sedentary lifestyles.
		Less than 50% of adults exercise enough to gain significant health. Inactivity is among the top causes of preventable death in the world.
		Driving can mean long periods of being sedentary. Try leaving the car behind if it is a short journey and walk instead
		Walking increases the blood flow to the brain and can increase thinking skills.
		Only 13% of children walk to school nowadays compared with 66% in 1970.
		Lose weight by taking longer, moderately paced walks. Shorter, faster walks are better for your heart and lungs.
	Low-level	You have driven a total of 50 minutes this week. You could have avoided between 20 and 30g of carbon dioxide emissions if you had walked.
		You have driven a total of 50 minutes this week. You could have saved between 5 and €10 if you had walked.
		You have driven a total of 50 minutes this week. You could have burnt between 300 and 350 calories if you had walked.
		20% of your trips are short ones. These could be replaced by less than 35 minutes of walking.
		By walking as much as you have during this week, you can end up saving €224 a year in health care costs.

		By walking as much as you have during this week, you are significantly lowering your risk of suffering a stroke.
		You are improving your health by walking as much as you have up to now.
		You are more likely to lose weight if you keep walking as much as you have up to now.
		Up to now you have walked for 20 minutes. Exercising for at least 30 minutes a day enhances physical and mental wellbeing.
		You still haven't taken any breaks at your current location. Try walking a bit every 30 minutes.
		You walked 200m during your 2h30min stay at Home. A healthy number is at least 330 meters per hour.
		You have been sitting for more than 2 hours. Try taking a break every 30 minutes.
		Yayy! During your last call with João, your physical activity was high. Try walking when talking on the phone.
		Try walking when talking on the phone. During your last call with Jorge, you were sedentary. A lost opportunity :(
		You have walked 5km already. Walking more than 7km per day decreases the risk for type-2 diabetes and cardiovascular diseases.
		Walking 2km a day burns around 200 calories. You could lose up to 0.85kg in a month if you keep walking this much.
		Well done! You are taking breaks every 20 minutes. A minimum recommended frequency is every 30 minutes.
		Last week, you reached your daily walking goal 2 times. Perhaps updating it to 8 km?
	High-level	You are today's most active person from M-ITI, out of 10 people!
		You are the 2nd most physically active in São Martinho, out of 5 people.
		You are the 10th most physically active in Funchal, out of 30 people.
		You are the 90th most physically active in Portugal, out of 400 people.
		You are the 2nd most active driver in São Martinho, driving an average of 30 minutes per day.
		You are the 10th most active driver in Funchal, driving an average of 30 minutes per day.
		You are the 90th most active driver in Portugal, driving an average of 30 minutes per day.
		In average, people from São Martinho walk less per day than those from Camberley (2km vs 8km).
		In average, people from Funchal walk less per day than those from Faro (3km vs 5km).
		In average, people from Portugal walk less per day than those from United Kingdom (3km vs 7km).
		This has been your 2nd most active driving day of the week. You have been driving more than usual.
		Today you drove 5 minutes more than usual (35 minutes).
		You took 2 breaks with an average duration of 10 minutes at your current location.
		In your breaks, you walked an average of 80 meters at your current location.
		Last week, in average, you walked 25% further on weekdays than on the weekend (5km vs 4km).
		Sunday was your most active day of the past week. You walked 6km, and, in average, 3km on the rest of the week.
		Saturday was your least active day of the past week. You walked 500m, and, in average, 3km on the rest of the week.