Motivate: a context-aware mobile application for physical activity promotion

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Motivate: a Context-aware mobile application for physical activity promotion

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林玉锺

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Chapter 1. Introduction

1.1 Motivation and background

According to the WHO, in 2008 approximately 31% of the adults (age +15) were insufficiently active globally, and 1.5 billion adults (age 20+) were overweight. Of those over 200 million men and 300 million women were obese (World Health Organization, 2012). In the Netherlands, 40% of adults were overweight and 10% were obese in 2005 (Ministry of Health, 2005). According to NNGB (de Nederlandse Norm Gezond Bewegen – the health activity standard in Netherlands), adults must at least do 30 minutes of moderate physical activity (PA) 5 times per week, preferably every day. In the Netherlands, 56% of the population above 12 years old met this standard in 2007. People who were between 18-55 years old were less active than people who were between 55 and 75 years old (70% of them have met the standard) (RIVM, 2008).

Physical activity (PA) is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure.” Its subcategory “exercise” is the physical activity that is “planned, structured, repetitive and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective” (Caspersen et al., 1985). PA can be categorized in different ways according to intensity (moderate or vigorous), portions of daily life (sleep, at work or at leisure), time (weekdays or weekend), willingness (willful or compulsory), etc (Caspersen et al., 1985). Moderate intensity PA includes walking, cycling slowly, gardening, dancing, etc; and vigorous intensity PA includes jogging, swimming, cycling fast, hiking, etc. One study showed that the dropout rate for a moderate-level activity was between 25-35%, but 50% for vigorous exercise (Sallis et al., 1986).

Overweight and obesity, fortunately, is largely preventable by taking care of the daily diet and engaging in regular PA (World Health Organization, 2012). However, to maintain a certain level of activity is a challenge for many people, due to reasons such as lack of time, lack of energy and lack of motivation (Weinberg & Gould, 2007). In order to change people’s behavior towards healthy life, many behavioral change theories and models are applied. For example, the Health Belief model (Becker & Janz, 1984), Ajzen’s theory of Planned behavior (Ajzen, 1991), Bandura’s Social Cognitive Theory (Bandura, 1986), ecological model (Wicker, 1979), etc. These theories focus on the individual or/and environmental level and adopt behavioral and cognitive approaches. Another approach is “Captology”, which refers to a series of principles for technological solutions to influence human behavior. In Captology technology and persuasion are integrated together to interact with users in order to change their behaviors or attitudes. This kind of technology is called “Persuasive technology” (Fogg, 2003).

Some applications use the principles and strategies of persuasive technology to promote healthy lifestyles. For example, the applications DirectLife (Philips Research, 2008) and PAM (PAM, 2012) use “self-monitoring” strategy to motivate physical activity. An activity monitor with
accelerometers to measure daily activities in terms of calorie burning is carried by users and direct feedback is given on the activity monitors using lights (DirectLife) or activity scores (PAM). The users can also upload their activity data to the web application and view their progresses and achievements. Goal setting with timely feedback about performance and cognitive variables such as motives and self-efficacy play their roles for effective persuasion, and researches are conducted to explore their impact within the context of Direct Life program (Lacroix et al., 2008; Lacroix et al., 2011; Saini & Lacroix, 2009).

In the PAM intervention experiment, the computer-tailored PA advice on how to adopt a physically active lifestyle is generated based on individual preferences as a part of the online coaching. The tailored advices suggesting either moderate or vigorous activities based on the users’ performance, currently doing activities and preferred activities. In an evaluation experiment with 102 participants, no significant intervention effect was found in the PA outcomes after the 3-month intervention or 8-month follow-up. Most of the users expected more varied and concrete advice and found the advice not applicable to their daily life (Slootmaker et al., 2009). This suggests the need for tailored and practical PA advices that fit into people’s lifestyle and context. Besides, the advices are only available when the users are viewing the website but not “pushed” at the time that a user is more likely to follow the advice. “Just-in-time” message on a mobile device can intervene at any proper moment to trigger a desirable behavior change.

Some research challenges of persuasive technology have been proposed as follows: the benefits of just-in-time messaging depend on the quality and relevance of the machine sensing and inference algorithms; it takes a long time to change human behavior (IJsselsteijn et al., 2006). The potential and challenge of mobile persuasive technology inspire us to investigate the feasibility and effectiveness of a mobile application to provide PA advices for healthy lifestyle promotion at the right time and location.

1.2 Exploring the potential of LBS

Location-based services (LBS) can be found in navigation guides, alarming system, tourist/shopping guides, friends finding, advertising, points of interests, safety and security, etc (Marco et al., 2007; D’Roza & Bilchev, 2003). Location-based technologies are used to identify personal location, as well as the surrounding environment (service location) to provide information (D’Roza & Bilchev, 2003; Rao & Minakakis, 2003). Other Location-based systems try to provide personalized, interactive and dynamic information with collaborative filtering for recommendations, such as Cityvoyager (Takeuchi & Sugimoto, 2009), CRUMPET (Schmidt-Belz et al., 2003), GeoVector (GeoVector, 2008), etc. The routing and navigation is presented to help users to plan their trips according to their preferences.

At the same time, users can also attach information (messages, photos, etc.) to a geographic location in order to help urban planners to understand citizen activities, such as the application of Mobile Landscapes (Ratti & Frenchman, 2006), My Experience (Froehlich et al., 2006), Urban
Tapestries (Lane & Thelwall, 2005) and our previous Sense-of-the-city project (Sense of the city Eindhoven, 2011; de Vries et al., 2008). In this way, some personal experience can be shared among common users who cross the same places.

Geographic information system (GIS) is a system that processes geographic data. GIS data of points, lines, polygons, etc can model the places in the real world. The geo data can be used for distance, size calculation which can determine the accessibility of certain places to users (Virrantaus et al., 2011). Internet GIS can provide geographic information via the Internet or mobile-networked environments to mobile devices. Various services that are based on user location can be presented to mobile users, such as Google maps for way finding. From hardware and software perspective, LBS are based on diverse platforms and packages which involve the use of Internet, GIS, location-aware devices and telecommunication technologies (Jiang & Yao, 2006).

The LBS are used for health care such as an alarming system, which can detect abnormal movement patterns (e.g., falling), and provide emergency assistance (Marco et al., 2007). A LBS system collects information from physical activity monitor and GPS units, to be synchronized and analyzed in a GIS. The results are used to determine how the urban environment may influence an individual’s decision to use a particular walking/running route (Seeger, 2007). This research shows us the feasibility of combining location, activity data and GIS data to understand the activities of people in the urban environment.

LBS are often called location-aware computing or context-aware services, since location and context play importation roles. Context changes and has impact on information retrieval, user actions, and user behaviors with LBS application (Jiang & Yao, 2006). Location is part of context, but context is far more than location (Schmidt et al., 1999). Location and context are the key players in Location Based Services (LBS), therefore it is often called location-aware computing or context-aware services (Jiang & Yao, 2006). Context-aware systems are a part of a ubiquitous computing or pervasive computing. Location is a primary requirement but context-aware includes nearby environment, people, weather, etc. At the beginning of our research, a review on pervasive computing systems related to healthcare concluded that most systems are still in their prototype stage. More attention should be given to the performance of pervasive computing systems in order to ensure user acceptance, societal acceptability, etc (Orwat et al., 2008).

We have gained experience of deploying LBS with mobile technologies by conducting the Sense-of-the-city project in 2006 (Sense of the city Eindhoven, 2011; de Vries et al., 2008), which was developed by the Design Systems group of the department of Built Environment of Eindhoven University of Technology. The development is based on GeoTracing, which is a software platform for creating multimedial geo-applications for tracking or tracing purposes (Geotracing, 2012). GeoTracing integrates GPS, mobile technology, GIS and content management (CMS) within an extensible client-server framework. Users can tell their multimedial story via locative media applications based on this software framework. In this
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project, the devices employed to enable localization are a Bluetooth GPS receiver and a mobile phone with an application called MobiTracer. This mobile application can read GPS location data and send these data to the GeoTracing server. Users can use the functions of the mobile phone such as Camera and Recorder to send various media (text/photos/audio/video) to the server. They can also access and modify their media data through internet whenever they want. On the server a GIS application maps the received position data on the city map. Hence, the users could be traced in real time, using Google Maps as a viewer. The recorded track can be replayed afterwards at any time. Replaying the tracking will automatically show all the pictures made on the track. Additionally, the users can add text to the pictures using a web application.

By deploying Bluetooth GPS and mobile applications for real-time tracking and information integration, we obtained the confidence to further explore the potential of LBS on mobile platform to communicate and interact with users. This project showed us the feasibility of location based technology, mobile technology and GIS application at the start of this PhD research. In the beginning of our research in 2008, the integration of the aforementioned technologies was innovative and challenging. The existing applications normally applied GPS receiver coupled with PDA, handheld PC to interact with users, instead of using mobile phones (Marco et al., 2007; D’Roza & Bilchev, 2003). The usage of Smartphone was still at the developing stage. Although during our research period, many location-based mobile applications become available for the market, for example, Foursquare (Foursquare, 2011), Google Latitude, etc., many technical challenges still remain. Therefore we aspire to explore the feasibility of applying these advanced technologies to understand user context and provide just-in-time information.

In summary, we contend that LBS based on a mobile platform has the potential to create recommendations for PA and healthy lifestyle promotion. Based on a user location, the opportunities for various PA activities in their urban surroundings can be created to trigger more movements and explorations of their environment at the same time. A mobile device with the location sensing technology can be used to sense and understand user context in order to provide context-aware and personalized advice at the right location and right time. We are motivated in this research to investigate the technical feasibilities of such a system and its effectiveness on persuading behavior change.

1.3 Research goal, questions and scope

This research is explorative and it begins with the understanding of the existing LBS and mobile technologies. To which extent this research can achieve depends on the availability and development of the technologies within four years. As an exploratory research, we did not formulate a concrete research plan and expected results. Instead, we defined our optimal final goals, explorative questions, and the scope of our research.
1.3.1 Research goal

The initial research question of this research is about the key properties of existing information technology and consequently what are their potentials and limitations. Information can be provided in terms of actual information, describing the state of the system at hand or may be presented in terms of recommendations in an attempt to stimulate particular kinds of user reactions. We are interested in the influence of information, especially the location-based recommendations on user behaviors.

The main goal of this research is to design and develop a location-based system on mobile platform that provides users with real-time recommendations on PA to stay active. The advice should be context-aware, especially sensitive to the change of the urban environment. We would start our endeavor by exploring the mobile technologies and the feasibility of automatically generating context-aware advices. The second goal is to find out the user acceptance of such a system, how they react to the context-aware advices and whether and why they will comply with the advices. To find out the effectiveness of the advices on PA promotion, we need to have a good understanding of PA behavior and PA promotion interventions to start with.

1.3.2 Research questions

The two main research questions are described as follows.

1. What is the feasibility of LBS on a mobile platform as a context-aware adviser?
2. How strong is the user acceptance of such technologies and what are the reactions to the context-aware advices?

1.3.3 Research Scope

As this research is conducted in the Design System group of the department of Built Environment, the focus is on the design of a decision support system that helps people make a better decision by providing context-aware advices on PA. The intention is to explore the possibility of LBS that makes the best use of the urban environment features for healthy living promotion. The definition of healthy living or active living in our research is performing healthy physical activities at healthy places. The system is designed for people who are at the risk of being inactive and induce them to become active.

The design, development and evaluation follow software development approaches, which is not exactly the same as a traditional PA promotion intervention design and evaluation. The research about healthy living promotion and behavior change interventions require considerable knowledge and expertise in the medical and healthcare field, which is outside the scope of the faculty. Therefore, the designing of the PA advices aim at offering ideas about physical activities to conduct at convenient and pleasant places at an appropriate time.
1.4 Methodology for development and evaluation

1.4.1 Incremental development

We adopt an incremental approach in developing working prototypes towards the final application. The development methodology is “software prototyping”, namely creating prototypes of software applications. To be more specific “evolutionary prototyping” method is adopted. As shown in Figure 1.1, evolutionary prototyping is based on the idea of developing an initial implementation, exposing this to user comments and refining this through many stages until an adequate system is developed (Sommerville, 2001). In an incremental development process, system components are incrementally developed and delivered. Users are involved in the development through evaluation tests and user feedback from delivered components can influence the future design of components.

In our research questionnaire and Wizard-of-Oz experiment method are used at the first step of the development. The questionnaire study presents the concept to respondents and learns their acceptance and preference. In the Wizard-of-Oz experiment, without technical implementation of the system, the advices are sent manually as SMSs to participants in order to gain user opinions. GPS loggers are adopted as tools for user location collection. The goal of this first stage is to create the concept design of the adviser system and specify system requirements.

The next steps are to build prototypes and use prototypes to improve the design. In total, three prototypes are implemented and three user evaluation tests are performed. For the second step, the core “Motivate Service” is implemented, which generates advices based on if-then rules and user location, geo information, weather, time, user agenda and profile. To test the quality of the advice generation, a web application (1st prototype) with offline inputs data is first developed and evaluated in a user test. Based on the results, the next step is to implement the Motivate mobile application (2nd prototype) that generates advices based on real-time input and communicate with users by sending them advices and collecting user feedback. A small-scale user experiment is conducted to evaluate this application. As a final step the first version of the Motivate mobile application is improved with added features for a better user interaction and data collection. The final version of Motivate (3rd prototype) is evaluated in a larger scale experiment. The final application is a working prototype sufficient for research purposes, but not as adequate as a commercial mobile application.
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1.4.2 Evaluations

The advantage of field testing with prototypes is that users can report their experiences during the actual usage period. The user feedback is contextual sensitive and leads to rather valid results (Khan, 2009). The evaluation of the application consists of field testing of both the web version and the mobile application version. The evaluation of the web version is mainly to test the suitability of advices in different contexts, however, the advice is generated based on the past context. Only in the last two user experiments of the mobile applications, the evaluation is contextualized. Contextualized methods of data collection allow real-time reporting of attitudes, opinions, experience to be captured close to the moment that a particular experience occurs (Khan, 2009).

The results of the small scale testing are analyzed and used for the improvements of the application design and the data collected in this final experiment are considered as the final results for a more elaborated analysis. The user intention to follow the advices and self-reported behaviors of whether following the advices are recorded and analyzed to study the system usage and user preferences for advices.

In all the four user experiments, including the Wizard-of-Oz experiment and three evaluation tests, questionnaire and face-to-face interview methods are applied to obtain user opinions and experience. In addition to the descriptive analysis, a logistic regression analysis is applied. The purpose is to find out the underlying reasons for their decision making of following the advices or not, with respect to advice type, context and profile.

1.5 Outline

First, a literature review study (Chapter 2) is presented to discuss theories relevant to physical activity as a fundamental basis and the related works in the fields of PA promotion through messaging, context-aware persuasion and location-based mobile applications. With a chronological order, we describe our design process of developing abstract specifications and

Figure 1.1 Evolutionary prototyping (Sommerville, 2001)
prototypes through the user experiments. In Chapter 3, we describe the questionnaire study and a Wizards-of-Oz experiment. From these results, we decided on the content of the activity suggestions and the inputs for creating context-aware advices. In Chapter 4, we describe our design and implementation of the Motivate advice generation mechanism and the Motivate web application. The user experiment to evaluate the Motivate web application is described. The results of the experiment prove the stable performance of the advice generation and give us the confidence for further development. In Chapter 5, we introduce the design and development of the Motivate mobile application, the first small-scale evaluation test and how the application is improved towards the final version. Real-time user location is detected by a mobile localization method and sent to the server to generate advices. Based on user feedback the Motivate application is adapted by extra features for a better data collection and interaction. Chapter 6 describes the process and the results of a big scale user evaluation experiment to test the final Motivate mobile application. In order to elaborate their decision making process, in addition to the descriptive analysis, we further analyzed the results with a logistic regression analysis in Chapter 7. The last chapter of this thesis summarizes the content, concludes main findings and reflects on the study in terms of achievements and limitations. The structure of the thesis is illustrated in Figure 1.2. The main topics of each chapter are described in the blocks with the chapter number.
Figure 1.2 Outline of the thesis
Chapter 2. Literature review

2.1 Introduction

The focus of this research is to develop a mobile “adviser” application to promote PA and healthy living by deploying up-to-date mobile and location-based technologies. It is expected that the context-aware PA recommendations as prompt via mobile devices can trigger healthy behavior change. First of all, reviews of the general models and determinants of PA behavior are studied to help us understand PA behavior as the foundation of the research. Especially, the interventions deploying tailored messages via mobile phones for PA promotion are in the center of our attention.

From another perspective, the context-aware persuasive applications aiming at healthy behavioral change with various strategies show us the opportunities and challenges for creating contextualized messages at the right time and location. Moreover, the up-to-date Smartphone applications with location-sensing technologies indicate the technical feasibility and potentials.

Therefore, there are three main topics of the literature review in this chapter:

- PA behavior promotion: theory, determinants and interventions
- Context-aware Persuasion: concept and applications
- State-of-the-art location-based mobile applications on PA promotion

2.2 Understanding PA behavior

To create effective interventions to promote PA behaviors, the first step is to understand the theoretical models and determinants of physical activities. The factors that are related to the PA behavior can be considered as a basis for PA promotion interventions design. An overview of some theoretical models and determinants are given, followed by some literatures with findings concerning the influence of individual and environmental factors on PA.

2.2.1 Theoretical model to understand PA behavior

Several theoretical models to understand PA behavior are briefly introduced as background knowledge in this section. Different models have their different focuses on aspects such personal, social and environmental aspects.

HBM model

The Health belief model (HBM) was first developed by social psychologists Hochbaum, Rosenstock and Kegels in 1950. According to this model, the likelihood of a health-promoting behavior depends on the demographic situation and the social status of people, their prior attitudes, their perceived threat of getting a certain health problem, their self-efficacy (confidence) to take action and whether they are exposed to “cues to action”. In order to be ready
to act, people need to believe that taking action would reduce risk and gain health benefits, be confident in their ability as well as being exposed to factors that prompt action (such as a reminder) (US National Institute of Health, 2005). The HBM emphasizes that the belief in a personal threat together with the belief in the effectiveness of the proposed behavior will predict the likelihood of that behavior (Rosenstock et al., 1988).

The effect of using this model to predict exercise behavior has been inconsistent, due to the fact that this model was originally developed to focus on disease, not physical activity (Berger et al., 2002). We believe that the information provided by a decision support system can play the role as a “cues to action” to influence the likelihood of a particular behavior.

SCT model
Social cognitive Theory (SCT) developed by Bandura argues that personal factors, environmental factors and human behavior exert influence upon each other (Bandura, 1986). The SCT is a learning theory which suggests that people learn from their own experience and also by observing the actions of other people. The social and physical environment affects behaviors while behaviors may also affect the environment. Three personal factors that affect likelihood of behavior change are: self-efficacy, goal and outcome expectancies. This model also emphasizes “self-efficacy”, which is similar to the HBM Self-efficacy theory. Self-efficacy is a good predictor of health behavior. The theory brings up the dynamic relationship between the physical and the social environment, observable behavior and the cognitive personal determinants. However, the “environmental” aspect of this model does not include specific environmental factors.

TPB model
The Theory of Planned Behavior is frequently used to explain health related behaviors. The diagram of Theory of Planed Behavior (Ajzen, 1991; Ajzen, 2012b) is shown in Figure 2.1. The model is based on the model of Reasoned Action (TRA) (Ajzen & Fishbein, 1980), in which “Intention” is a central factor. Intention can indicate how hard people are willing to try, or how much effort they are planning to exert in order to perform the behaviors. In the TPB model “perceived control” is added which can affect the intention and is another important factor for prediction of behavior (Ajzen, 1991). “Perceived control” refers to people’s perception of their ability to perform the behavior, which is similar to “self-efficacy” that is included in the HBM and SCT models.

As illustrated in Figure 2.1 behavioral beliefs produce attitude towards behavior, normative beliefs results in subjective norms and control beliefs generate perceived control. In combination, "attitude toward the behavior," "subjective norm", and "perceived behavioral control" lead to the formation of an "intention" (Ajzen, 2002a). Attitude, subjective norm and perceived control are independent determinants of intention and their impacts on prediction vary across behaviors and situations. Perceived control together with behavioral intention can be used to predict behavioral achievement directly. Their relative importance in behavioral prediction differs across situations and various behaviors as well.
Empirical findings show that “attitudes” significantly contribute to the prediction model, and the addition of perceived behavioral control improves considerably the prediction of intentions (Ajzen, 1991). Reviews of TPB applications in health behavior domains concluded that TPB variables better predict intentions than behaviors (Armitage & Conner, 2000). Another research showed that the TPB variables were the most proximal determinants of both subjectively and objectively measured physical activity (Maddison et al., 2009).

Extended TPB model

Many researchers studied the gap between intention and behavior. Some have suggested “Past behavior” as another predictor of future behavior. Past behavior often predicts future behavior directly and is a stronger predictor than intention in some cases (Sheeran, 2002). Ajzen (1991) argues that “Past behavior” may reflect the impact of factors that influence later behavior, but not be considered as a causal factor. The relation between past and later behavior is an indication of the behavior’s stability or reliability. When the behavior involves strong habits, intentions do not predict future behavior, whereas when habit is weak, behavior is predicted better by intentions (Ouellette & Wood, 1998; Aarts, 2007).

The weak intention-behavior relation can be attributed to people who have good intentions to act, but fail to act on them (Sheeran, 2002; Orbell & Sheeran, 1998). One of the effective means to bridge the intention-behavior gap is to encourage people to form a specific plan about when and how the desired behavior will be performed. A detailed planning to achieve the behavior goal is referred as “implementation intentions” (Gollwitzer, 1999). For example, people intend to exercise regularly can form implementation intentions that specify when, where and how they want to exercise (e.g., “when I finish work, I will take the stair”). It is assumed that they are mentally ready to act on the goals whenever the good opportunities appear, even when they are busy.

To sum up, these three conceptual models (HBM, SCT and TPB) all similarity mention the importance of the factor of “self-efficacy” or “perceived control”, which is the confidence to conduct a certain behavior. Other mentioned personal factors are psychological or demographic.
In addition, the SCT and TPB models include the influence of social factors as well. The actions and beliefs of the other people may affect the likelihood of a certain behavior. Although the model of SCT stated that environmental factors may influence behaviors, no specific determinants are discussed.

**Ecological model**
The ecological model of human behavior focuses on how individual, social and environmental factors and their interactions influence behaviors. The idea is that environment restricts the range of behavior by promoting and sometimes demanding certain actions and by discouraging or prohibiting other behaviors (Wicker, 1979). As Titze (2003) mentioned, “Ecological models are conceptual frameworks suggesting that there is much to be gained when intervention goals are moved from the individual to the environmental level”. It means that when the environment is taken into account in addition to individual factors, a greater effect on behavior change can be expected.

To conclude, the behavior of PA can be determined not only by personal and social factors according to the HBM, SCT and TPB models, but also by environmental factors (the ecological model). The specific determinants in these three aspects are discussed in details in the following section.

2.2.2 Literature reviews on determinants of PA

The behavior theory as discussed in the previous section can help us understand the process of adopting, maintaining PA behaviors, and it is the foundation for intervention design. The other approach to study the behavior of PA is to investigate the determinants. The determinants can be categorized as personal, social and environmental according to the three aspects of the ecological model.

**Personal factors**
The most studied personal factors include demographic (e.g., gender, age, education, income, family status, etc.) and cognitive variables (e.g., attitude, self-efficacy, intention, etc) as mentioned in the theoretical models in the previous section.

**Social factors**
Behavioral intentions can be influenced not only by a person’s attitude toward performing a behavior, but also by beliefs about whether other important people approve or disapprove the behavior (US National Institute of Health, 2005). Thus, social factors (e.g., social support) play a role on influencing PA behavior by affecting attitudes and intentions. A review study showed that the impact of family support and important others on attitudes about exercise was the strongest predictor of the adherence of PA behaviors (Carron et al., 1996).

**Environmental factors**
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The most studied physical environmental factors include safety/attractiveness/type of the neighborhood, perceived distance to destination, accessibility to nature/facilities, green places in the neighborhood, land use patterns, transportation, street design and built facilities, etc. Studies between 1998 and 2002 started to give more attention to physical environment factors and brought up more needs to better understand environmental influences on PA (Trost et al., 2002).

We summarize reviews on determinants of PA. The goal is to get a whole picture of the up-to-date research in this field in order to find out the essential keys for an effective PA promotion intervention. Some research studies that focus on a few specific determinants of PA are also included.

An earlier review of (Sallis & Owen, 1999) concluded that adults’ participation in PA is associated most strongly and consistently with socioeconomic status and perceived self-efficacy. Another early review (Sallis et al., 2000) of the correlates of physical activity of children and adolescents showed that variables that are consistently associated with both children and adolescent’s physical activity are gender (male), intention to be active and previous physical activity. This result supports the ecological model of behavior that suggests behavioral influences from personal (biological, psychological, behavioral), social and physical environmental factors (Sallis & Owen, 1999).

As an update of the review of Sallis & Owen (1999), the review study of Trost et al. (2002) consistently showed that self-efficacy and self-motivation as the most consistent predictors of PA. Besides, changes in status in relation to correlates of marital status, weight, attitudes, lack of time, past exercise behavior, smoking and several environmental variables were added. More studies included in this update began to adopt the “ecological” approach and focused more on environmental factors.

A survey study of Pan et al. (2009) was conducted concerning individual, social and environmental correlates with PA in Canada. The results showed that self-efficacy and intention were the strongest correlates and had the greatest effect on PA. Self-rated health, family income, perceived health benefits and perceived barriers were also consistently associated with PA, with the influence of the variables depending on the age and gender of the participants. In this study, the environmental factor “facility availability” was found to be more strongly associated with PA among people with a university degree than people with a lower education level.

In the paper of van der Horst et al. (2007), the literatures from 1999 to January 2005 were reviewed to identify the correlates of physical activity and sedentary behavior by children and adolescents. The conclusion was that gender, self-efficacy, and family/parental support were associated with physical activity, both in children and adolescents. The positive association for gender (male) and no association between single-parent status and self-esteem were shown in both reviews (van der Horst et al., 2007; Sallis et al., 2000).

A recent review (Uijtdewilligen et al., 2011) elaborated on the reviews of van der Horst et al. (2007) and Sallis et al. (2000). It included 30 papers of studies between 2004 and 2010,
investigating the association between determinants of overall physical (in)activity and/or sedentary behavior by healthy children or adolescents. It was concluded with only few determinants of physical activity. Intention was found as a determinant of children’s physical activity. Determinants of adolescents’ physical activity were age, ethnicity and planning. They stated that most studies on determinants of physical activity and sedentary behavior showed a poor methodological quality and few focuses on environmental determinants (Uijtdewilligen et al., 2011).

A literature review of research between 1990 and 2011 included 30 studies on determinants of PA or exercise for community dwelling for healthy older adults. It was concluded that “insufficient evidence” was found for most associations between determinants and physical activity (or exercise), due to the lack of high quality studies and often only one research reporting on a particular determinant. Supported by 2 studies, moderate evidence was found for a positive association between male gender and younger age with PA (Koeneman et al., 2011).

These reviews indicate some consistent findings on the influence of personal determinants such as self-efficacy, intention, gender, age, etc. Some recent reviews raised attention for the limitations of the research on PA determinants and the needs to further explore environmental determinants. The correlates at a personal level have been more intensively studied compared to the social and physical environmental factors. According to the ecological models, social and physical environmental factors are also important factors. In this research, we are particularly interested in the influence of physical environmental factors on the behavior of PA. In the following paragraph, research on the topic of environmental factors is presented.

Some research began to show interests in both social and physical environmental factors. In the review of Trost et al. (2002), studies that included a measure of social support for PA all found a significant positive association. Furthermore, the study investigated the association between physical and social neighborhood environments and PA/obesity. After controlling for children’s sociodemographic factors, it was found that a favorable social environment was positively associated with several measures of PA, while PA was negatively associated with obesity in these children. Physical environment was not significantly associated with physical activity. Favorable social environment appeared to be more strongly related to physical activity than the physical environment (Franzini et al., 2009). Similarly, social environmental variables were found to be positively associated with active transportation and leisure-time sports (Deforche et al., 2010).

Trost et al. (2002) brought up the need to better understand the environmental factors that influence different types of PA. The concept “Behavior setting” is defined as the physical and social context in which behavior occurs by Wicker (1979). Physical activities taking place in specific physical environments are likely to be influenced by the environmental settings (Sallis et al., 1998). The daily physical activities in various contexts include transport, leisure, occupational, etc. Owen et al. (2000) examined the determinants of PA in different contexts, and raised a need for studies to identify the determinants of PA and sedentary behaviors in the
context of work and daily living. The determinants can be different for transport, leisure, occupational and incidental activities. For example, walking for transportation or leisure has been studied. The paper of Craig et al. (2002) proposed a model that explores the effect of the environment on “walking to work” behavior. A positive association was found between the environment score (e.g., neighborhood characteristics, walking route, time, effort, etc) and “walking to work”. Alfonzo (2005) further investigated on the needs for “walking” to understand the walking decision making process. The five levels of walking needs from the most basic level to the top were: feasibility (e.g., time, mobility, etc), accessibility (e.g., distance to destinations), safety, comfort, and pleasurability (level of appeal, liveliness of activity level, etc). In addition, the research of Deforche et al. (2010) found that better access to recreational facilities was associated with both active transportation and leisure-time sports. Respectively, higher land use mix diversity, higher street connectivity, more attractive environment, and higher emotional satisfaction with the neighborhood were associated with more active transportation. While higher perceived safety from traffic, more physical activity equipment at home, and fewer electronic devices in the bedroom were associated with more leisure-time sports.

There is a difference between objective and perceived environment, in the sense of their impact on PA behavior. A study examined the feasibility of integrating environmental (perceived and GIS measured), individual, and psychological variables to better understand PA behavior. The perceived environmental variables were related to the TPB variables and self-reported PA. Only the perceived environmental variables were directly related to the self-report measures of PA. Built environment variables were not directly or indirectly related to the PA measures (Maddison et al., 2009).

Hoehner et al. researched on whether perceived and objective environmental measures were associated with transportation or recreational activities. They found that having destinations within walking distance was the strongest correlate of transportation activity, while recreational activity was positively associated with perceived access to recreational facilities and objective measures of attractive features (Hoehner et al., 2005). Both subjective and objective measures of recreational opportunities were associated positively with physical activity. Greater access to recreational opportunities seems essential to facilitate youths’ healthy levels of physical activity (Tucker et al., 2009).

Compared to personal and social determinants, the relative influence of physical environmental determinant was found to be less on PA. The physical environment appeared to have only a weak direct influence on behavior (Giles-Corti & Donovan, 2002). The association of some factors with PA appears to be less consistent. For example, although in the paper of Sallis et al. (2002) “access to facilities” was found to be associated with PA, this factor was not associated with PA in a more recent review (van der Horst et al., 2007). The study of Giles-Corti & Donovan (2002) found that accessible recreational facilities provide opportunities, thus good access is necessary to create a supportive environment and enhance the achievement of recommended levels of PA.
Nevertheless, it appears that the access to a supportive physical environment alone may be insufficient to increase community recreational activity levels.

A lot of research has shown interests in the natural environment, for example, green places and PA behavior. It was stated that people are inclined to undertake PA in appealing environments (Giles-Corti & Donovan, 2002; Sallis et al., 1998). Natural environment may stimulate people to undertake healthy PA, such as walking or cycling for transportation or leisure purposes. The natural environment in and around the city also influences participation in PA, together with weather conditions. Extreme heat, cold and icy conditions inhibit participation in outdoor activities such as walking, cycling and playing at the park (Edwards & Tsouros, 2006). The relationship between attractive streetscapes (e.g., trees, garden, street, parks, etc) and the amount of walking and cycling was found. However, no association between the trees along the neighborhood streets and transportation or recreational activity was found (Hoehner et al., 2005). Consistently, another study showed no relationship between the amount of green space in the living environment and whether or not people meet the Dutch public health recommendations for PA. People who live with more green place in their environment even walk and cycle less in their leisure time according to this study (Maas et al., 2008).

Some studies looked into specifically the relationship between built environment and obesity. A review study of Papas et al. (2007) has reported a significantly positive association between some aspects of the built environment and obesity in 84% of the 20 articles included in the review. Wells et al. (2007) stated that physical environmental characteristics, such as neighborhood, urban design and natural environment, either support or hinder the healthy habits of the inhabitants. Although some evidence of association between a variety of measures of the built environment and the risk of obesity has been found, the uncertainty remains due to conceptual and methodological challenges (Papas et al., 2007; Feng et al., 2010).

It seems that some environment factors have been found to be associated with some types of PA, such as accessibility and attractiveness of the facilities. Appealing natural places may trigger people to be more active. However, some research results also indicate that these environmental factors may be not or only weakly associated with some types of PA. They may be helpful due to the opportunities they offer, but may be insufficient to increase PA level. One focus of this research is to investigate how to make the best use of environmental features to stimulate healthy outdoor activities. The aforementioned research with mixed findings indicates the possibilities of triggering more PA with offering better opportunities, but with uncertainties.

To conclude, more consistent findings on the influence of personal determinants such as self-efficacy, intention, gender, age, etc have been shown compared to the environmental determinants. The need to explore environmental determinants on PA has been raised. The perceived environment and context may influence the perceived difficulties of conducting PA e.g., bad weather may diminish the confidence that a personal can exercise outdoor. In this sense, the environmental factors can influence the decision of conducting PA behavior indirectly but to large extent. Ecological models combining individual, social and environmental aspects have
been applied in this research field and help us understand PA behavior from various angles. The relevant studies in the theoretical models and determinants show us that many factors may influence PA directly or indirectly.

2.3 Related works on PA promotion through tailored (mobile) messaging

Based on the basic understanding of PA behavior and its determinants, interventions are made in order to change the determinants and thus the behavior. PA behavior change interventions can be delivered through different channels, via face-to-face communication, letters, emails, phone calls, notifications/messaging through mobile phones, etc. Tailored interventions with tailored advice may be more effective to change behaviors. The advantage of tailored advice for PA promotion over standard advice has been found in many studies. The tailored physical activity advice was more positively evaluated than the non-tailored advice (Spittaels et al., 2006; Ryan & Lauver, 2002). The review paper of Tufano and Karras showed that tailored informational interventions were the most effective approach of conventional health behavior interventions for weight loss (Tufano & Karras, 2005).

The use of interactive computer programs makes tailored interventions more cost-effective and useful at the population level. There is growing evidence showing that behavior change programs applying computer-tailoring can be effective in changing lifestyle risk factors (Kroeze et al., 2006). Computer-tailoring uses a computerized expert system and generates feedback and advice based on users’ information. The latest generation interventions include mobile and remote devices such as mobile phones and handheld computers which may enhance the potential for timely feedback and assessment (Norman et al., 2007). We are particularly interested in this newest generation of the computer-tailoring interventions aiming at promoting PA via mobile devices. Firstly we look into research which describes some computer-tailored interventions to promote PA, preferably using mobile phones. Some up-to-date review papers focusing on the effectiveness of this type of interventions are summarized as follows.

One type of intervention provides people with tailored PA advices. There are different methods to “Tailor” messages. A review of computer-tailored interventions for PA behavior showed most commonly used methods as tailoring “feedback” according to the participant's motivational stage of change, or providing feedback that compares participant's behavior to current recommendations (Neville et al., 2009). Besides, advices can be tailored according to theoretical models (e.g., TPB model) or targeted at intentions, attitudes, self-efficacy social support, knowledge, benefits, barriers and special action plans (Spittaels et al., 2006). Other ways are to tailor messages based on the self-report of target behavior characteristics (motivation, preference, habit, etc) (Woolford et al., 2010) or based on the specific health needs and personal preference (Krishna et al., 2009).

In the study of Krishna et al. 25 studies of using cell phones and text messaging interventions in improving health outcomes were evaluated. The messages were tailored to their specific health needs and personal preference and sent to users by “Push” technology. The results showed that
information and education interventions delivered through wireless mobile technology resulted in both clinical and process improvements in the majority of studies. Twenty studies reported significant differences between control and intervention groups as a result of cell phone and text messaging interventions regardless of the frequency of message delivery (Krishna et al., 2009). Besides, an updated review on the basis of a review in 2006 studying the effectiveness of computer-tailored interventions to promote PA and dietary behavior (Broekhuizen et al., 2012) showed that after 2006, a larger proportion of studies found positive effects for computer-tailored programs compared to generic or no information, including those for physical activity promotion (Soureti et al., 2011). However, the evidence for long-term effects of computer tailoring remains inconclusive.

Similarly, in another review ten out of the 17 studies found significant positive effects of the computer-tailored interventions on physical activity or weight reduction outcomes. However, the majority of interventions were delivered using the Internet and/or email, followed by desktop computer programs or telephones, while only one included additional mobile phone technology. No conclusions on their effectiveness can be drawn, given inconsistent results of the studies. The uncertainty lies in whether the reported behavior changes found can be sustained long-term, and whether they are generalizable (Neville et al., 2009).

The advantages of mobile SMS have been shown in a more recent review of the current state of research (2006-2011). It evaluated the effectiveness of text messaging as a health intervention for adolescents and young adults. The on-the-go, discrete nature of mobile SMS is applicable to the age group who is not only frequently mobile users but who also lives and makes decisions in the moment. The review showed that present mobile technology makes portable, interactive, real-time, individualized health interventions possible. Besides, text messaging is an efficient health information delivery method and reminder tool with acceptability and high use in adolescent and young adults. However, it is hard to conclude that the mobile SMS interventions consistently influence healthy behaviors in adolescent and young adult (Preston et al., 2011).

Consistently, a newest systematic review of using text messaging to deliver healthy lifestyle behavior interventions in pediatric and adolescent populations suggests that tailored and personal user friendly interventions delivered by mobile phones is an attractive option for both clinicians and patients, with documented short-term compliance. Interventions with short messaging service may be most effective as a reminder system. However, more vigorous theory-based intervention research using mobile technology is needed (Militello et al., 2012).

The timing to send the messages has not been explicitly mentioned in these aforementioned research studies. Some research schedule a specific time to send the message. For example, in the study of Gerber et al. (2009) participants received regularly scheduled text messages as well as reminder messages concerning healthy diet and physical activity. The results showed that although they were positive toward receiving messages, no evidence was provided to show whether they have followed healthy behaviors subsequent to receiving text messages. In the study of Woolford et al. (2010), a typical computer-tailored intervention consists of a total of 90
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tailored and targeted text messages based on the self-report of target behavior and is programmed to send the messages in a pre-determined order from day 1 to day 90 at 16:00 each day. The participants perceived the intervention as an enjoyable way to improve their adherence to healthy lifestyle practices. In addition, it is suggested that daily message reminders should be timed to parallel the behavior targeted to be effective. This idea is in line with the essence of ecological momentary interventions (EMI), where in the interventions are provided to people during their everyday lives (in real time) and in natural settings (real world) (Heron & Smyth, 2010). The EMI applies devices that are relatively small and convenient for people to carry on in their daily lives thus can provide real-time support in the real world. One particularly appealing aspect of EMI is that the content and timing of the intervention can be tailored to people and intervene at specifically identified moments in everyday life, in order to effectively trigger behavioral change.

Applications running on Smartphone can be used to interact with users at the right time in daily contexts. Mobile phones is a new delivery mode that was not yet available in the studies included in the review of 2006 (Broekhuizen et al., 2012) while the potential of mobile phones have been shown in the latest research. Due to the advantages and given the massive increase of the use of Smartphone worldwide, mobile technologies will and probably should be used more often to promote lifestyle changes (Soureti et al., 2011).

To sum up, researches about computer tailored interventions to promote PA show that only recently mobile devices are used as a new delivery method in tailored intervention design. The content of the messages are tailored to be personalized and suitable for behavior change models, while less attention is given on the timing and context of the intervention. The advantage of the newest generation of computer-tailored interventions is that they are portable, interactive, accessible, and can sense the real-time context. The effectiveness of these interventions in behavioral change in a long term needs to be further studied. To explore the potential of mobile technology in behavior change lies in the center of our attention. In the next section, we describe the concept of “context-aware” persuasion to study PA promotion interventions from another point of view.

2.4 Overview of Context-aware persuasion

In this section, we firstly introduce the concept of context-aware persuasive technology, and some existing applications that apply these technologies for PA and health promotion. These applications show us the potential and challenges of applying context-aware persuasion to trigger behavioral change towards being physically more active.

2.4.1 Context-aware persuasion concept

With the development of information technologies in the 21st century, various new approaches to influence people’s behavior have emerged. For example, computers can be used as a medium to persuade people into certain behavior change. According to Fogg, the technology either designed or employed to intentionally change attitudes or behaviors through persuasion and social influence is defined as “Persuasive technology” (Fogg, 2003). Fogg has defined seven persuasive
technology tools: Reduction, Tunneling, Tailoring, Suggestion, Self-monitoring, Surveillance, and Conditioning. We are particularly interested in the tools of Tailoring, Suggestion and Self-monitoring.

Context is defined as “location and the identify of nearby people and objects when “context-aware” is first introduced (Schilit & Theimer, 1994). Another early definition of context is “location, identity, environment and time” (Ryan et al., 1997). From an operational point of view, context is defined as “any information that can be used to characterize the situation of an entity” (Dey, 2001). It means that, when a user interacts with an application, the relevant information to define the situations forms the context. Location is part of context, but context is far more than location (Schmidt et al., 1999). The need to consider context beyond location has been raised by stating context awareness provides added value by delivering desirable content not only at the right location, but also at the right time and in a proper way (Bisdikian et al., 2001).

The awareness of the user context can enable context-sensitive system behavior and deliver persuasive content that is tailored to the user at the right time and at the right place, which is definition of the concept “Ambient Persuasion” (Aarts et al., 2007). The three persuasive strategies of tailoring, self-monitoring and suggestion used in “Ambient persuasion” are explained as follows.

Tailoring provides information relevant to individuals to change their attitudes or behaviors. The information can be personalized or contextualized, which means that user needs, preference and the context of users are taken into account. Personalization is an essential aspect of ambient intelligence and it requires rich, privacy-sensitive information of users including not only preferences but also their personality, health status, social networks and context, etc (Aarts et al., 2007). In the previous section, we summarized research about computer-tailored interventions. Most of the interventions provide tailoring messages based on the feedback, changes of stages, and user profile and needs, without considering the context of the usage. This confirms what Fogg (2003) mentioned in his book that delivering contextualized information was not easy from a technical point of view. It is difficult to not only locate a user but also determine what activities people are performing, whether they have time, in which mood, etc. Although a decade has passed, the challenge seems to still remain. To effectively persuade people more elements should be taken into account in order to be “context-aware”.

Self-monitoring allows people to monitor themselves and to inform themselves about how they could modify their behaviors. To make sure the persuasion is effective, the information that is presented to people about their physical state, location, or progress on task should be real time (Aarts et al., 2007). People can know better about their performance, and evaluate whether they have the ability to change their behavior, which can be related to “self-efficacy” or “perceived control”.

Suggestion technology reminds people to perform certain behaviors at the most opportune moment. The persuasion is more effective when the advices are given at the right time to prompt
behaviors. To determine the best timing, it requires the understanding of the context, which is a key in ambient persuasion (Aarts et al., 2007).

Tailoring, monitoring and suggestion technologies can be integrated best in users’ interaction with mobile devices, because mobile devices can intervene in the right context and a convenient way. They tracks context and prompt users to take action, as Fogg’s description of one persuasive role of mobile phones - “coach” (Fogg & Eckles, 2007). Persuasion on mobile platforms can be integrated into users’ daily life and interact with people at any time. As Intille stated, ubiquitous computing and context-aware persuasive technologies offer a new healthcare opportunity to promote health behavior by presenting “just-in-time information” (Intille, 2004a; Intille, 2004b). Mobile phone and sensors can be used to achieve “context-awareness” of user activities and location in order to give feedback of their performance (self-monitoring) and provide personalized messages (tailoring) at the right time (suggestion) to stimulate healthy behavior. This is the design concept of the context-aware advice system that we aspire to develop.

In addition to the interventions that are mainly applying “tailoring” messaging described in section 2.3, many applications focus on self-monitoring or “in time” suggestions. Therefore, in the following section, an overview of such applications is given as inspirations for the design of our system.

2.4.2 Related applications of “self-monitoring” and “suggestion”

“Self-monitoring”
Applications applying monitoring and sensing technologies have the advantage of providing feedback about people’s performance and help them adjust their behavior in order to keep up with the optimal goal. The applications such as PAM (Slootmaker et al., 2009; Arteaga et al., 2010; Damen, 2007; PAM, 2012), DirectLife (Philips Research, 2008) and Fitbit (Fitbit, 2012) use a portable device with an accelerometer to measure the activity level of users. The activity data needs to be either uploaded to a PC or wirelessly communicate with a base station near the PC to a web service. Users can view their weekly/daily performance on the website and set their weekly/daily goals. Some other features such as comparing performance with others, getting coaching advice are also included. A randomized control trial for 9 weeks to evaluate the PAM intervention was conducted and the results proved a significant increase of PA level, weight loss and improvement of some PA determinants (Slootmaker et al., 2009; Hurtling et al., 2007). However, the randomized controlled trial study of PAM intervention showed that office workers did not improve their PA behavior or its determinants significantly due to the usage of PAM for either 3 or 5 months. They did not find the tailored advice appealing as well (Slootmaker et al., 2009).

Instead of using PC, another application called BeWell Mobile system transmitted personalized motivational messages to patients’ mobile phones to help them control various diseases. This study indicated advantages of using mobile phones to support behavior change due to the immediate interaction for an easy self-management of users (Boland, 2007). Another more
commercial product called BudyBugg (BodyBugg, 2012) measures body temperature, step count and acceleration with an accuracy of 89-98% of calories burned of users. The calories data is transmitted on users’ personal mobile phone application for reviewing.

A prototype application called “Activity Monitor” adopts Windows mobile phone with Bluetooth support and combines acceleration and radio data to evaluate a user’s activity all day long. Feedback including statistics about user performance, points of Interest (PoI), user location and activity are presented to users for their awareness (Iglesias et al., 2011).

UbiFit system (Consolvo et al., 2009b) used an interactive display of a garden to represent one week’s activity of users, based on their individual goal setting. The activities of users are measured by a separate device (MSP’s 3D accelerometer) to determine the activities of walking, running, cycling, activities, etc. Their research has focused on motivational effects of the interactive interface design on behavior change (Consolvo et al., 2009a). They argue that supporting persistent cognitive activation of goals, encouraging various healthy behaviors, focusing on patterns of activity, and facilitating social support, effective systems can be developed that motivate behavior change when and where people make decisions (using mobile & personal sensing).

These applications focus on cognitive and social aspects in persuasion, such as goal-setting, personality, social support, etc. Feedback about user performance can help people be aware of their progress towards their goals and at the same time they can compare with other people or get social supports.

“Suggestions” in time

The advantage of suggestion technology is that it can help people identify when and where they may make a decision to change behaviors. In this way, the suggestion technology can help them reframing the way they see the world and incorporate new behavioral strategies into their lives (Andrew et al., 2007). To achieve successful persuasion, the suggested action must be able to be implemented within enough time. Timing involves many elements in the environment including physical setting to the social context, as well as the feelings and mood of people. People are more open to suggestions when they are in a good mood. They are more likely to comply with a request are able to take actions immediately, or when they feel obliged to return a favor or make up for their mistakes (Fogg, 2003).

Some example of applications that use mainly “suggestion” persuasion is combined with monitoring technology to sense real-time data. MPTrain (Oliver & Flores-Mangas, 2006) and SportsCoach (Westerink et al., 2011) both monitor the heart rate and pace of runners by a chest-band, and use changeable music with different tempo to implicitly instruct runners to adjust their running speed, in order to reach the optimal heart rate. Similarly, Nike+iPod uses a sensor in the runner’s shoe to help them keep track of their pace and distance, and provide some audio feedback during the running process to keep them motivated (Nike+iPod, 2012). The timing of
the suggestions from these applications is based on the activity status of the users. It is the moment for a best exercise effect, but it is not at the time that people are persuadable.

There are rather fewer applications that take advantage of suggestions as the primary persuasive strategy for persuading, some possible reason have been proposed by Andrew et al. (2007). An effective suggestion strategy using context-aware mobile system should require the system to be robust and predictable, while at that moment, the context-aware mobile technologies were rather new, and still in the exploration phase (Andrew et al., 2007). With the technology development in the recent years, context-aware mobile applications become prevalent in both research filed and for commercial usages. In the following section, we give an overview of some latest mobile applications, especially with location-based technologies to promote PA behaviors.

2.5 State-of-the art Location-based mobile applications for PA promotion

LBS are often called location-aware computing or context-aware services, since location and context play importation roles. Context changes have its impact on information retrieval, user actions, and user behaviors with LBS application (Jiang & Yao, 2006). Context-aware mobile application requires location-sensing technologies to locate the users. Some applications take interests in mobile applying location sensing technology on mobile device as health promotion tools. User location sensing is introduced in many applications, as another approach to determine PA level. The prototype called Shakra tracks the daily exercise activities of people carrying phones. The visible GSM cells and their signal strength are analyzed with Artificial Neural Network (or Hidden Markove Models) to estimate a users’ movement such as stationary, walking or driving. Users can share their activity overview weekly with friends and relatives (Anderson et al., 2007). Another prototype called Footpaths was designed to suggest most suitable walking route, by measurement of a user’s cardio respiratory fitness level, through the use of a wearable wireless sensor network. The GPS function in the mobile device was enabled to record parameters such as user location, destination, and land contour to determine the best route (Waluyo et al., 2009). A most recent research “CASanDRA Mobile” proposed a design to evaluate a user’s activity level by using external accelerometer while indoor and outdoor location sensing by Bluetooth, Wi-Fi, GPS, etc. Thus ‘motion patters’ and ‘activity profiles’ can be combined to decide which activities to suggest to users (Bernados et al., 2010). These ideas of these prototypes are inspiring for us, but all these studies are still on their development stages.

On the other hand, the commercial products emerge since Smartphone becomes popular. Some mobile phone applications engage users to do PA while having fun. For example, Neat-o-games is a collection of games use accelerometer information as input to estimate users’ PA level, which determine their winning or losing (Fujiki et al., 2008). A mobile persuasive application motivates teenagers to be physically active by presenting iPhone games that involve PA based on their personality, while users need to manually input their PA data (Arteaga et al., 2010).

Recently many newest Smartphone applications emerged in the category of health and fitness. For example, some applications record the route, time and speed of the exercise of users (i.e.,
running, cycling and walking). Accelerometers and GPS built in smartphones are used to record their activities and provide feedback by presenting their performance and location traces on maps, e.g., Map My Tracks OutFront, Nike+GPS, RunKeeper, Runtastic, etc. The other type of the applications such as Virtual Trainer, Fitness Pro, GAIN Fitness provide instructions for fitness workouts based on users’ body, goals and schedule. The users can log their activities to the application and see their progress (Apple Store, 2012; Android developers, 2012). In a most recent study, three iPhone applications (iTreadmill, iFitness Hero and Exercise Tracker) were evaluated to learn users’ desired features of applications for PA promotion. The results indicated a few user preferences such as user-friendly interface, automatic tracking of PA, calories burned and progress. They also stated that an optimal application should be used for a range of indoor and outdoor activities and include features that help them overcome common barriers to PA (e.g., bad weather) and set weekly goals (Rabin & Bock, 2011).

The newest trend of using Smartphone and location-based technologies makes the just-in-time information presented at a right location and time feasible. The findings of a recent survey of the usage of healthcare applications on Smartphone, showed an optimistic future for mobile health and wellness applications (Euro RSDG Life 4D, 2010). The potential of mobile and location-technologies is clear. Mobile phone is not only a real-time tailored message delivering device, but also can capture user context and monitor their behavior. If these technologies are considered with persuasive technology together, effective systems can be developed for behavior change.

2.6 Conclusions

The overview of the fundamental theoretical models and determinants of PA behavior helps us understand the process of initializing and maintaining the PA behavior. Personal and social factors such as demographic situation, intention, social norms and especially perceived control (self-efficacy) are associated with PA behavior. In addition, more recent literatures suggest the possible influence of environmental factors and a need to explore these factors more with higher quality methodologies.

The literature review of PA promotion interventions with tailored messages via mobile device shows the potential and challenge of applying mobile technologies to effectively trigger behavior change. The concept and related works of context-aware persuasion presents how applications influence behaviors by using self-monitoring and suggestion. The up-to-date Smartphone applications also show the feasibility of mobile and location-technologies together to capture user real-time context, monitor their behavior and deliver tailored messages.

We conclude that many existing applications adopting tailoring and self-monitoring strategies to monitor user activity, give feedback and provide users with personalized suggestions. The challenge is to create contextualized tailored suggestions and find the best timing to interact with people. How to incorporate “suggestion” strategy into a personal mobile assistant application that provides just-in-time advice at the right location is our motivation for this research.
To sum up, the literature review provides us with insight into the fields of PA, interventions, context-aware persuasion, and state-of-the-art mobile applications. The main focus of our system design is to explore how to motivate people to behave more physically active by providing personalized and context-aware messages at an appropriate time and place. The system that we intend to develop will evolve up-to-date mobile and location-based technologies.
Chapter 3. Concept Design of a location-based adviser system

3.1 Introduction

This Chapter introduces our endeavor of designing the concept of a location-based adviser system. With the purpose of understanding people’s general behavior of physical activities and how they thought about the concept of the adviser system, we began with our first attempt of a questionnaire study. Based on the results we detailed our design and sequentially we conducted a Wizard-of-Oz study to find out the feasibility of context-aware advice generation and user feedback to the suggestions.

The goals of the questionnaire and the Wizard-of-Oz study are to answer the following questions:

- Which activity suggestions to use to encourage PA
- User acceptance of the concept of the system and advices
- How to define Context

3.2 Questionnaire Study

The first aim of an online questionnaire was to gain insight into the general behavior and attitudes with respect to PA and related aspects such as motivation, habit, barrier, etc. This can help us understand the current situation and the needs of people in order to find the best strategy for healthy lifestyle promotion. The second aim was to investigate the user acceptance of the idea of a location–based activity adviser. Finally, we intended to explore the effects of some design rules on encouraging PA. An online questionnaire system designed and developed by Joran Jessurun of the DS group was used to program this questionnaire study in both English and Dutch language.

3.2.1 Questionnaire design

Part 1: general questions about PA

Questions were designed to learn about the general behavior with regard to conducting physical activities of the citizens in the Netherlands. The aspects of PA that we were interested in were activity level (Q1), daily physical activities (Q2), reason for PA (Q3), awareness (Q4), intention (Q5) and motivation to become more active (Q6). In total 6 questions with multiple choice answers were constructed as follows:

Q1: How many days a week do you practice moderate to vigorous activities of at least 30 minutes? (for instance: brisk walk, cycling, jogging, playing basketball, squash, football, swimming, dancing, gardening, etc).
Q2: Which physical activity (activities) do you usually do? Choose (one or more than one) from the list below: walking, cycling, jogging, football, swimming, fitness, dancing, aerobics,
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housework, take stairs, stretching, activities at home, gaming, walking/cycling to do shopping, etc. How often do you do these activities, with whom?

Q3: Why do you do physical activities?
Q4: Do you think you do enough physical activities?
Q5: How would you feel about getting personalized advice on physical activity?
Q6: Which circumstances would motivate you towards becoming more physically active?

Other general information of respondents such as age, gender, marital status, work status, education, etc was also collected. All the questions and multiple choices of the answers were described in details in Appendix A (a).

Part 2: willingness of using the system
We asked respondents to assume that they had a mobile application described as follows:

“An activity adviser is embedded in your mobile phone which can detect your location. Meanwhile an activity measuring device can calculate how many calories you are burning. The system will compare your performance with your personal target and provide activity advice to you during the day.”

They were asked to give their opinions about this system by answering:

*What do you think about this system?*
- I like this idea and might consider using the system.
- I don’t like this idea and I won’t consider using the system.
- I don’t know yet, but I may want to give it a try.

Part 3: opinions about advice with various variables
We are interested in how personal and social factors that we derived from the literature study would influence people’s acceptance of advices. An overview paper of Byrne and Esrambolchilar looked into technologies and methods utilized to encourage people to have an active lifestyle and proposed some design guidelines: goal setting; social feature; feedback and reminders (2010). Consolo et al. indicate four key design requirements of technologies that encourage physical activity (2006): Provide personal awareness of activity level; Give users proper credit for activities; Support social influence; Consider the practical constraints of users’ lifestyles.

Based on these design rules that can influence the effectiveness of encouraging physical activity, we would like to find out the effects of four factors on acceptance of advices. These four variables are:

- Performance: provide information about current performance of users compared with their target (25%, 50%, 75% and target reached).
- Encouragement: Provide encouragement of reaching an increase of 25% of their target if following the advice.
Social feature: with companionship to do the activities together.

Advice: specific advice (take stairs, go to park) vs. general advice of “do some physical activities”.

The encouragement is given to reach 25% of the target more. When the performance of a subject already reaches the target, the encouragement becomes “stay above the target”.

The advices are created for two situations.

**Situation 1**: During lunch break on a weekday, when at work.

**Situation 2**: On a weekend morning, at home.

The details of the four variables are described in Table 3.1.

For each situation, all possible combinations of the four variables created 32(4*2*2*2) profiles in total. An orthogonal ½ fractional factorial design was used to generate 16 profiles, which were blocked into 2 sets of 8 profiles. Half of the respondents received 8 profiles (set 1) and the other half received the other 8 profiles (set 2). Details of all 16 profiles in situation 1 and situation 2 are shown in Appendix A (b).

### Table 3.1 Variables description

<table>
<thead>
<tr>
<th>Variable</th>
<th>Values</th>
<th>Text for the advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>0</td>
<td>You have achieved 25% of the target</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>You have achieved 50% of the target</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>You have achieved 75% of the target</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>You have achieved 100% of the target</td>
</tr>
<tr>
<td>Advice</td>
<td>0</td>
<td>How about taking stairs (Situation 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How about walking to the park nearby (Situation2)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>How about doing some physical activities</td>
</tr>
<tr>
<td>Social feature</td>
<td>0</td>
<td>With your colleagues (Situation 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With your friends (Situation2)</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>Encouragement</td>
<td>0</td>
<td>Then you will reach (50%/75%/100%/Above) your target</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>None</td>
</tr>
</tbody>
</table>
An example of the advice with four variable values (0, 0, 0, 0) for Situation 1 was: “You have achieved 25% of your target. How about taking the stairs with your colleague? Then you will reach 50% of your target.

Another example with variable values (1,1,1,1) was: “You have achieved 50% of the target. How about doing some physical activities?”

One example of the advice with four variable values (3, 0, 0, 0) for Situation 2 is: “You have achieved 100% of your target. How about walking to the nearby park with your friends? Then you will stay above your target.”

Each respondent were assigned 16 advices in total (8 advices representing 1 profile set for Situation 1 and 8 advices representing 1 profile set for Situation 2). The online questionnaire system was programmed to make sure that the occurring times of profile set 1 and set 2 for each situation were as same as possible.

The respondent could choose their response to each piece of advice from the list:

- Yes, I will follow this advice
- No, I will not follow this advice

3.2.2 Respondents

We sent this online questionnaire in both Dutch and English to a random sample of 1800 residents who were living in the surroundings of North-Holland. After two weeks, 75 (4.2%) people (18 male, 57 female) had answered the questionnaire. 95% of them were aged between 21 and 50, with 43 (57.3%) respondents aged between 31 and 40. In total, 64 (85.3%) of them were married, and 63 (84%) respondents were working.

3.2.3 Results

Results for general PA behavior

The respondents conducted moderate or intense physical activities for more than 30 minutes for 3.8 days per week on average, while 34 respondents for at least 5 days per week (Q1). 37 out of the 75 respondents thought that they already had enough physical activities (Q4). The most frequently conducted activities were: walking (68%), cycling (55%), doing housework (53%) and doing sports (32%), such as football, basketball, tennis, dance, aerobics, etc. The activities of walking, cycling and doing housework were conducted more frequently (> 4 days per week) compared to doing sports (on average 1 day per week). The majority of the respondents normally conducted activities of walking (65%), cycling (89%) and doing housework (93%) alone while only 30% of them were doing sports alone. They did sports with group members or friends (Q2).

The most popular reasons for doing physical activities were for health (58%), relaxation (55%), and fun (40%) (Q3). Factors that motivated them to be physically more active were chosen most as “more time” (78%), “affordability of the facilities” (35%), “companionship to exercise
“more nature around the neighborhood” (28%) (Q6). In total, 32% of the responders were positive towards getting personalized advice on physical activities, while 47% were negative and 21% chose “I don’t know” (Q5).

**Willingness of using the system**
When respondents were asked about their willingness of using the system, six (8%) respondents chose “I am enthusiastic about the system and I want to use it”. 26 (33%) respondents chose “I am not enthusiastic and I am not going to use it”. The remaining 43 (59%) respondents chose “I don’t know yet, but I may want to give it a try.”

**Acceptance of advices**
A logistic regression analysis was performed on the respondent responses and the four variables. In situation 1 (weekday, take stairs) the results showed that the variables of advice type and social feature significantly predicted the acceptance of the advice ($P < 0.05$). The results represented by Decision Tree CHIAD analysis suggested that the specific advice was more likely to be accepted (Figure 3.1). In general, 58.5% of the messages received the “Yes” response. When the advice was specific (take stairs) instead of general (do physical activities), the “Yes” rate was 71.8% instead of 45.2% for general advice. When the advice suggested “with your colleagues”, for both specific and general advice, less positive responses were found.

No significant results were found for situation 2 ($p > 0.1$). 40.3% of the advices of going for a walk to the park received a positive response, while 48.6% of the advices of general physical activities received a positive answer.
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3.2.4 Discussion

The very low response rate to the questionnaire suggested their rather low interest for participating in this survey on PA. The request of answering to a questionnaire by email has the chance of being considered as a spam for the receivers, which may cause the low responses rate. About half of the respondents met the standard NNGB (de Nederlandse Norm Gezond Bewegen in Dutch or health activity standard), which was consistent with the situation of the Dutch population according to the data of CBS StatLine (2008) (RIVM, 2008). More females than males answered the questionnaire and the majority of respondents were married and currently working. This highly selective small sample of respondents cannot be generalized to understand the PA behavior of all Dutch citizens.

Most activities the respondents did were common activities such as walking, cycling and doing housework, rather than specific activities such as doing sports, fitness, or jogging. This is in line with the research showing that the most important activities are domestic work and movement by means of bicycle or on foot for the Dutch citizens Breedveld et al. (2006). These simple to do activities fit into people’s daily schedules easily and do not consume extra time, which is an advantage for people who have limited time. Besides, “More time” was rated as the most important factor that can motivate them to be more active, thus easily accessible lifestyle activities can be highly recommended as physical activity ideas. Apart from health reasons, one

Figure 3.1 CHAID analysis of advice acceptance
important reason for doing PA is relaxation and leisure. This motivation indicates the necessity to
develop more appealing advices related to leisure and fun. “More nature around the
neighborhood” was rated as a potential motivation, which is in line with the research of Giles-
Corti & Donovan (2002) and Sallis et al. (1998), and our expectation of the impact of the
environment on doing physical activities.

The opinions about this adviser system indicated that the majority of the respondents were not
sure whether they would like this kind of system. This can be due to the fact that half of them
were quite active and stated that they did not want to get personalized advice, which may be
indicative of sample bias. The reason could also be that they were not familiar with the new
technologies due to the rare possession of Smartphone in 2008. In total, more than half of the
respondents would like to try this new concept, which suggests the potential of such a system in
the future.

The results related to the responses to various advices indicate a significant and positive
influence of “specific” advice compared to general advice, which is in line with the research of
Spittaels et al. (2006) and Ryan & Lauver (2002). But it seems that the involvement of social
features (take stairs with your colleague) reduced the intention of following “taking stairs”
advice. The reason could be that “taking stairs” is not a social activity therefore a companionship
is not necessary. Although “social contact” was not rated as a major reason for the purpose of
exercising, “companionship to do exercise together” was considered to be a motivating factor.
We can conclude that the impact of social factors depends on the characteristic of the activity.
The variables performance and encouragement were not significant predictors for user response.
The extra information about user performance and encouragement to reach the goal has no
impact on the intention to follow the advice. This may be attributed to the fact that imagining this
information to make a choice was rather difficult.

3.2.5 Indications for concept design

As our starting point, this questionnaire study enriches our knowledge of people’s general
behavior of doing physical activities and their first impression of our system design. Although
picturing how the technology works within a specific context is a challenge for respondents,
more than half of the respondents show their willingness to use such a system, which is
encouraging.

The results provide us with some guidelines on how to create motivating advices to encourage
PA.

- Lifestyle activities such as walking, cycling and housework that fit into daily schedule
  and take little time can be good advices.
- Relaxation and fun was another reason for PA in addition to health. Attention should
  be given on appealing recreational activity as well.
- Concrete advice is more motivating than general advice.
Motivate: a Context-aware mobile application for physical activity promotion

3.3 Wizard-of-Oz Experiment

Factors such as environment and context can influence people’s perception in various circumstances and their motivation of doing PA. This inspires us to explore the impact of contextual factors on PA behavior in addition to interpersonal factors. In order to achieve that, the application should be “context-aware”. The localization technology needs to be explored to find out the feasibility of a LBS integrating GIS, mobile and communication technologies together.

In the questionnaire study we have explored the user acceptance of the activity advisor system concept and how to make the content of the suggestions motivating. We have only presented the system with the feature of giving advice based on user location and activity level, without offering any real context-aware advices. Therefore, the next step is to explore how to identify user context and create context-aware advices. We intend to test the concept design of the advice system through a Wizard-of-Oz experiment, in which we operate the advice generation process manually.

“Wizard-of-Oz” is a user evaluation method that explores the design and usability of pervasive computing applications when the technology is not implemented. The users interact with a system that they believe to be autonomous, while it is operated manually by people. This technique can be used to test the concept and functionality, gather user feedback, and test input techniques, before it is implemented (http://usabilitybok.org/wizard-of-oz).

Following this method, we sent SMSs with physical activity advices to people’s mobile phone, in order to learn their opinions on how suitable and motivating the advices are. The creation and selection of the messages during the experiment provided us with the opportunity to explore and extract user context information for advice generation. The main purpose of the small-scale experiment is to answer the following question: How to define user context in order to create suitable advice?

3.3.1 Initial concept design

The basic concept design is inspired by the literature review reported in Chapter 2. The combination of tailoring and suggestion technologies for persuasion requires personalized and contextualized information that is presented at the right time. In our research, how to create contextualized information and how to determine the good timing is the center of our attention. Thus, we aspire to explore to what extent information technology can be applied to generate contextualized information at the right time.

Location-based technologies can be used to track user location in order to create suitable advice for that specific location. The basic feature of LBS is location-sensitive. Therefore, user location is essential. Based on the user location, the surrounding environment information (geographic information) together with weather condition can be important for creating a suitable suggestion, especially for outdoor activities.
Chapter 3: Concept Design of a location-based adviser system

The question is how detailed the information of user location needs to be. In the research of Khan (2009), it is suggested that a design should provide only meaningful and qualitative place information. This course information of place is proven to be meaningful without threatening the privacy of users. Therefore, for our research, the user significant places “home” and “work” are set as the location information for triggering relevant advices.

In order to determine the good timing, we need other information about user activities, time availability, etc. A good timing depends on which activity a user is doing, whether they are available, which plan they have in mind, what they need, how their mood is, etc. When people are rather inactive, they may be more willing to follow activity advices. The activity level being recorded by an activity monitor can be used to determine the time when people need more physical activities.

Bearing this in mind, we started off with the concept design of a context-aware recommendation system that requests user location, environment, weather and profile as system inputs. The first version of the concept design of our system is shown in Figure 3.2. A user carries a location sensing device and an activity monitor, while the collected data of user location and activity level are transmitted to the Activity Adviser system. The advice generation takes the context inputs such as weather and geo information of the surrounding environment into account. User profile can be essential to generate “personalized” advice and should be considered. When an advice is created, it is sent to the mobile device in the form of a short message.

Figure 3.2 concept design
3.3.2 Experiment Materials

GPS loggers

The Global Positioning System (GPS) is widely known due to the worldwide satellites that have reliable and ubiquitous coverage. Some inexpensive GPS receivers can localize positions to within 10 meters for approximately 95% of measurement and expensive receivers can reach 1-3 meters accuracy in 99% of the time (Hightower & Borriello, 2001). GPS localization is accurate with reliable and ubiquitous coverage. GPS logger is a device that logs the position at a regular time interval and save them in its memory. The advantage of GPS logger is its low costs and long battery life. We employed the model iBlue 747A+ GPS logger as location-sensing device (Figure 3.3). The GPS logger has an up to 32 hours battery life, is light weighted (64 g) and easy to carry (TranSystem Inc., 2012).

![Image of GPS logger](image)

Figure 3.3 GPS logger

The GPS loggers recorded location data in terms of date, time, latitude, longitude, height, speed, distance, PDOP (position accuracy of 3D coordinates) and HDOP (horizontal accuracy of 2D coordinates). In this thesis we call the location point at a certain moment that is recorded by GPS loggers “GPS data”, and a collection of GPS data ordered by time “GPS trace”.

The software of “DataLog” was used to download the GPS trace to a PC. The user interface of the software is shown in Figure 3.4. The GPS logger recorded every 5 seconds in the setting. The GPS trace can be saved as “.csv” format file to a local PC.
Figure 3.4 GSP data details uploaded to PC by software “DataLog”

Activity Monitor
We used DirectLife activity monitors (Philips Research, 2008), which is a water-proof activity monitor using a 3D accelerometer to measure daily activities in the term of calorie burning. The activity data needs to be updated to a PC in order to be sent to a web service. Users can view their daily and weekly performance on the website and set their weekly goal. The screenshot of the DirectLife website is shown in Figure 3.5. The performance of a user during one day is shown on the website for viewing.

In order to be able to define the appropriate timing of triggering, we will need to have access to detailed activity data of all participants. Therefore, we had temporary access to the required data only during the experiment period.
3.3.3 Procedure

Participants
Participants were recruited through emails to a group of DirectLife users within Philips. Four male employees (three at the same group) responded to take part in the study. They aged from 27 to 33 years old, worked five days per week, lived in Eindhoven and the surrounding area. The distance between their home and work places varied from 4 to 6.5 km. Three of them had higher education.

Method
Participants wore the GPS loggers and the activity monitor every day for four weeks. They uploaded their log data of GPS loggers to their PC and send the file to us by email. Their activity data from the activity monitors were uploaded to the DirectLife website. For the first two weeks, no message was given. After two weeks, participants received SMS messages on their mobile phone at different times, such as in the morning, during lunch break, or in the evening. They were asked to read the SMS when they received them. At the end of the two weeks, participants filled in a questionnaire and were interviewed individually. In the interview they were asked their opinions on the SMSs in general and also their reactions to each SMS.

Activity pattern
We deployed the software called “TraceAnnotator” using Bayesian belief network to process GPS traces automatically and impute transportation modes (walk, by bike, by car/bus/train) (Moiseeva et al., 2012). Activity type is identified by fusing GPS data with GIS land use data and personalized land use data. For each participant, we use the address of their significant places (home and work) to fuse GPS data and determine their activity type, time, duration and location. One example of the output of processing one day GPS trace data of a participant is shown in a

Figure 3.5 Screenshot of DirectLife website. The activity monitor (left); One day’s activity level of a user (right)
Chapter 3: Concept Design of a location-based adviser system

HTML file (Figure 3.6). The location and route of the participant of that day is presented on Google Earth (Figure 3.7).

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Event</th>
<th>Duration</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>06-04-2009 07:56:01</td>
<td>06-04-2009 09:27:11</td>
<td>ACTIVEZONE</td>
<td>1 hours, 31 minutes and 10 seconds</td>
<td>work</td>
</tr>
<tr>
<td>06-04-2009 09:27:11</td>
<td>06-04-2009 09:30:41</td>
<td>WALKING</td>
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</tr>
<tr>
<td>06-04-2009 09:30:41</td>
<td>06-04-2009 09:36:02</td>
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<td>5 minutes and 21 seconds</td>
<td>work</td>
</tr>
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<td></td>
</tr>
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<td>work</td>
</tr>
<tr>
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<td>06-04-2009 10:14:05</td>
<td>BIKE</td>
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</tr>
<tr>
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<td>06-04-2009 11:10:25</td>
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</tr>
<tr>
<td>06-04-2009 11:29:22</td>
<td>06-04-2009 16:28:11</td>
<td>ACTIVEZONE</td>
<td>4 hours, 58 minutes and 49 seconds</td>
<td>work</td>
</tr>
<tr>
<td>06-04-2009 16:38:47</td>
<td>07-04-2009 05:00:00</td>
<td>ACTIVEZONE</td>
<td>12 hours, 1 minutes and 13 seconds</td>
<td>home</td>
</tr>
</tbody>
</table>

Activity agenda of 06-04-2009

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Event</th>
<th>Duration</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>07-04-2009 05:00:00</td>
<td>07-04-2009 06:31:25</td>
<td>ACTIVEZONE</td>
<td>1 hours, 51 minutes and 25 seconds</td>
<td>home</td>
</tr>
<tr>
<td>07-04-2009 06:51:25</td>
<td>07-04-2009 07:33:16</td>
<td>ACTIVEZONE</td>
<td>35 minutes and 8 seconds</td>
<td>work</td>
</tr>
</tbody>
</table>

Activity agenda of 07-04-2009

After observing the output of multi-day GPS log files on Google maps and the analysis of TraceAnnotator, we derived activity patterns on weekdays for each participant. We categorized the time and location of their main activities, such as commuting, working, staying home, etc. The trace for weekend differed and it was hard to extract a fixed pattern. Since we only had
offline data at our disposal, we assumed that in the last two weeks the participants would follow the same activity pattern as the first two weeks.

One example of a weekday pattern for one participant is as follows:

<table>
<thead>
<tr>
<th>Time slot</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00-8:00</td>
<td>Get up</td>
<td>home</td>
</tr>
<tr>
<td>8:00-8:30</td>
<td>bike to work</td>
<td>Home-&gt;work</td>
</tr>
<tr>
<td>8:30-18:00</td>
<td>Work</td>
<td>work</td>
</tr>
<tr>
<td>12:00-13:00</td>
<td>Lunch walk to canteen</td>
<td>near work</td>
</tr>
<tr>
<td>18:00-18:30</td>
<td>bike home</td>
<td>Work-&gt; Home</td>
</tr>
<tr>
<td>18:30-23:00</td>
<td>Unknown</td>
<td>home</td>
</tr>
</tbody>
</table>

At the same time we reviewed the activity data of participants on DirectLife website in the first 2 weeks. Figure 3.5 shows the calories burned hourly of one participant during one day and it can be concluded the time that a participant is rather active (morning cycling to work/home) and inactive (at work, evening at home). The inactive time period might be a good moment for sending advice.

**Rational for advice creation**

*Advice choice: lifestyle activities*

Within the context of physical activity research, lifestyle activities are defined as “fit easily into a one’s daily routine” (Frank et al., 2003), or more specifically as “includes all leisure, occupational, or household activities that at least moderate to vigorous in their intensity and can be planned or unplanned activities, that are part of everyday life” (Dunn et al., 1998). The advantage of lifestyle activities is that they have higher prevalence and adherence rates than fitness-related exercises (Dishman et al., 1985). Reviews also showed that lifestyle PA interventions have long-term effects, both on increasing moderate-intensity PA and reducing sedentary activity (Dunn et al., 1998). Although people may get greater health benefit from structured exercise, they are easier encouraged to perform leisure activities, particularly young adults (Shephard, 1997).

Lifestyle physical activities are activities that can be done as part of one’s normal daily routine. They require little skill, and can be easily performed by most people. Therefore we picked up activities of walking, cycling, stretching etc, in different contexts.

*Location choice*

The suggested locations of lifestyle activities we include in our system are: everyday activity destinations (shops, homes, schools, workplaces etc.) and informal activity for leisure - playgrounds, parks, gardens, etc. Based on their GPS traces, we listed the parks, lakes, supermarkets, walking/biking routes, or other places suitable for doing physical activities within each participant’s living/working area by using Google map and Google earth.
Timing
During weekdays we only sent messages at the time based on their activity pattern. We tried to send SMS during the time that the participants were rather inactive at work or at home. Due to the flexibility of the weekend schedule, the advice for the weekends was not restricted to the nearby environment but also including activities at more distant places. Outdoor activities for leisure purposes such as cycling or walking to a park, and events were suggested in the weekends, mostly in the morning and afternoon.

Other considerations
Advices for outdoor activities were sent only when the weather condition was fairly good. Due to the weather conditions during the experiment period in April (average temperature is 12 degree, min average 8 max average 18) (weather underground website), we defined good weather as “sunny with a temperature above 15 degrees); fair weather as “cloudy with a temperature above15 degrees” or “sunny/cloudy with a temperature between 10-15 degrees); bad weather as “a temperature below 10 degrees, or when the condition is not sunny or cloudy, e.g., raining”.

Transportation mode is considered as a main user profile. A participant who commuted to work by car and the distances to work location was within 30 minutes by bike would get advice of going to work by bike for a change.

Advice examples
Details for the considerations of each advice are described in the table below:

<table>
<thead>
<tr>
<th>Advice</th>
<th>Time</th>
<th>Location/geo information</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>coffee break</td>
<td>Weekday, 10:00-15:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lunch walk</td>
<td>Weekday, Lunch time</td>
<td>A green place near work location</td>
<td>Good/fair</td>
</tr>
<tr>
<td>active home</td>
<td>Evening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>walk after dinner</td>
<td>Evening</td>
<td>A green place nearby home location</td>
<td>Good/fair</td>
</tr>
<tr>
<td>shopping</td>
<td>Weekday, After work</td>
<td>A supermarket within in cycling distance</td>
<td></td>
</tr>
<tr>
<td>detour/bike</td>
<td>Weekday, After work</td>
<td>A green place on the way back home from work</td>
<td>Good</td>
</tr>
<tr>
<td>weekend cycling/walk</td>
<td>In the morning</td>
<td>A green place (park, lake)</td>
<td>Good</td>
</tr>
<tr>
<td>event</td>
<td></td>
<td>Event in Eindhoven and surrounding area</td>
<td>Good/fair</td>
</tr>
</tbody>
</table>

In the last two weeks we sent 10 SMS messages to each participant in total. Advice examples are as follows:
Motivate: a Context-aware mobile application for physical activity promotion

<table>
<thead>
<tr>
<th>Activity</th>
<th>SMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>coffee break</td>
<td>“Break time! How about getting off your chair and walking to the coffee corner (maybe the one on the next floor)? Take your time, stretch your body and relax!” (sent at 15:00, 16th April, Thursday)</td>
</tr>
<tr>
<td>lunch walk</td>
<td>“Walking along the Dommel River, to the small lakes next to the HTC after lunch is a nice way to exercise and enjoy the sunshine!” (sent at 11:30, 9th April, Thursday)</td>
</tr>
<tr>
<td>active home</td>
<td>“You can be active at home too. Walk around, stretch…get active during ads breaks on TV! Washing dishes and tidying up are good exercise as well!” (sent at 20:00, 21st April, Tuesday)</td>
</tr>
<tr>
<td>walk after dinner</td>
<td>There’s still time till it gets dark. Feel like doing something instead of staying home? How about taking a walk along the channel nearby after dinner? “(sent at 19:00, 18th April, Saturday)</td>
</tr>
<tr>
<td>shopping</td>
<td>“Do you want to go to the supermarket X in your neighborhood to buy something fresh? It is just 15 minutes by bike from your home!” (sent at 18:30 8th April Wednesday)</td>
</tr>
<tr>
<td>detour/bike</td>
<td>“How about going to work by bike instead of by car today? It’s warm and fresh outside!” (sent at 7:30 10th April, Friday)</td>
</tr>
<tr>
<td>weekend cycling/walk</td>
<td>“How about biking to Karpendonkes Plas or stadwandelpark, and walking around the beautiful lakes?” (Sent at 15:40 17th April, Friday)</td>
</tr>
<tr>
<td>event</td>
<td>“Have any plans for Sunday? There are walking activities ‘familiewandeling’ starting at 9am organized by IVN in Geldrop tomorrow. Isn’t that nice to walk in the nature with your family or friends?” (sent at 16:00 11th April, Saturday)</td>
</tr>
</tbody>
</table>

### 3.3.4 Results

We compared the activity level of participants in terms of calories burned during the first two weeks with the last two weeks and found no significant difference ($p > 0.1$). The participants filled in a 7 point Likert-scale questionnaire about their general opinions on all the messages they received. Their ratings are listed in Table 3.4. They were fond of the idea of receiving SMS with suggested activities and they felt that the content was rather personalized and clear, but averagely motivating.
Table 3.4 Score for general opinions

<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you think about the idea of receiving SMS about activities to improve your health? 1:Bad...7:good</td>
<td>5.8</td>
</tr>
<tr>
<td>What do you think of the contents of the SMS? 1: demotivating ...7: motivating</td>
<td>4.5</td>
</tr>
<tr>
<td>What do you think of the text of the SMS? 1: unclear...7: clear</td>
<td>6</td>
</tr>
<tr>
<td>How much personalized is the SMS? 1:general...7:personalized</td>
<td>5.5</td>
</tr>
</tbody>
</table>

The 7 point Likert -scale questions were asked for each piece of advice: How “motivating”/“feasible”/“appropriate of timing”/“relevant to your location” do you think of the advice?” Score 1 was Not at all while score 7 was Very much. Table 3.5 describes the activity advices they received, the average score of their answers to the questions and how many advices they have followed. The average score showed that participants considered the advice as rather motivating (4.6) and feasible (4.6). The timing (5.3) and location (5.6) were suitable. The advices of a small break at work or at home and lunch walk were rated as most motivating and feasible advices and followed more than other advice. The recreational activities of a trip to the nature or an event during weekend received rather lower scores and were not followed. The shopping advice received good scores expect for “feasibility” and that could explain why none of them were followed. Except for the event advice (score < 4), all the advice were rated as being sent at the right time and location, which shows the feasibility of determining the timing of location-based advices. However, the follow-up rate was rather low.

Table 3.5 Average rating for each advice

<table>
<thead>
<tr>
<th>Activity</th>
<th>Motivating</th>
<th>feasible</th>
<th>timing</th>
<th>location</th>
<th>the number of advices being followed</th>
<th>total number of advices</th>
</tr>
</thead>
<tbody>
<tr>
<td>coffee break</td>
<td>4.8</td>
<td>6.5</td>
<td>6.3</td>
<td>5.8</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>lunch walk</td>
<td>5.1</td>
<td>5.9</td>
<td>6.1</td>
<td>6.0</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>active home</td>
<td>6.0</td>
<td>6.3</td>
<td>6.0</td>
<td>6.0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>walk after dinner</td>
<td>4.5</td>
<td>4.8</td>
<td>5.5</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>shopping</td>
<td>5.2</td>
<td>3.6</td>
<td>5.2</td>
<td>6.6</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>weekend cycling/walk</td>
<td>4.0</td>
<td>3.0</td>
<td>5.3</td>
<td>6.7</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>event</td>
<td>3.9</td>
<td>3.4</td>
<td>3.6</td>
<td>3.3</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>detour/bike</td>
<td>3.4</td>
<td>3.0</td>
<td>4.8</td>
<td>5.3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Average</td>
<td>4.6</td>
<td>4.6</td>
<td>5.3</td>
<td>5.6</td>
<td>10</td>
<td>38</td>
</tr>
</tbody>
</table>
In the interview, we asked about the reason why they had followed the advice or not. The participants mentioned frequently that the reason for rejecting recreational advices was that they already scheduled something beforehand, and they had no intention of changing their initial plan. The shopping advices received good scores but were not followed. Two participants had their habits of doing shopping by car only once a week so they did not want to change to go shopping by bike. Since all participants were males, they all mentioned that grocery or leisure shopping was mostly of the time not needed.

We asked everyone whether they consider their privacy as an issue when giving away their location information to get advice. Three participants thought it was no problem. One participant considered sharing location as very private, but with friends and family could be motivating (such as Google Latitude application).

Other valuable comments from the user interview are listed as follows:

- Participants were positive about personalized advices based on their environment and location because they felt being taken seriously.
- Two participants appreciated the suggestions of places and activities they had not considered and they were triggered to explore their neighborhood.
- One participant stated that he favored advice with information of the current weather.
- Three participants liked the lunch break advice together with other participants (colleagues).
- Carrying GPS loggers was not very convenient and it took considerable effort to charge the device and upload data.

### 3.3.5 Discussion and conclusions

During the observation of the first weeks, we found the similarities between the activity pattern from TraceAnnotator analysis results and activity levels of the users. When the activity level was high, the users were generally actively moving. That was an indication that users were doing outdoor activities or traveling. Most activities occurred during the trip to work, lunch break, and shortly after work. Participants were rather inactive when they stayed indoors. Location change or transport mode change normally is related to activity level change. There is an potential to synchronize the physical activity data with GPS location data and present the results in GIS application, such as in Seeger’s research (2007). However, we could not retrieve the physical activity data in its original format but only observe the performance on the DirectLife website. This limitation hinders the usage of the physical activity data for the further design of the adviser system.

We analyzed users’ activity in the past to extrapolate their behavior and provide just-in-time advice. Because of the hardly changing activity pattern during weekdays, most of the advices were sent at appropriate time and location. However, the follow-up rate for the advices was in general very low. A tendency has been shown that the easy to do daily activities were preferred
and followed more than the recreational activities. As they mentioned, the main obstacle which prevented the participants from following the weekend advice was that they already have something else scheduled. This implies that it is necessary to add “agenda” as one of our system input. The system should be aware of whether users have that time slot available to act as suggested. It is also an opportunity for the system to help people make a better plan in order to improve their wellness by adjusting their agenda.

To conclude, the small-scale Wizard-of-Oz experiment shows that it is highly encouraging that the strategies we deployed to create context-aware advice were proven to be reasonable in the sense that advices were sent at rather good locations and times. Advice that takes user context into account is personalized and motivating. However, the challenge is how to trigger behavior change when people have difficulties due to their initial plan. It is necessary that we include the personal agenda in our system design.

Coming back to the question “How to define user context in order to create suitable advice?”, information about user activity (location and activity level), user profile and environment (nearby green place, weather) can be used to define context and create a suitable advice at the right location and the right time.

3.4 Conclusion and future work

From the questionnaire study we obtained a first insight into the general behavior of PA, the willingness of people to use this type of technology and application, the acceptance of the various advices. In the Wizard-of-Oz experiment, we practiced the rational of advice generation based on various inputs and tested the feasibility of creating context-aware advice at the right location and time.

The answers to the three questions are described as follows:

- Which activity suggestions to use to encourage PA?
  Suggestions on lifestyle activities that fit daily life and recreational activities for leisure time are preferred.

- User acceptance of the concept of the system and advices
  Respondents are willing to try the system and prefer specific over general advices. Their preference for daily simple-to-do activities over leisure activity in the weekend is shown.

- How to define Context?
  Activity pattern can be derived from location, activity level and current time.
  Environment condition can be deduced by weather and Geo environment information.
  Others inputs need to be considered are user profile and agenda.
It took some effort for participants to carry the GPS logger and activity monitor together with their mobile phone. To improve the usability of our system, it is preferable to integrate these devices into one mobile device, while the ultimate goal is to design a mobile application that interacts with users by presenting advice and getting feedback. The next step is to achieve advice generation automatically by an intelligent system. We need to investigate which state-of-art location-based and mobile technology is suitable for the implementation to put the concept design into practice.
Chapter 4. Motivate Web Application

4.1 Introduction

From the previous studies we have gained insight into how to define context and generate advice based on user location, time, agenda, weather and profile. The advice generation is the core of the final design which is a real time context-aware mobile application (called “Motivate”). Towards the ultimate goal, it is the first step to build a prototype that can achieve advice creation automatically.

Mobile devices compared with desktops have limited processing power, memory, electrical power and networking capability (Razazi & Hejazinia, 2011). Considering these technical constraints, we decided to test the feasibility and performance of the automated advice generation with a desktop prototype. User location is a key element to define context and this data can be collected by GPS loggers as in the Wizard-of-Oz experiment. Although the recorded location data is not real time, it can be used to generate advices suitable for the context of the recorded moment. If people upload the trace of their one day location to a website and get advice accordingly for where they have been, they can judge the feasibility and suitability of these advices and give their opinions of whether they would like to follow them. This is our motivation to develop a web application (1st prototype) to find out the user feedback to the advices.

In our initial concept design we had the ambition to include physical activity level as one of the user inputs. In principle we could implement this component by using an extra activity measuring device, e.g., an activity monitor such as the settings of PAM (PAM, 2012), DirectLife (Philips Research, 2008) or Fitbit (Fitbit, 2012). However, the activity data is not easy to retrieve and use automatically. In the case of the Wizard-of-Oz experiment, only the coaches and system administrators have the access to the detailed physical activity data of the participants. Besides, carrying an activity monitor in addition to the GPS logger requires extra user effort. Another option is to use location data such as Shakra (Maitland et al., 2006) or CASanDRA Mobile (Bernardos et al., 2010) to estimate physical activity levels. In principle it is possible to use the location data collected by GPS loggers and the software “TraceAnnotator” (section 3.3.2) to estimate transport mode (walking, biking, driving a car, etc). However, the algorithm for efficient and accurate calculation from location and transport mode to energy expenditure needs to be developed and tested. That investigation is beyond our expertise and research scope. Therefore, we decided to exclude activity level measurement as a system input.

In this chapter, we describe our approach of developing the Motivate web application which takes recorded GPS data as user location input to provide users with activity advices accordingly. A user evaluation test was conducted to find out:
Motivate: a Context-aware mobile application for physical activity promotion

- Whether the system can automatically yield reasonable advice based on various contexts (feasibility)
- User acceptance of the advices

4.2 Design and development of Motivate Web application

4.2.1 System architecture of the Motivate web application

Users can interact with the Motivate web application and receive advice after they upload their GPS data (Figure 4.1). The web application communicates with the Motivate Service which generates advices. Figure 4.2 shows the Motivate Service with the services and database. After receiving a request containing user location, the Adviser Service tries to find a proper advice from the advice database based on rules and data from the other services. If any suitable advice is found, the Adviser Service creates a message for a user and stores it in the Message Database.

Figure 4.1 Motivate web application system architecture
4.2.2 Motivate Service

A design and implementation of the Motive Service is given in this section. The inputs include location, agenda, weather and profile, which are based on the conclusion of the previous chapter (section 3.4, pp. 47).

**Location Service**

*User location data*

We used the same location tracking device GPS loggers as what we have used in the Wizard-of-Oz experiment (section 3.3.2 pp.38). The data that was useful for advice generation were date, time, longitude and latitude. Here is an example of GPS data (Table 4.1).

**Table 4.1 GPS data**

<table>
<thead>
<tr>
<th>DATE, TIME, LATITUDE, LONGITUDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009/03/24, 07:52:34, 51.413127, 5.454161</td>
</tr>
<tr>
<td>2009/03/24, 07:52:37, 51.413095, 5.454141</td>
</tr>
</tbody>
</table>
Motivate: a Context-aware mobile application for physical activity promotion

**Geo database**
We use Quantum GIS software to manage the geo database, which consists of geo information of places in the urban environment and individual significant places such as home and work place. Each record of the database includes information of the name, type and geometry information of the place. An Active Travel Route is a safe, attractive, direct and convenient link which can accommodate walking, cycling or running activities between Everyday Activity Destinations like shops, homes, schools, workplaces, etc (Sport England, 2007). We should include these pleasant locations for suggestions such as taking a detour to a park, walking around a lake, etc. Therefore, the geo information about green places or facilities, such as parks, lakes, forests and shopping centers were extracted from OpenStreetMap (Open Street Map, 2012) and added to the database. To add places like home and work we used admin page in the web application applying the Google maps API (explained in section 4.2.4, Figure 4.10). The places in Eindhoven and the surrounding area are shown in Quantum GIS (Figure 4.3).

The location of user and places in the geo database are originally presented with latitude and longitude in degree. For distance calculation in meters we project the location on Amersfoort / RD New spatial reference system. The functions provided by PostGIS are used for distance calculation.

![Screenshot of Quantum GIS. Map of Eindhoven and surroundings. Dark green: forest; Light green: park; Blue: lake & river, Dark Pink: working location; Light Pink: shopping center](image)

**Agenda Service**
Google agenda is used as the agenda input. The scheduled time of daily activities “Go to work”, “Work”, “Lunch”, “Go home” and “Dinner” can be used for determining the timing to send advices. Therefore, we made a Google calendar sample that includes only these 5 activities with
special settings. For example, the setting of “shown me as” should be “available” instead of “busy”, since we assume that the users are open for suggestions when they are doing these activities.

The users need to import this calendar sample to their own Google calendar, and set the beginning and end time of each activity. When they already have something scheduled and are not available for other suggestions, they should set an event to “Busy” in order to prevent intrusion. An example of a user’s Google calendar with these 5 daily activities is shown in Figure 4.4. By sharing their agenda address, the system can access their agenda data and store the activities into the Agenda cache database.

![Figure 4.4 Screenshot of Google calendar sample of activities](image)

**Weather Service**

The weather history data of city Eindhoven is retrieved from the website of Weather Underground (http://www.wunderground.com/history/). The weather information is updated every half an hour on average and can be retrieved as a comma delimited file. The Weather Service gets the weather data and stores it in the Weather cache database. The information useful for advice generation includes time, temperature and conditions. The Motivate Weather Service updates the database regularly and picks the weather record with the time closest to the query time as system input. An example of some entries of the weather database is shown in Table 4.2. We only look at the weather in Eindhoven and the weather information for this prototype is not location dependent.
Table 4.2 Example of data entries of whether database

<table>
<thead>
<tr>
<th>Date_time</th>
<th>Temperature</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/2/2010 12:00</td>
<td>18</td>
<td>Scattered Clouds</td>
</tr>
<tr>
<td>9/2/2010 12:25</td>
<td>18</td>
<td>Overcast</td>
</tr>
<tr>
<td>9/2/2010 12:55</td>
<td>17</td>
<td>Scattered Clouds</td>
</tr>
<tr>
<td>9/2/2010 13:25</td>
<td>18</td>
<td>Mostly Cloudy</td>
</tr>
<tr>
<td>9/2/2010 13:55</td>
<td>18</td>
<td>Scattered Clouds</td>
</tr>
<tr>
<td>9/2/2010 14:25</td>
<td>18</td>
<td>Mostly Cloudy</td>
</tr>
<tr>
<td>9/2/2010 14:55</td>
<td>17</td>
<td>Light Rain</td>
</tr>
</tbody>
</table>

Profile service
The profile service provides profile information about the user. Users can add and edit their profile such as gender, age, family status, transportation, etc by using the Motivate web application.

Time service
This service provides information about the current time of the day, day of the week and if it is a workday or weekend.

Adviser Service
Advice database
The barriers that prevent one’s ability to adapt and maintain PA over time can be either personal or environmental. Personal barriers include one’s level of motivation, availability of time, social support, financial, physical capabilities, etc (Frank et al., 2003). “Perceived lack of time” and “lack of motivation” are two most frequently mentioned barriers to regular participation in PA (Booth et al., 1997). Perceived barriers to exercise were proven to be similar for active and inactive respondents in one survey study, and the major barriers were lack of time, lack of willpower and “just don’t feel like it”. Twice as many sedentary as active people chose the barrier “just don’t feel like it” (Anon, 1979). Other personal factors such as fatigue or lack or energy, also constrain people’s ability to get enough PA (Weinberg & Gould, 2007), especially for recreational exercise (Frank et al., 2003). Similarly Trost (2002) summarized that “barriers to physical activity” as not only lack of time, too tiring, too weak, but also fear of falling, bad weather, no facilities, and lack of exercise partners. Environmental barriers are obstacles that are imposed by the built environment and occasionally the natural environment (e.g. weather). They include the availability of facilities for different types of PA, the distance to the destinations, and perceived quality and safety of environment (Frank et al., 2003). Taking the barriers to PA into account, an intervention should suggest reasonable activities that fit into one’s daily life easily, and overcome environmental barriers. The barriers to PA show that daily lifestyle activities with short duration are more likely to overcome the obstacle of “lack of time”.

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Some advantages of lifestyle activities to promote healthy living are mentioned in section 3.3.3, pp. 42. Lifestyle interventions can yield positive and long-term effects, in terms of increasing the levels of moderately intense PA (Frank et al., 2003). The advantages of lifestyle activities include

- You can do lifestyle activities at any time
- No special place is needed, since opportunities are all around
- No special requirement, exercise clothes or special skills to be needed to perform
- Less chance to get injured, since no vigorous activity

These daily activities can be either gardening, walking or household chores in short duration for 5-10 minutes each time. Research has shown that accumulated short bouts of exercise can have the similar health benefits compared with the single long bouts, such as brisk walking (Woolf-May et al., 1999), aerobic fitness and weight loss (Schmidt et al., 2001) or home equipment exercise (Jakie et al., 1999). Frank et al. (2003) categorized PA into two types based on purposes: recreational PA (undertaken for discretionary reasons on someone’s leisure time, e.g., jogging, hiking) and utilitarian PA (undertaken in order to accomplish another purpose, e.g., walk to work, go to supermarket). Therefore, we compile the database of advices suggesting both utilitarian and recreational activities.

We chose advices suggesting moderate activities that can fit well in daily lives as a principle. In addition to the 8 kinds of advices chosen for the Wizards-of-Oz experiment, we added some other daily activities such as climbing the stairs, doing housework, gardening, social activities, etc. The utilitarian activity advices suggests activities that take short time, such as “a small lunch walk”, “coffee break”, “cycling to supermarket”, “doing housework”, “taking stairs”, etc. The recreational activities are like “a walk after dinner around the neighborhood”, “cycling in the weekend”, “go to event”, etc.

Each advice consists of a “process” and a “template”. The If-Then rules defined in the “process” specify which constraints must be met for each advice. The Adviser service calculates the suitability of each advice for the given situation by processing various input data. The Adviser Service sends a query to one or more of the Services and acquires their analysis results. If all the constraints are met, the advice becomes a candidate. If there is more than one candidate advice, one randomized advice is chosen and a message is generated by the “template”. Based on the “template”, we create positive, realistic and friendly sounding messages in order to increase the acceptance and effectiveness (Fishbein & Cappella, 2006).

**IF_THEN rules constraints**

The if-then rules are defined based on the principle that it must be feasible and convenient for people to follow the advice. The constraints for one activity are mainly the contexts such as user location, user agenda, environment, time, and weather. Some advices also take user profile into account, i.e., gender, transport mode.

The principles are:

- Suitable and accessible place
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- Available time & Good timing
- Suitable weather condition
- Suitable profile

**Suitable and accessible place (check Location Service)**
The research of Troped et al. (2010) found that MVPA occurred more outside of home buffer (within 50m) and work buffers (within 1km) than occurred within these areas. It suggests the possible opportunities to stimulate activities at/around home and work. The places nearby each participant’s home and work location for PA are selected to be suggested. A distance of 400 to 800 meters of walk equates to 5-10 minutes walking one way. This distance is reasonable to fit into daily activities. Cycling distances of up to 3km are generally accepted as being a reasonable cycling distance with an upper threshold of 5km (Sport England, 2007). Based on this, we define the constraints of the Location: suggested activity location must be within a certain distance or travel time. We define the distances for several activities as:

- **Lunch walk distance**: 200-500m
- **Leisure walking distance**: 200m – 2km
- **Leisure/active cycling distance**: 2-6 km

When the Location Service searches for a location to be suggested, the location must be within the defined distance.

**Available time & Good timing (check Agenda Service and Time Service)**
Agenda Service: the User Agenda need to be “free” as the basic requirements. Besides, it should be a good timing for them to receive advice and conduct the suggested action. For instance, when their agenda is “lunch”, and 15 minutes before that time slot of “lunch”, they may receive an advice of “taking a lunch break”.

Time Service: suggested activity is applicable for a certain specified time period (e.g., Saturday morning to go to the market).

**Suitable weather condition (check Weather Service)**
Outdoor activity advice requires good or fair weather conditions. The thermal comfort for people in active occupations is 16-21 degrees in summer and 16-19 degrees in winter. The factors that can influence the comfort of people outdoor include sunlight, temperature, wind, humidity, clothing, etc (Occupational Safety & Health Service, 1997).

Generally speaking, the temperature may influence the outdoor physical activity when it is too hot (above 30), too cold (below 5), too humid, or when it is rainy, windy, or other extreme weather conditions. The average temperature in the Netherlands in the autumn when the evaluation would take place is around 10 degrees (September: 15; October: 12, November: 7) (EuroWeather, 2012).

The weather conditions are defined as follows:
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- **Bad**: temperature < 5 with any weather condition; any temperature with all bad conditions (e.g., raining, storm)
- **Fair**: 5-15 degree with cloudy or clear sky; 15 to 25 degree and (mostly) cloudy
- **Good**: 15 to 25 degree and (mostly) clear sky

Suitable profile (check Profile Service)

User Profile: gender, possession of bike, transport mode, etc (e.g., advice such as “cycling to work” requires users’ possession of bike; go to work normally by car; work place is within 30 minutes distance by bike).

One example of a “Lunch walk advice” contains the following constrains: the day of week is a weekday; a user’s agenda activity “Lunch” starts within twenty minutes; a user’s agenda is free for one hour; the current weather is good; there is a green place within 500 meters. The field “template” of the chosen advice can dynamically compile the text of the message to be sent. In this example the message is “It's such good weather now! How about going to Dommel River for a short walk (with your colleagues) after lunch?”

The original code for this piece of this lunch walk advice is shown as follows:

```python
def process
  if day_of_week == 'weekday'
    and agenda.next([lunch, 10 | >= 20 | agenda.next([lunch] > 0 )]
    and agenda.next([available, 80] >= 10 \n    and weather.score > 10 \n    and 'location'([park, water, forest], 500).empty?
      10
    else
      0
  end
end

def message
  "It's such good weather now! How about going to #location_pick([park, water, forest], 500).name:
  for a short walk (with your colleagues) after lunch?"
end
```

The If-Then rule differs for each advice. There are in total 35 pieces of advice including 20 kinds of activities with different constraints. We list some main constraints for 11 categories of advices in the table below (not in a detailed level). Some advice also consider user profile, such as transportation type, which is not listed in this table. The essential of the advice content can be found in Appendix B, which describes all the advices in the final advice database.

One or two advices about the event in and around the city are sent manually every week. The events include cycling activity along special “Lighting route”, walking tour for light show “GLOW”, visiting “Dutch design week”, etc.

Advice frequency/configuration

We keep track of the sent messages and make sure users do not receive the same or similar kind of advice repeatedly. We set that the time interval between 2 messages should be at least half an hour, since they might need some time to follow the advice before they received another one. We do not want to bother the users with too frequent messages. The categorization of the 11 groups
are described Table 4.3 are how we configure the frequency of each type of advice. The advice from the same group is set to be sent at most once in a certain time (normally once per day). Some groups of advice such as “shopping”, “transportation” (changing transportation mode) are set to be sent once every 3 days. Leisure activity advices of “Nature_weekend”, “Social_weekend” are set to be sent at most twice every weekend. “Taking a break” advices are sent two times per day.

<table>
<thead>
<tr>
<th>Group</th>
<th>Suggested activity examples</th>
<th>Location</th>
<th>Agenda/time</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break at work</td>
<td>Coffee break, take water /walk around,</td>
<td>Work</td>
<td>10AM/15PM 10AM/15PM</td>
<td></td>
</tr>
<tr>
<td>Take the stairs</td>
<td>take the stairs</td>
<td>Work</td>
<td>Go to work/go home/lunch</td>
<td></td>
</tr>
<tr>
<td>Lunch</td>
<td>A lunch walk (to green place)</td>
<td>Work</td>
<td>Lunch time Good/fair</td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>Housework, gardening, indoor exercise, take break when watching TV</td>
<td>Home</td>
<td>Evening/weekends</td>
<td></td>
</tr>
<tr>
<td>Shopping</td>
<td>weekend shopping , supermarket</td>
<td></td>
<td>Weekend after work/weekend</td>
<td>fair</td>
</tr>
<tr>
<td>Dinner</td>
<td>Wash dishes, after dinner walk, walk to supermarket after dinner</td>
<td>Home</td>
<td>After dinner</td>
<td></td>
</tr>
<tr>
<td>Nature_weekend</td>
<td>Walk to green place cycle to green place</td>
<td>Green place</td>
<td>Weekend Good</td>
<td></td>
</tr>
<tr>
<td>Close_nature</td>
<td>Nature place to go (&lt;200m)</td>
<td>Green place</td>
<td>Nearby Good/fair</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>Go to work/home by bike, park your car further, take a detour, go to supermarket after work</td>
<td>Home/work</td>
<td>Go to work/ go home Good/fair</td>
<td></td>
</tr>
<tr>
<td>Social_weekend</td>
<td>Visit friends, go to movie</td>
<td></td>
<td>Weekend</td>
<td></td>
</tr>
<tr>
<td>Event</td>
<td>Weekend events</td>
<td></td>
<td>Weekend</td>
<td></td>
</tr>
</tbody>
</table>

### 4.2.3 Implementation and simulation of Motivate Service

We implemented the Motivate Service using the web framework Ruby on Rails (http://rubyonrails.org/). The UML class diagram shows the class structure of the Motivate web application (Figure 4.5). A user has a profile, several locations (home and work) and an agenda. The agenda includes many events (daily activities). The “Adviser” looks into the current location of a user, weather condition, information of the user and generates a message. All the classes have been explained in the previous section except for the “Message” class. The “Message” class includes the “content” of the message that is created by “template” and presented to a user, and the “response” of the user to the message (explained in the following section).
The Adviser class implements the Adviser Service. It processes GPS data and search for a suitable advice. To test the feasibility of the Motivate service, we first did a simulation test by processing the GPS traces of the participants collected in the Wizard-of-Oz experiment (section 3.3.3). We set the processing frequency to every 15 minutes, which means the time interval between two subsequent GPS data points that are processed is 15 minutes. Some examples of generated messages are listed in Table 4.4. The average number of advices is about 2-3 per day. After this simulation test, we continued to implement the web application for users to upload their GPS traces and get advice.

<table>
<thead>
<tr>
<th>Time</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thu Apr 09 17:57:01</td>
<td>Take a detour to &lt;park A&gt; on your way home</td>
</tr>
<tr>
<td>Thu Apr 09 19:12:20</td>
<td>how about walking to &lt;lake Karpendonkseplas&gt; after dinner</td>
</tr>
<tr>
<td>Fri Apr 10 12:07:36</td>
<td>It's a good idea to take stairs instead of elevator</td>
</tr>
<tr>
<td>Fri Apr 10 12:33:42</td>
<td>walk around &lt;De Dommel river&gt; during lunch break</td>
</tr>
<tr>
<td>Sun Apr 12 13:47:29</td>
<td>Do you want to enjoy some nature? There's a &lt;park A&gt; close by that you can go to have a walk around</td>
</tr>
<tr>
<td>Sun Apr 12 14:17:30</td>
<td>How about going out of the house, for example, cycling to &lt;Anne Frankplantsoen&gt;?</td>
</tr>
<tr>
<td>Sun Apr 12 19:18:00</td>
<td>Move from your computer or couch, stretch your body and relax</td>
</tr>
</tbody>
</table>

### 4.2.4 Design and implementation of Motivate web interface

The main Motivate website interface is illustrated in Figure 4.6. After logging in the Motivate website, users can upload the GPS trace of the day and get advice (in the Common Actions). The green arrow indicates what the users should do. In the case of the screenshot below, there are unanswered messages. Users can also use the website to edit their agenda (linked to Google calendar) and profile (Figure 4.7). The “Status” dashboard shows how many traces have been processed and how many messages have were responded.
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Figure 4.6 Motivate web application (main interface)

Figure 4.7 Interface of editing user profile
The GPS trace of user location data is updated to the web application. The Motivate Service processes the GPS trace and checks for advice with a 15-minutes frequency. Based on the recorded time of a GPS data point, the context information from all services, such as time, weather and user agenda are accordingly taken into account to generate an advice. The chosen advice will appear on the website (Figure 4.8). The text on top “Assume you would have received the following message on Wednesday, June 08th at 17:09” indicates the time that the messages was generated for. The message of “How about taking a detour to Dommel River on your way home?” is shown on the phone screen on the left. On the right, the user location (red point) and the suggested location (blue line) are both shown on Google Map. The question for users to answer is presented as follows:

“Would you follow that advice?” The answers to be chosen are:

- Yes, I would have followed the advice (referred as “Yes now”)
- Yes, but I would have followed the advice some other time (referred as “Yes later”)
- Yes, because I was already doing or had planned something similar (referred as “Yes already”)
- No, I would not have followed the advice (referred as “No”)
- No, I would never have followed the advice (referred as “Never”. If one chooses this option, this advice will be filtered out and never sent to this user again)

Users are also asked to give their reason for their choice in the text box. For each message they are asked about the timing of the message, assuming that they have received that message at that moment. They can choose from:

- “just on time”
- “too late”
- “too early”.

After “submit response” button is clicked, the response for this message is sent to server. The users will see another message if there are any unanswered ones. This design is to make sure they give answers to all advices.
4.3 User experiment

To evaluate this web application and learn from user feedback to these advices, we conducted a user experiment. In this section we describe the experiment and the results.

4.3.1 Participants

For the user experiment we recruited participants via email (and personal contact) to a group of around 20 employees working at the department of Built Environment at TU/e. Nine (four female, five male) people were recruited. Eight of them were colleagues, and one was a friend of one participant. They aged from 26 years old to 60 years old (average 44 years old). Seven of them were married and 5 out of them had children. 6 of them normally commuted to work by bike, while 3 by car and 1 on foot. According to the BMI calculation 3 of them were overweight while the other 6 had normal bodyweight. They all worked at least 4 days a week. On average they preferred to receive 7 messages per day (varied from 2 to 10). All nine participants had higher education.

According to the user profile, six out of nine participants considered themselves as “I am quite active”, while the other three participants chose: “I am just active enough”, “I am a bit inactive”
and “I am not active at all” respectively. All participants thought “being physically active” as either “very important” or “rather important”. Three of them would like to be more active, while the other three participants chose “I don’t want to be more active” and the other 3 chose “I don’t know”.

4.3.2 Procedure

Set-up
In a face-to-face setup meeting, instructions were given about how to upload GPS traces and use the Motivate website. First of all, the participants installed the driver for the GPS logger and the software called “GPS Photo Tagger” which can export the GPS trace to the CSV file format and visualize the GPS trace (software interface shown in Figure 4.9). Secondly, we helped them with the Google calendar settings. Afterwards they were required to edit their profile information and locations of home and work on the Motivate website (Figure 4.10). After completing the configuration, a test message was sent and they could practice how to give responses. In the end, the participants were asked to fill in a questionnaire concerning some general questions about PA.

Daily procedure
Participants were required to upload their GPS traces everyday and empty the GPS logger afterwards. This is to guarantee enough memory for recording new location data for the next day. They could choose the time that they used the Motivate web application. For the first week of the assessment period participants uploaded their GPS trace for the day and received no advice. After this assessment period, every day when they uploaded their GPS traces, they could see new messages appearing on the website for them to respond. They were required to answer these questions about their opinions on each piece of advice. The time that they used the Motivate website could be decided by the participants at their convenience. Participants were required to use the Motivate website for at least another 4 weeks. In the end the participants were invited for a face-to-face interview.

Measures

Responses to advices
We logged the information of every message that was created and sent to the users. The moments of a message being created and responded by a user were recorded. The user willingness to follow the advice and their reason, judgment of the timing of the messages were logged for analysis. The PA level of the participants was not measured objectively due to the purpose of this evaluation experiment. For this prototype the user acceptance of the advices was what we were interested in.
Motivate: a Context-aware mobile application for physical activity promotion

Figure 4.9 GPS photo tagger used to download and export GPS track

Creating new location for user penny

<table>
<thead>
<tr>
<th>Name</th>
<th>TU/e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kind</td>
<td>work</td>
</tr>
<tr>
<td>User</td>
<td>penny</td>
</tr>
<tr>
<td>Longitude</td>
<td>5.494351,51.59344</td>
</tr>
<tr>
<td>Latitude</td>
<td>51.44595,51.985801</td>
</tr>
</tbody>
</table>

Figure 4.10 Add a work location to a user

Physical activity level

Physical activities were measured by the International Physical activity questionnaire (IPAQ) long last 7 days self-administered format (IPAQ, 2012). It includes questions about the job-related physical activity, transportation PA, housework, recreation/sports/leisure time PA and time spent sitting. Every week the questionnaire was sent to the participants to report their PA
during this week. The questionnaire was sent either by email or delivered personally. However, we had difficulties of collecting the filled questionnaires. Only two participants finished all the five questionnaires without delay. Quite often the participants reported that it was difficult to recall the activities in the past 7 days. In total 45 questionnaires for 5 weeks were sent while only 31 valid questionnaires were returned. It was guaranteed that after the assessment week and the last week, all the participants filled in the questionnaire. Therefore, only the results of these two weeks are presented.

**Questionnaire & Interview questions**

In the end the participants answer 4 multiple choice questions about the knowledge of what to do to improve PA level, awareness of the green place and visiting frequency, difficulty of fitting PA into daily life, and feelings of change (whether become more active). In the interview, open questions about their opinions on the suitability of advice content, timing, preference for various kinds of advices, whether following up the advices were asked.

### 4.3.3 Results

**System performance**

The distribution of messages throughout the weekdays and weekends is shown in (Figure 4.11). It shows that that in weekdays more advices were sent around noon and after dinner time; while in weekends the peak hour of advice was a bit early in the morning. Similarly, the advices were sent more frequently during lunch and dinner time in the weekend. In general the percentage of advices sent during afternoon for both weekdays and weekends were almost the same (around 35%); while in the weekend advice were sent more in the morning compared with the frequency of ones in the evening. But during weekdays almost half of the advices were sent during evenings (Figure 4.12).

![Figure 4.11 Percentage of sent messages for each hour of the day](image)
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In total 886 messages were generated, on average 3 messages for each user per day. The messages are categorized into 7 groups according to suggested activity types, and the percentages of messages of each type are described in Table 4.5. The most frequently sent messages were outdoor activities such as a lunch walk during work or a leisure walk to a green place in the weekends. The second frequently sent messages were taking small breaks during work or at home.

Table 4.5 Percentage of advice

<table>
<thead>
<tr>
<th>Advice types</th>
<th>Examples</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor activity</td>
<td>a small walk during lunch; go to a park for a walk, walk to a park nearby; cycling to green places</td>
<td>28.2%</td>
</tr>
<tr>
<td>break</td>
<td>walk to the coffee corner, stretch, workout on the chair</td>
<td>26.9%</td>
</tr>
<tr>
<td>housework</td>
<td>mopping, washing dishes,</td>
<td>14.3%</td>
</tr>
<tr>
<td>take stairs</td>
<td>Take stairs during work</td>
<td>9.1%</td>
</tr>
<tr>
<td>shopping</td>
<td>Walk/cycle to supermarket; weekend shopping</td>
<td>8.6%</td>
</tr>
<tr>
<td>transportation</td>
<td>walk/cycle to work instead of car use; detour home</td>
<td>6.5%</td>
</tr>
<tr>
<td>Other weekend</td>
<td>Go to movie, events in the city</td>
<td>6.3%</td>
</tr>
</tbody>
</table>

Usage of Motivate web application

During the experiment three GPS loggers stopped to function due to battery problems. Sometimes the location data was not recorded, due to the empty battery of the GPS loggers. For the rest the participants used the Motivate web application once every one or two days.
User Responses

Willingness to follow

In total 876 messages (98.9%) were given user responses. In total, 59.8% of the messages received positive response and 40.2% of them received negative responses. The details are described in Table 4.6.

<table>
<thead>
<tr>
<th>Positive Responses (59.8%)</th>
<th>Number of Valid responses</th>
<th>Percentage of valid responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes now</td>
<td>232</td>
<td>26.5%</td>
</tr>
<tr>
<td>Yes later</td>
<td>124</td>
<td>14.2%</td>
</tr>
<tr>
<td>Yes already</td>
<td>168</td>
<td>19.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Negative response (40.2%)</th>
<th>Number of Valid responses</th>
<th>Percentage of valid responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>no</td>
<td>319</td>
<td>36.4%</td>
</tr>
<tr>
<td>never</td>
<td>33</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

Total 876 100.0%

The responses to different types of advice are analyzed and shown in Figure 4.13. More than 75% of the advices of taking a break and housework received positive responses. Almost half of housework advices (46.8%) were given the response of “Yes already”. The outdoor activity, transportation and weekend advices received more negative responses than positive responses. “Never” was responded more to the “shopping” and “transportation” advices (e.g., park the car further, weekend shopping).

![Figure 4.13 User responses to different category advice](image-url)
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**Reason for negative response:**
The participants were asked to give their reason for each negative response. We summarize their reasons in Table 4.7. The most frequently mentioned reasons for negative responses were “have other plans” and “busy/no time”. The other reasons mentioned were, for example, the advice was not possible to follow, or the suggested location was not suitable.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Number of occurrence</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>I already have other plans</td>
<td>92</td>
<td>26.1%</td>
</tr>
<tr>
<td>I am too busy and have no time</td>
<td>56</td>
<td>15.9%</td>
</tr>
<tr>
<td>It’s impossible/unpractical to do it</td>
<td>46</td>
<td>13.1%</td>
</tr>
<tr>
<td>The location is not suitable (too far)</td>
<td>36</td>
<td>10.2%</td>
</tr>
<tr>
<td>I don’t need to do that (active enough)</td>
<td>34</td>
<td>9.7%</td>
</tr>
<tr>
<td>I don’t feel like doing it</td>
<td>23</td>
<td>6.5%</td>
</tr>
<tr>
<td>The timing is bad</td>
<td>18</td>
<td>5.4%</td>
</tr>
<tr>
<td>The weather is not suitable</td>
<td>12</td>
<td>3.4%</td>
</tr>
<tr>
<td>I am tired</td>
<td>10</td>
<td>2.8%</td>
</tr>
<tr>
<td>Others (ill, no company, personal preference, etc)</td>
<td>25</td>
<td>6.9%</td>
</tr>
</tbody>
</table>

**Timing**
829 (93.5%) messages were given the answer about the timing of the messages. Among them 55.9% of the message were considered as sent just on time, while 31.2% of them were sent “too late” and 12.9% were “too early”. The timing for different types of advices did not differ much (all above 50%). It is noticeable more outdoor and take stairs advices were considered as being sent too late.

<table>
<thead>
<tr>
<th>Advice</th>
<th>On time</th>
<th>Too late</th>
<th>Too early</th>
</tr>
</thead>
<tbody>
<tr>
<td>outdoor</td>
<td>50.1%</td>
<td>39.5%</td>
<td>10.4%</td>
</tr>
<tr>
<td>break</td>
<td>59.0%</td>
<td>23.9%</td>
<td>17.1%</td>
</tr>
<tr>
<td>housework</td>
<td>53.8%</td>
<td>31.0%</td>
<td>15.1%</td>
</tr>
<tr>
<td>shopping</td>
<td>61.6%</td>
<td>27.4%</td>
<td>11.0%</td>
</tr>
<tr>
<td>take stairs</td>
<td>50.6%</td>
<td>42.0%</td>
<td>7.4%</td>
</tr>
<tr>
<td>transportation</td>
<td>68.8%</td>
<td>25.0%</td>
<td>6.3%</td>
</tr>
<tr>
<td>weekend</td>
<td>58.0%</td>
<td>23.0%</td>
<td>19.0%</td>
</tr>
<tr>
<td>Total</td>
<td>55.9%</td>
<td>31.2%</td>
<td>12.9%</td>
</tr>
</tbody>
</table>
A crosstab analysis was conducted of user responses and the timing of the advices (Table 4.9). A correlation between the response and the timing of the advice was found ($\chi^2 = 34.781, p = 0.000$). The advice that were considered as “on time” received more positive responses compared with the advices that were sent too early or too late.

<table>
<thead>
<tr>
<th>Timing</th>
<th>Count</th>
<th>Positive</th>
<th>Negative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>On time</td>
<td>321</td>
<td>142</td>
<td>463</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>69.3%</td>
<td>30.7%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Too early</td>
<td>59</td>
<td>48</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>55.1%</td>
<td>44.9%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Too late</td>
<td>123</td>
<td>136</td>
<td>259</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>47.5%</td>
<td>52.5%</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>503</td>
<td>326</td>
<td>829</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>60.7%</td>
<td>39.3%</td>
<td>100.0%</td>
<td></td>
</tr>
</tbody>
</table>

Physical activity

The average scores of physical activity level (in MET minutes per week) measured by the international Physical activity questionnaire (IPAQ) after the first week (week 1) and last week (week 5) are shown in Table 4.10. Paired-sample T-test shows that the total PA of all participants on average in the last week decreased significantly ($p<0.05$). This is due to the significant decrease of Moderate intensity activities ($p<0.05$), which includes cycling for transport, moderate activities at work, domestic, garden and leisure-time domain, plus vigorous yard chores. No significant change has been found for walking and vigorous activities ($p>0.05$).

<table>
<thead>
<tr>
<th>PA</th>
<th>Week 1 MET-minutes/week (Mean ± SD)</th>
<th>Week 5 MET-minutes/week (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>653.8 ± 872.6</td>
<td>573.3 ± 464.9</td>
</tr>
<tr>
<td>Moderate intensity</td>
<td>1845.6 ± 1782.3</td>
<td>728.1 ± 676.9</td>
</tr>
<tr>
<td>Vigorous intensity</td>
<td>105 ± 197.0</td>
<td>90 ± 178.6</td>
</tr>
<tr>
<td>Total PA</td>
<td>2604 ± 2107.8</td>
<td>1391.5 ± 919.7</td>
</tr>
</tbody>
</table>

User questionnaire & interview

In the end the participants answer 4 multiple choice questions about their knowledge about what to do to improve PA level, awareness of the green place and visiting frequency, and feelings of change (whether become more active).

After the experiment, most of the participants (seven out of nine) reported that they did not feel any behavior change and only two of them felt a bit more active. In general participants liked the lifestyle activities they received, especially the advice such as “lunch break”, “coffee break” and
“walk to a nearby green place”. The advice they liked least was “housework” (such as doing dishes).

The recreational activity ideas for weekend were appreciated since they could get more ideas of where to go in the leisure time. However, sometimes the green place being suggested was not suitable for leisure purpose (for example, it is not safe to go to a lake for an after dinner walk).

4.3.4 Discussions

More than half of the messages were considered as “just on time” and “bad timing” was not the main reason for rejecting the advice. The approach of using daily activities on Google calendar to determine the timing for suggestions is proven to be sufficient. But the setting up procedure for each participant’s Google calendar took quite some effort, especially for people who did not have a Google account. A simpler solution is needed.

The user responses to the advice showed that more than half of the advices received positive responses, which is encouraging. Although the advice was meant for the past, the user reaction still reflected their willingness to comply with the suggestions. The advices of “break”, “housework” and “take stairs” received the most positive responses, although “housework” advice was not their favorite. The reason was probably that in almost half of cases they had already done it. In fact one fifth of the advices were responded as “Yes already”. This may indicate a bias of the participant sample.

Indeed the participants considered themselves to be already quite active and were aware of the importance of being active. The majority did not have the intention to become more active. After the experiment most of them did not feel any chance of becoming more active, while no PA level increase was found. It seems that the activity suggestions about the possible PA activity in the past would not change their behavior in the present. Therefore, the next step is to investigate the possibility of generating real-time data context-aware advices to trigger behavior change.

4.4 Conclusions and future work

In this Chapter, we have introduced the design and development of the core of our system “Motivate Service” for advice generation. The design, implementation and evaluation of the Motivate web application are also described. The input information of geo information, weather history, user recorded location and user Google calendar were aggregated and processed with certain simple rules to generate contextual sensitive advice. The performance of the advice generation and the usage of the website provided us with the answers to the questions we had in mind.

- The system can automatically yield reasonable advice based on various contexts
- More than half of the advices were accepted by users, and more than half of them were considered as “just on time”

The offline data web application is the first step towards our final goal of developing the real-time mobile application. The results give us the confidence of applying simple advice generation
algorithm to create context-aware advice. The next step is to investigate how to incorporate real-time weather, location and agenda data that reflect the user context. The components of a mobile interface that interacts with users and the communication API with motivate service need to be added in the future.
Chapter 5.  

Motivate mobile application design and development

5.1 Introduction

Based on Motivate web application evaluation results we continued with designing the mobile phone application. The challenge is to transform the user interaction on the web application to the mobile phone interface. The Motivate web application needs to be adapted for users to easily adapt their personal information, e.g., profile and agenda.

We decided to develop the application on Android platform due to its advantage that open sources are available for the development. The goal is to generate real-time context-aware advice based on current user location, agenda, environment and weather. In this chapter the development of the mobile application and a small scale pilot study of the application are described. From the pilot results we improved our design and finalized the Motivate application. The design of the final version of the Motivate application is illustrated in details.

5.2 Design challenges for mobile application

5.2.1 Real-time localization

GPS loggers used in the previous experiment were proven to be accurate to record location traces offline. However, the drawback of GPS is that the broadcasting signal becomes weak, when the receiver cannot get a reasonably open view of the sky. Sometimes a GPS receiver is unable to obtain a position inside buildings, under the trees, or even when between tall buildings with a restricted view of the sky, which is called “urban canyon” (D’Roza & Bilchev, 2003).

GSM (Global System for Mobile Communications) cellular localization is another widely used positioning technology that uses mobile telephone network. For example, CellID localization is one way that works simply by detecting the base transceiver station (BTS) with which the telephone is registered. The mobile telephone is normally registered to the nearest BTS and the cell size greatly affects the accuracy of the position of BTS. Typically the accuracy of CellID localization in urban locations may be around 500 m, but in rural location this can increase up to about 15 km (D’Roza & Bilchev, 2003). Latest researches have employed GSM localization technology to estimate mobile phone’s location with a 100-150 meters accuracy in a city environment (LaMarca et al., 2005), and even an accuracy of 4 meters in large multi-floor buildings using wide signal-strength fingerprints (Varshavsky et al., 2007).

Compared with GPS localization, the CellID localization has the advantage that the signal is much stronger and is unaffected by the urban canyon effect. The work of LaMarca et al. showed that the GPS coverage is available only 4.5% of the time for a device carried by users during a typical day (without measuring the percentage of time that the application can make a meaningful guess at the user’s location). In contrast, the cellular coverage is available throughout most of a personal day (2005).
Another interworking localization technology is wireless network, which can detect presence and proximity of people and objects. The median accuracy of Wi-Fi localization ranges between 15 and 60 meters, with high coverage (LaMarca et al., 2005). Wi-Fi-enabled mobile devices and rapid deployment of Wi-Fi access points make Wi-Fi localization attractive (Pfeifer, 2005).

It is clear that the advantage of using a mobile phone for localization, because people carry them for most of the time, and mobile network is continuous. Besides, nowadays smart phones have built-in GPS receivers, which can also be used for outdoor localization with high accuracy. However, Smartphone mobile applications cannot guarantee continuous and ubiquitous location access due to the high energy expense of using location sensors (Kjærgaard et al., 2009).

We explored the potential of using Android mobile phones to achieve localization. To acquire the user location, a location-aware application for Android can utilize GPS and Android's Network Location Provider (Android developers, 2012). GPS localization is accurate, but only works well for outdoors. The built-in GPS receiver of a Smartphone drains the battery fast, and does not return the location as quickly as users want. Android's Network Location Provider also determines user location using cell tower and Wi-Fi signals, providing location information indoors and outdoors. The advantage is a faster responding speed and less battery power consumption. The choice of which localization method to use is a trade-off among accuracy, speed and battery-efficiency (Android developers, 2012).

5.2.2 Real-time activity monitoring

It is ideal to include physical activity data as inputs to generate advices that are suitable for the currently activity level. However, at the stage of the system development, Smartphone usage just started to increase. It was not easy to find reliable mobile application that transit accurate activity data that we could incorporate in our system. The reliable activity monitoring systems that are used for research and commercial purposes, normally apply sensors or accelerators that are integrated in activity monitor, chest band, etc. To focus on a simple mobile application to interact with users, we do not want to add an extra monitoring device in the system design. Besides, the financial costs and time needed to process data make activity monitoring not very practical. The other alternative is to use location sensing such as GPS or GSM signals to predict activity, such as the design ideas of Shakra (Anderson et al., 2007) or CASanDRA Mobile (Bernardos et al., 2010). It requires location recording with high frequency and quite a lot of training data to guarantee accurate learning results. Considering these practical limitations we decided on the inputs for user context determination still as user location and agenda, but without activity level measurements.

5.2.3 Real-time /future weather

Weather condition can change any time, and real-time weather information should be the ideal inputs to generate weather-sensitive advices. In order to send advice suggesting future activities, weather forecast should also be included. However, we did not find a better data source than the
one we have used in the web application (section 4.2.2, pp. 53). Since the update frequency of the weather website is about every 20 minutes, we think the quality of the weather data is sufficient.

5.2.4 Mobile application interface

As indicated by Gerber et al. (2009) one challenge of the implementation of text messaging to change behavior is to notify the users of the incoming message when it arrives. An audio or vibration prompt at a particular time may effectively serve as a notification or reminder as well. In the mobile application design, how to effectively interact with users by presenting an advice and getting their responses is one design challenge.

5.3 Design of Motivate mobile application

5.3.1 System architecture

Motivate system consists of Motivate service, Motivate web application and Mobile API which communicates with Motivate mobile application. The mobile application sends the phone location data to Motivate Service to look for a suitable advice. When an advice is generated, it will appear in the Motivate application for a user. Then a user can send back their feedback to the Motivate Server. The Motivate web application, as we have described in Chapter 4, section 4.2.4, can be used for users to edit their profile (Figure 4.7) and personal agenda (Figure 5.3). The administrator can also use this web application to easily manage user data and observe how users are using the mobile application. The system architecture is illustrated in Figure 5.1. The Motivate mobile application is compatible with Android phone version 2.0 and above.

Figure 5.1. System Architecture of Motivate mobile application
5.3.2 Motivate Service

The Motivate Service is basically the same as described in Chapter 4 Figure 4.2. After receiving a request containing user location from a mobile phone, the Adviser Service tries to find a proper advice from the advice database by asking the other services. If any good advice is found, the Adviser Service creates a message to send to the mobile UI and then record it in the Message Database for analysis afterwards. Figure 5.2 shows the Motivate Service with the services and database.

![Figure 5.2 Motivate Service](image)

**Location Service**
The geo database of the places of the city is not changed. The significant places of user home and work locations are added by administrator manually.

**Agenda Service**
In the previous user evaluation test we have observed quite some user efforts to set up their Google agenda, especially for those who did not have a Google account. Therefore we decided to offer users another alternative, which was a Simple Agenda function on our Motivate web application. As shown in Figure 5.3, users can add activities from a drop-down list which contains: “Go to work”, “Work”, “Lunch”, “Go home”, “Dinner” and “Busy”. They only need to specify the starting and ending time of that activity. It is a weekly schedule and users can copy the agenda of another day in the week to easily set up the whole week agenda.

Agenda Service updates every day and save the details of activities as entries of Agenda database. It deals with the query by checking what the user’s current activities or future activities
are as indicated in the agenda. Only the entry called “Busy” indicates the user does not want any advice for that period.

![Figure 5.3 Screenshot of Simple agenda of Motivate Web application](image)

**Weather Service**
We still use the weather history data from the website of Underground Weather and store it in whether cache. The Weather Service updates the database and picks up the weather record with the time closest to the query time. Since the weather data is updated only around 20 minutes, the weather for the current moment can be the weather of some minutes ago.

**Profile Service**
The profile services returns the profile data for a specific user.

**Adviser Service**
The rational of the adviser is the same as described in Chapter 4, section 4.2.2, pp.54. Some small changes were made, based the user feedback for the advice during using the Motivate web application. The configuration and constraints of some advices (pp.57) were adjusted. Besides, more advices during weekend were set to be sent earlier in the morning, in order to give users more time for the preparation.

### 5.3.3 Motivate Mobile User Interaction design

The application is developed using the Android Software Development Kit. To minimize the battery usage of the Motivate application, we activate the application every 15 minutes to search for location and communicate with the Motivate Server. The activated timing is synchronized with the system default wake-up time for all the other applications running on Android system. In this way the battery consumption can be reduced. The phone location can be detected either by GPS, GSM or Wi-Fi connection.

The application runs at the background. “Status bar notification” is used when the application needs to alert the users about the new message. When a new message arrives, there is either a notification sound or a vibration that users can choose. Users can choose by clicking...
“preferences”. A small icon will appear on the top left corner as an indication of a new message (details explained in Figure 5.10). The message does not interfere with the other application and does not pop up. Users need to click the notification’s message in the notification window to review the message. They can always click the Motivate application icon to view the messages as well.

On the application main page, users can see the total number of advices they have received and their number of positive and negative responses (Figure 5.4, left). Users can set “preferences” for the basic setting such as: account information, localization method (default: GPS), notification sound, operation frequency (default: 15 minutes), etc. The “Edit agenda” button is to direct users to the Simple Agenda page of the Motivate web application. The “Check now” button is used to check for advice immediately instead of a scheduled moment being set.

![Figure 5.4 Motivate mobile APP interface](image)

When a user starts the Motivate to view a new message, they will see the interface as shown in Figure 5.4 (middle). The 5 possible options to choose are as follows:

- “Yes, I will do it now” (referred as “Yes Now”): when you are willing to follow the advice right now.
- “Yes, I will do it later” (referred as “Yes Later”): when you are willing to follow the advice some time later.
- “Yes, because I am already doing or have planned something similar” (referred as “Yes-Already”): when you are already doing the suggested activity or just about to do it.
- “No, I will not do it now or later” (referred as “No”): when you do not want to follow the advice
“No, I will never follow this kind of advice” (referred as “Never”): when you do not want this kind of advice any more (If one chooses this option, this advice will be filtered out and never sent to this user again).

They are asked about the timing of the message by choosing from the list of “just in time”, “too late” or “too early”. When the users choose negative responses to the messages, they will see a text field (Android standard) to type their reason. By pressing the “Show Map” button, a user can view the suggested place on Google map and where he or she is at that moment (Figure 5.4, right). After the answer is given, the advice will disappear and users will return to the main interface (Figure 5.4, left).

5.4 Evaluation

5.4.1 Participants

In November and December 2010 we conducted a small-scale user evaluation test. We sent an email to the DDSS group as the previous experiment to recruit Android users who lived and worked in Eindhoven or surrounding areas. Through their personal contacts of acquaintances as well, we got responses of nine people who possessed an Android phone and would like to participate. Three of them were employees of TU/e and the other six were the acquaintances of some employees in the DDSS group. These nine people were contacted by email and invited for a set-up meeting. Two of them did not come to the set-up meeting. One of them had problems of the GPS localization. Therefore six people (5 male, 1 female) in total finished the evaluation test. The average age was 37 years (range: 24-63 years old). Four of them were married and 2 of them had children. Four participants commuted to work by car, one by bike and the other one by bus. They worked five days a week (three of them were colleagues at TU/e). According to Body mass index (BMI) measurement, five of them were with normal weight and 1 of them was slightly overweight. They all had desk work who sat in front of computer for long hours. Two participants were using HTC Hero mobile phones and the other four with Samsung Galaxy S. Five of the six participants had higher education.

Three out of the six participants considered themselves to be physically quite active and all of them agreed on that being physically active was important. Four participants wanted to be more active while the other two did not know.

5.4.2 Procedure

Set-up meeting

Participants were invited for a face-to-face set-up meeting. They download the “Motivate” Android application on their mobile phone. The default setting checked every 15 minutes for advice and used GPS as default localization method. If the GPS data was not be able to find, GSM or wireless connection would be used (dependent on user’s setting and connection with wireless internet). Participants could access the “Motivate” web API with their user account and edit their personal profile, locations of home and work (detailed in section 4.3.2, pp. 63). They were instructed to edit their Simple Agenda on Motivate website (details explained in section
5.3.2, pp. 76). If the configuration was successful, they could receive a test message. The explanation of how to answer the questions was given. After the setup we asked participants some questions concerning their initial attitudes of physical activity, awareness of green places and preference of receiving messages, etc.

**Location adjustment**

During the first assessment week participants did not get any advice but their coordinates were sent to the Motivate Service. The user location data including date, time latitude, longitude and accuracy was sent to the server and saved in the database (Table 5.1). The level of accuracy shows whether the location was sent from GPS (accuracy of below 100 meters) or from GSM. (on average 200-1000 meters).

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIME</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>ACCURACY (in meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/9/2010</td>
<td>17:57:34</td>
<td>51.44842</td>
<td>5.486492</td>
<td>644</td>
</tr>
<tr>
<td>11/9/2010</td>
<td>18:11:42</td>
<td>51.44757</td>
<td>5.486163</td>
<td>32</td>
</tr>
<tr>
<td>11/9/2010</td>
<td>18:56:56</td>
<td>51.46969</td>
<td>5.476561</td>
<td>32</td>
</tr>
</tbody>
</table>

The location data of each day are saved in both CSV file and KML file to be viewed on Google Earth. In Figure 5.5 some location points of a user are shown. For each user, we looked through the tracks collected in the assessment period to verify their home and work location. Due to the location of the nearby cell tower, some discrepancy between the detected location and their self-reported location of their home and work place could appear. For one participant we have seen three locations with most points near his work location. Therefore we need to add multiple location points or a polygon (for an area of working place) into the geo database for his work location in this situation.

![Figure 5.5 Location points of one participant for one day](image-url)
Daily procedure
During the first week, the participants sent their location via mobile phone to the Motivate Server every 15 minutes, without receiving any advices. Afterwards, messages of physical activity advice were generated by the Motivate Service automatically based on user location, agenda, weather, profile and If-then rules (section 5.3). The created messages were sent to participants’ mobile phone through the “Motivate” application. After receiving the advice, they were required to answer the multiple choice questions concerning that piece of advice. The questions asked about whether they would follow the advice, the timing of the message, and why they would not follow the advice. After responding to the advices for 4 weeks participants were interviewed about their user experience and they answered a simple questionnaire. The average temperature of the experiment period is 6 degree with minimum average of -3 degree and maximum 16 degree (weather underground website). Due to the difficulties we encountered concerning collecting PA data with the questionnaire during the previous experiment, we decided not to burden the participants with this extra task.

5.4.3 Results
System performance
Each day the location data (Table 5.1) of each participant sent by the mobile phone were saved as one trace in one “.CSV” format file. For 5 out of the 6 participants, they sent their traces every day for the 5 weeks. One participant only sent 23 traces. The missing traces were due to that the participant only used Wi-Fi internet connection, and for many days internet connection was disabled.

During the 4 weeks, 475 messages were sent in total for all participants. On average 3 messages were sent for each participant per day (exclusive the days that no trace was sent for one participant). The total number and timing of the messages depended on the If-then rules and the configuration. The location and agenda differed for each user, thus the timing of receiving each type of messages also differed.

Overall, the distribution of all messages throughout the day is shown in Figure 5.6. During weekdays from 10 AM to 11 AM more advices were sent (break at work advice). The trend during weekends differed a bit since more messages were sent between 9 and 12 AM. The distribution of messages sent in the morning, afternoon and evening is shown in Figure 5.7. In the weekend more messages were sent in the morning compared with in the weekday situation. In general the messages were distributed evenly during the day. Compared with the distribution of message in the previous experiment with the web application (section 4.3.3, pp. 65), the percentage of messages sent in the morning increased, especially for the weekend. The percentages of the seven different types of advices are shown in Table 5.2. The advices of taking a break at home or at work and outdoor categories were sent more often compared to other advice types.
Motivate: a Context-aware mobile application for physical activity promotion

Figure 5.6 Percentage of messages sent per hour

Figure 5.7 Percentage of message during the day

Table 5.2 Percentage of various advice

<table>
<thead>
<tr>
<th>Activity</th>
<th>Example</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>break</td>
<td>walk to the coffee corner, stretch, workout on the chair</td>
<td>33.5%</td>
</tr>
<tr>
<td>Outdoor activity</td>
<td>a small walk during lunch; go to a park for a walk, walk to a park nearby; cycling to green places</td>
<td>23.2%</td>
</tr>
<tr>
<td>housework</td>
<td>mopping, washing dishes,</td>
<td>11.2%</td>
</tr>
<tr>
<td>take stairs</td>
<td>Take stairs during work</td>
<td>10.8%</td>
</tr>
<tr>
<td>transportation</td>
<td>walk/cycle to work instead of car use; detour home</td>
<td>7.6%</td>
</tr>
<tr>
<td>weekend activity</td>
<td>Go to movie, events in the city</td>
<td>7.2%</td>
</tr>
<tr>
<td>shopping</td>
<td>Walk/cycle to supermarket; weekend shopping</td>
<td>6.5%</td>
</tr>
</tbody>
</table>
User responses to messages

**Willingness to follow**

In total 443 (93.3%) messages were responded by the users. The responses to messages are listed in Table 5.3. In total 53.9% of the messages received positive responses which includes “Yes-Now” (25.5%), “Yes-Later” (17.6%) and “Yes-Already” (10.8%), 46.1% of the messages were given negative responses with “No” (43.6%) and “Never” (2.5%).

<table>
<thead>
<tr>
<th>Table 5.3 User responses to advice</th>
<th>Number of Valid answers</th>
<th>Percentage of valid answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Responses (53.9%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes now</td>
<td>113</td>
<td>25.5%</td>
</tr>
<tr>
<td>Yes later</td>
<td>78</td>
<td>17.6%</td>
</tr>
<tr>
<td>Yes already</td>
<td>48</td>
<td>10.8%</td>
</tr>
<tr>
<td>Negative response (46.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>193</td>
<td>43.6%</td>
</tr>
<tr>
<td>never</td>
<td>11</td>
<td>2.5%</td>
</tr>
<tr>
<td>Total</td>
<td>443</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

The responses to different types of advice are analyzed and shown in Figure 5.8. The advices of taking a break, taking stairs and outdoor activities received the most positive responses. The transportation advice received the most “Never” responses (most of them were given for the advice of “parking the car a bit further and walking to work/home”). In comparison with the results of user responses during using the Motivate web application (Figure 4.13), except for “taking the stairs” advice, all the advices received less positive responses. The advice of doing housework received most negative responses. However, in the previous experiment almost half of the housework advices received “Yes already” response. This difference could be due to the fact that most participants in this test of the mobile application were males.

<table>
<thead>
<tr>
<th>Advice</th>
<th>Yes Now</th>
<th>Yes Later</th>
<th>Yes Already</th>
<th>No</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>break</td>
<td>42.0%</td>
<td>20.7%</td>
<td>8.7%</td>
<td>28.7%</td>
<td>0.0%</td>
</tr>
<tr>
<td>take stairs</td>
<td>29.8%</td>
<td>17.0%</td>
<td>8.5%</td>
<td>44.7%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Outdoor</td>
<td>21.0%</td>
<td>15.2%</td>
<td>12.4%</td>
<td>47.6%</td>
<td>3.8%</td>
</tr>
<tr>
<td>transportation</td>
<td>12.1%</td>
<td>27.3%</td>
<td>6.1%</td>
<td>42.4%</td>
<td>12.1%</td>
</tr>
<tr>
<td>shopping</td>
<td>16.7%</td>
<td>10.0%</td>
<td>10.0%</td>
<td>60.0%</td>
<td>3.3%</td>
</tr>
<tr>
<td>weekend</td>
<td>7.1%</td>
<td>21.4%</td>
<td>7.1%</td>
<td>64.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>housework</td>
<td>6.1%</td>
<td>10.2%</td>
<td>4.1%</td>
<td>75.5%</td>
<td>4.1%</td>
</tr>
</tbody>
</table>


Reason for negative response:
We analyzed the answers to the open question of their reason for not following the advices. A number of 84 out of 204 negative responses were given an explanation by participants, underlying their reason of not following the advice. We categorized the reasons into 10 types (see Table 5.4). The reasons mentioned most were “I already have other plans” and “I am too busy and has no time", which was consistent with the results of the previous experiment with Motivate web application (Table 4.7). Not good timing was mentioned as a reason for not following the advice, for example, “I saw the message too late", “I already went to bed”.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Number of occurrence</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>I already have other plans</td>
<td>15</td>
<td>17.9%</td>
</tr>
<tr>
<td>I am too busy and has no time</td>
<td>14</td>
<td>16.7%</td>
</tr>
<tr>
<td>Timing not right</td>
<td>12</td>
<td>14.3%</td>
</tr>
<tr>
<td>Not feasible</td>
<td>9</td>
<td>10.7%</td>
</tr>
<tr>
<td>Feel no need to do the activities</td>
<td>9</td>
<td>10.7%</td>
</tr>
<tr>
<td>I don’t feel like doing it</td>
<td>6</td>
<td>7.1%</td>
</tr>
<tr>
<td>Feel tired</td>
<td>6</td>
<td>7.1%</td>
</tr>
<tr>
<td>The weather is not suitable</td>
<td>3</td>
<td>3.6%</td>
</tr>
<tr>
<td>The location is not suitable</td>
<td>2</td>
<td>2.4%</td>
</tr>
<tr>
<td>Other (I am sick, personal issue, etc.)</td>
<td>8</td>
<td>9.5%</td>
</tr>
</tbody>
</table>

Timing
In total the participants judged the timing for 411 messages. More than half of these messages (57.7%) were considered to be sent just on time, while 25.3% of them were too late and 17% of them were too early. Compared with the web application experiment Table 4.8, the timing for real time advices was considered as almost the same. However, the timing for different types differed (Table 5.5). Higher percentages of transportation and take stairs advices were sent “too late” compared to the other advices. The suggestions such as taking off the bus one step earlier require rather strict timing. The timing of decision making of taking stairs is also hard to predict. For some weekend events the timing of the message were considered as too early, and the explanation was that we intended to give users more time for the preparation.
A crosstab analysis was conducted of user responses and the timing of the advices (Table 5.6). A correlation between the response and the timing of the advice was found ($\chi^2 = 11.491, p<0.05$). The advice that were considered as “on time” and “too early” received more positive responses compared to the advices that were sent too early.

Table 5.6 Response and timing of the advices

<table>
<thead>
<tr>
<th>Timing</th>
<th>Count</th>
<th>%</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>On time</td>
<td></td>
<td></td>
<td>149</td>
<td>105</td>
<td>254</td>
</tr>
<tr>
<td></td>
<td></td>
<td>58.7%</td>
<td>41.3%</td>
<td></td>
<td>100.0%</td>
</tr>
<tr>
<td>Too early</td>
<td></td>
<td></td>
<td>44</td>
<td>31</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>58.7%</td>
<td>41.3%</td>
<td></td>
<td>100.0%</td>
</tr>
<tr>
<td>Too late</td>
<td></td>
<td></td>
<td>45</td>
<td>67</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40.2%</td>
<td>59.8%</td>
<td></td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>238</td>
<td>203</td>
<td>441</td>
</tr>
<tr>
<td></td>
<td></td>
<td>54.0%</td>
<td>46.0%</td>
<td></td>
<td>100.0%</td>
</tr>
</tbody>
</table>

User questionnaire & Interview
Almost all of them reported that they had some ideas about how to increase PA level, they only knew a few green places in their living area and they did not go there often. On average they prefer to get 5 messages per day. After using Motivate for weeks, three participants considered that they were more active during this period while the other three considered themselves as active as usual. We asked the participants about their experience of using the Motivate application.

Usability
The discussion was focused on the usability of the mobile application and the possible improvements. One participant using HTC phone which he purchased a year ago mentioned more power consumption than usual due to this application. The other participants did not notice any
faster power consumption while using the application. Participants all reported that after editing their agenda for the first time, they did not change the agenda much afterwards.

All participants considered the interface of the application as simple and easy to use. But there was some confusion in the meaning of the choices, as mentioned by two participants who stated that the “Yes-Later” choice was not very clear. They did not know for how long they could postpone following the advice. Thus they sometimes chose “No” while they meant for “Yes, later”. Two participants thought that the “Show Map” button only would connect them with Google Map rather than showing them the suggested place (Figure 5.4 right). The other comments proposed some possible features such as an elaborated main interface with more information about their activity history, some pictures to enhance user-friendliness, sharing their locations with friends, etc.

Three participants mentioned that he would like to read the advices later again which was not possible. One participant mentioned that he sometimes deliberately did not answer that question so he could view it later or show it to other people.

During the assessment we noticed that one participant could not send his location data to the server. The problem was that wireless localization option was off and GPS happened to be not working properly. Since we did not monitor the localization setting of their mobile phone, it was difficult to solve the problem. Therefore, a better control of the setting needs to be added.

5.4.4 Discussions

Right location, right time

In order to generate contextualized advice, real-time information of user location and agenda are used to determine the user context. The location of the user could be detected rather accurately to determine whether they are at home or at work. Therefore the advice is location-aware. On average the timing of more than half of the messages are considered to be satisfactory. “Just on time” and “Too early” advices both received almost 60% positive responses, and “too late” advices only received 40% positive response. This difference indicates that an early timing is not so problematic, since a bit of time for users to consider if they will follow the advice later can be helpful. It is important to avoid sending the messages too late. However, since we do not include sensors in our system design, we cannot predict exactly which activity the user is performing. In another word, the timing of sending a message is based on the assumption that they behave according to their agenda.

A good timing may not guarantee that the advices are followed. More important is that participants should have enough time to conduct the activity. This is supported by the most frequently mentioned two reasons for not following the advice, which are “too busy” and “have other plans”. These results are consistent with our earlier Wizards-of-Oz study and Motivate web application experiment. Although we implemented the “Agenda” in order to prevent sending advice when they were busy or already had scheduled activities, the “Agenda” did not work out as we expected. In fact participants did not always update their agenda when they have planned
activities. They need to add the “busy” activity and remove it later, since the agenda will be repeated for another week. Thus the function of this simple agenda is mainly used to indicate the rough schedule of basic activities in order to determine the best timing. The ideal solution is to connect the application with the daily agenda that the user is using, for example, similar like the approach we first tried with Google Calendar (section 4.2.2, pp.52). However, there is no guarantee that all participants have and use the same type of calendar. Besides, it is difficult to interpret the calendar content to decide which type of event is on the calendar. For example, people can put their meeting appointment as well as a reminder for a friend’s birthday. This raises the challenge of how to extract the useful information from a user agenda without requiring too much extra user workload.

An alternative is to send the advice in advance in order to give users more time to prepare. For example, advice such as going to an event in the weekends should be sent days before the event. Users could choose “Yes, later” and indicate when they plan to follow the advice and get a reminder later as well. In this way users can schedule a future activity.

**Measure behavior**

In the experiment we only recorded the intention to comply with the advice and did not measure actual behavior of following the advice. In order to find out whether the advice can trigger more physical activities, a simple approach is to ask the participants to report their behavior. “Self-report” method is used quite often to assess PA behavior by questionnaires traditionally. For example, by using activity diaries or recall questionnaires, self-report method is the least expensive method. It is easy to collect and analyze data. The disadvantage, however, is the reliability and validity problems associated with recall of activity. Therefore, the method is lack of accuracy (Warren et al., 2010). In the previous experiment described in Chapter 4 we applied the IPAQ self-report questionnaire to measure actual PA. However, the quality of results and the feedback from the participants made us doubt about the reliability of using this questionnaire in our experiment (section 4.3.3, pp. 64). Self-reported levels of PA are based on the perception of their past PA and the accuracy depends on whether they can recall the type, intensity, frequency and duration of all daily activities. To improve the accuracy, methods in a feedback study can be applied. In a feedback study participants should provide information about an event immediately after they perceive it. The participants should be asked to answer questions about the event as soon as it occurs (Carter & Mankoff, 2005). Base on this, we think that mobile application is a good media to ask users to report their behavior after receiving the advice. Since they can come back to review the advice and give their initial response shortly after responding to the advice. Despite the drawback that this task may overburden participants, this method can provide rather accurate data about whether they have followed the advice. Of course, the approach of “self-report” is reliable under the assumption that the users are honest about reporting actual behaviors.

**Localization method**

The combination of GPS and Android's Network Location Provider is proven to be effective in localizing the users without consuming too much battery. Most of time the participants were
indoor and the GPS localization is less efficient and consume more battery. To guarantee a minimal battery usage, it is better to set the default to mobile GMS localization (or wireless internet). Besides, the location & security of the Android phone settings, the option of use “location determined by Wi-Fi and/or mobile networks” need to be allowed.

5.4.5 Summary

So far we have described the design, implementation and evaluation user test of the first version of mobile application “Motivate”. The performance of the Motivate mobile application during the evaluation test was stable. The results show us the feasibility of a real-time context-aware recommendation system on Smartphone. With the state of the art technology, we made personalized and contextualized recommendation available on a mobile device at any time. The real-time multiple inputs such as user location and agenda are simple but sufficient for analyzing user context to find a rather satisfactory timing.

This evaluation test focused mainly on testing the technique feasibility and usability of this mobile application, as well as a first impression of user responses to the advice. The user feedback and results provide us with ideas of possible improvements for the final version of the application. To sum up, some aspects of the Motivate application need to be adapted:

- Require users to report their action of whether following the advice
- A reminder function for users to be reminded at a later time
- Adaptation of interface design
- Localization method control

5.5 Final version of Motivate application

One major weakness of the previous application is that we only collected user intention of behavior change without real measurement of behavior change. Therefore, we would like to collect data about the self-reported actions. The other aspect that attracts our attention is the possibility of engaging more behavior change by giving users the opportunity to schedule an activity in the future by the “Reminder function”. Besides, we will add some more information to the user interface, for example, to review the old advice and see their history data. In this section we introduce the interface design changes and new features of the final version of Motivate.

5.5.1 Self-reported actions

A “self-reported actions” function is added for users to report if you have followed the advice. Five minutes after they give their answer to each advice, an “action” icon appears and the message is with pink background (Figure 5.9, left). By clicking at the message a user will get the interface with the question “Did you follow this advice?” (Figure 5.9, right). They can also view their previous answers. Another approach to report their action is directly clicking the icon. By tapping the icon once it will change into (meaning “No, I didn’t do it”). By tapping it a second time it will change into (meaning “Yes, I did it”). They have some time to make
modifications to this answer, before the answer is locked. Locked answers are displayed with a small icon of a lock (Figure 5.9, left).

![Figure 5.9 Main interface (left), Message after being answered](image)

### 5.5.2 Message Interface

If a new message arrives, a notification with the icon on the left corner of Figure 5.10 is shown. The icon means there are one or more messages that have not been answered. A map icon next to the message is added when the advice suggests a specific location. By clicking the map icon, a user can view the suggested place on Google map and where he or she is at that moment (Figure 5.10, middle). The four possible responses are as follows for users to choose:

- “Yes, I will do it now” (referred as Yes Now)
- “Yes, I will do it later” (referred as Yes Later)
- “Yes, because I am already doing or have planned something similar” (referred as Yes Already)
- “No, I will not do it” (referred as No)

If a user chooses “No, I will not do it” he is asked to choose from a list of reasons or give their own reason. The interface of all the reasons to choose is shown in Figure 5.10 (right). We removed the timing question and instead we add a new reminder function which is described in section 5.5.3. We removed the choice of “I will never follow it”, due to the very low rate of being chosen (less than 4% in previous user evaluation test of both web and mobile application). If a
user choose “No, I don’t like this kind of activity” from the reason list, they will not get this advice again.

5.5.3 Reminder function

From the previous discussion we mentioned the difficulties of understanding users’ currently activity by the information from their agenda. Thus, instead we would like to provide a simple way of planning an activity in the future by the Reminder function. When “Yes, I will do it later” is chosen, a questions of “When do you want to be reminded?” appears. A user can choose to be reminded in 5 minutes, 15 minutes, 30 minutes, 1 hour and 2 hours later or at a given time if needed (Figure 5.11, left). If users want to follow the advice later some other day they can also choose another date and time (Figure 5.11, middle). The original advice with the time to be reminded can be viewed at any time (Figure 5.11, right). The same advice will be sent when the reminded time comes.
5.5.4 Main interface change

The user feedback of the evaluation test of the Motivate mobile application suggests that it can be helpful to provide users with more information if the history of advice and their responses can be viewed at any time. Therefore, we change the main interface into a list of received messages. Users can review the history of advice (Figure 5.9, left, Figure 5.12). The icons on the left indicate users’ responses and the icon on the right indicates their self-reported actions. The meaning of each icon is listed in Table 5.7.

Table 5.7 Meaning of icons

<table>
<thead>
<tr>
<th>Icon</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>👍</td>
<td>I will follow the advice</td>
</tr>
<tr>
<td></td>
<td>I am already doing it</td>
</tr>
<tr>
<td>👎</td>
<td>I will not follow the advice</td>
</tr>
<tr>
<td>🕰</td>
<td>I will follow the advice later</td>
</tr>
<tr>
<td>🚫</td>
<td>No answer has been given</td>
</tr>
<tr>
<td>🐛</td>
<td>No self-reported action has been given</td>
</tr>
<tr>
<td>✔️</td>
<td>Yes, I did it (self-reported action)</td>
</tr>
<tr>
<td>☠️</td>
<td>No, I didn’t do it (self-reported action)</td>
</tr>
<tr>
<td>📣</td>
<td>The message only gives information and requires no answer.</td>
</tr>
</tbody>
</table>
Users can click the advice to view it at any time and change their responses within 1 hour after they have responded for the first time. They can also change their self-reported action within 15 minutes. Afterwards they can only view the message and the blue lock on the icons ( Assertions ) indicates that no changes can be made.

The message with icon includes notification, information or weekly statistics. Every week, a summary of the responses and self-reported actions are given, such as:

“This week you have received 24 messages. You have given response to 20 messages (11 positive / 9 negative). You have reported actions for 16 messages (8 yes / 8 no). Please respond to messages with! Mark on the left, and validate messages with pink background.”

5.5.5 Event service

In order to send event advice to users every week, we made a simple event service. We can specify event name, content, location ID and time period to send to create event advice for users (Figure 5.13). Normally we set the sending time as 1-3 days before that event. The detailed information of the event, such as the content, link, location, time is sent to all users.

![Creating new event](image)

Figure 5.13 Event Service on Motivate website
5.5.6 Other changes

Localization method
As we have discussed in section 5.4.4, pp.87, the localization default method is set to be GSM/wireless for an optimal battery usage. However, when the GPS can be used to localize the phone within a short time, it will be used for the localization, due to a better accuracy.

Configuration
Some adaptation of the Motivate service has been made. In the previous user study of the Motivate mobile application, the weather was rather cold and might restrict outdoor activities. The expected time period to test the next version of the application would be in spring and summer, which meant that the weather would be rather warm. The average temperature of May June and July of Eindhoven are around 13, 15, 18 degrees (EuroWeather, 2012). In fact, the average temperatures of May, June and July were 11, 17 and 20 degrees in the previous year (2010) according to Weather underground website. Therefore, we need to adapt the definition of weather conditions of “bad”, “fair” and “good”, in order to make the suitable categorization. The “bad”, “fair” and “good” conditions were defined as follows:

- **Bad**: temperature <10 or temperature >32 with any weather condition; any temperature with all bad conditions (e.g., raining, storm)
- **Fair**: 10-18 degree with cloudy or clear sky; 18 to 32 degree and (mostly) cloudy
- **Good**: 18 to 32 degree and (mostly) clear sky

Attentions are paid on providing more outdoor activities, since promoting various PA in the urban environment is one focus of the Motivate application. It is expected a rather suitable weather condition for outdoor activities during the period of the future experiment. Therefore, the frequency of outdoor activities was adjusted to be higher than before. Meanwhile, at least two advices about the event in and around the city are sent every week by using the Event Service, because these can be good outdoor activities as well during the weekend. The events include ballooning festival, music festival, open air concert, exhibition, walking activity in a park, etc.

The details of the advices in the database are shown in Appendix B.

The advices of the 11 groupes as we have desried in section 4.2.2, pp.55, the number of differenct advcies, the number of advcies within a certain time interval are shown in Table 5.8.
Table 5.8 Configuration for advice

<table>
<thead>
<tr>
<th>Group</th>
<th>Maximal times</th>
<th>Maximal times</th>
<th>Time interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break at work</td>
<td>4</td>
<td>1</td>
<td>5 hours</td>
</tr>
<tr>
<td>Take stairs</td>
<td>1</td>
<td>1</td>
<td>1 day</td>
</tr>
<tr>
<td>Lunch</td>
<td>4</td>
<td>1</td>
<td>1 day</td>
</tr>
<tr>
<td>Home</td>
<td>5</td>
<td>1</td>
<td>1 day</td>
</tr>
<tr>
<td>Shopping</td>
<td>2</td>
<td>1</td>
<td>3 days</td>
</tr>
<tr>
<td>Dinner</td>
<td>3</td>
<td>1</td>
<td>1 day</td>
</tr>
<tr>
<td>Nature_weekend</td>
<td>3</td>
<td>1</td>
<td>1 day</td>
</tr>
<tr>
<td>Close_nature</td>
<td>2</td>
<td>1</td>
<td>1 day</td>
</tr>
<tr>
<td>Transportation</td>
<td>7</td>
<td>1</td>
<td>2 days</td>
</tr>
<tr>
<td>Social_weekend</td>
<td>2</td>
<td>1</td>
<td>1 day</td>
</tr>
<tr>
<td>Event</td>
<td>1</td>
<td>2</td>
<td>1 day</td>
</tr>
</tbody>
</table>

5.6 Conclusions and future work

In this chapter we describe the incremental approach of the design and development of the Motivate mobile application. The mobile application was built up based on the Motivate web application but with the real time inputs. The integration of various inputs such as user location, geo information, weather, user agenda, and city events were proven to be feasible for contextualized advice generation. The user experience that was learnt from the small scale evaluation test provided us with insight into how to improve the design of the application. Adaptations have been made for collecting more data and a better usability.

The small scale user test results reflected the usage of only a limited number of people. Therefore, a larger scale user evaluation experiment is desired. In the next chapter we will describe the evaluation study of the final version of Motivate.
Chapter 6. Evaluation user study of Motivate Final Version

6.1 Introduction

In this previous chapter, we have described the finalized design of the Motivate application. In order to evaluate this final version, we have conducted a user experiment. The usage data of the application and the user reactions to the advices were observed and analyzed. We intended to find out to which extent the users will comply with context-aware advices.

In this chapter, we describe the design and the results of the evaluation experiment, and some reflections on the results.

6.2 User evaluation experiment design

6.2.1 Recruitment

We would like to recruit people who possessed an Android phone and subscription of Internet, live and work in Eindhoven (or surrounding area) and work regularly (not at home) at least 4 days a week. We started the recruitment from mid-April by sending invitations through medias such as LinkedIn groups, TU/e newspaper Cursor, newsletter by email, yammer (TU/e internal application), Motivate public website (http://motivate.ddss.nl/), etc. Based on our previous Motivate web service, we created the Motivate public website which describes the application in order to recruit participants. Potential participants could register through the website and be contacted by us for detailed information about installations and configurations. By the end of May 2011, 17 people responded by registering on the Motivate website after receiving the information from these medias. At the same time, participants were also recruited by personal contact.

After logging on the Motivate website, the users can edit their profile and agenda (see Figure 6.1). Three tutorial videos about how to install and configure “Motivate”, how to edit profile and agenda and how to use Motivate application were posted on the website for user instructions.
Motivate: a Context-aware mobile application for physical activity promotion

6.2.2 Measures

Questionnaire Design

The first part of the questionnaire with 8 questions was to measure their behavior of “being physically active”, which is defined as “On average 5 or more days per week of moderate-intensity activity for at least 30 minutes per day.” Some examples of moderate-intensity activities are given for participants to judge their PA level.

The questions measure their attitude, perceived norms, perceived behavioral control, intention of behavior change, and past behavior considering towards meeting this standard of being active. These determinants of PA are the same as the variables of the TPB model (section 2.2.1). The question design is based on the instruction of constructing a TPB questionnaire (Ajzen, 2002b).

Attitude (Q1, Q2), a positive or negative evaluation of a particular behavior. Two questions ask about how (un)important and (un)pleasant is meeting the standard of being active.

Subjective norms (Q3, Q4), perception of social pressures, or relevant others’ beliefs. Two questions ask how the family and friends of the participants and people who are similar to them meet the standard.
Table 6.1 Questions about PA behavior

<table>
<thead>
<tr>
<th>Question</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 Attitude</td>
<td>Meeting this standard for me would be (1: unimportant...7: Important)</td>
</tr>
<tr>
<td>Q2 Attitude</td>
<td>Meeting this standard for me would be 1: unpleasant...7: pleasant</td>
</tr>
<tr>
<td>Q3 Subjective norms</td>
<td>Most of my family and friends meet this standard 1: false...7: true</td>
</tr>
<tr>
<td>Q4 Subjective norms</td>
<td>Most people like me meet this standard 1: unlikely...7: likely</td>
</tr>
<tr>
<td>Q5 Perceived control</td>
<td>I am confident that I can meet the standard for the next 3 month 1: false ...7: true</td>
</tr>
<tr>
<td>Q6 Perceived control</td>
<td>Whether I can meet the standard for the next 3 month is up to me 1: disagree...7: agree</td>
</tr>
<tr>
<td>Q7 Intention</td>
<td>I intend to meet this standard for next 3 months 1: false ...7: true</td>
</tr>
<tr>
<td>Q8 Past behavior</td>
<td>In the past 3 months, I have met this standard 1: false ...7: true</td>
</tr>
<tr>
<td>Q9</td>
<td>How physically active do you think you are? 1: very inactive... 7: very active</td>
</tr>
<tr>
<td>Q10</td>
<td>Do you know what you can do in order to stay active? 1: Not at all...7: yes, very much</td>
</tr>
<tr>
<td>Q11</td>
<td>Do you have many ideas about what to do in order to stay active? 1: No idea...7: yes, many ideas</td>
</tr>
<tr>
<td>Q12</td>
<td>How do you think about fitting physical activities into your daily life? 1: Very hard...7: very easy</td>
</tr>
<tr>
<td>Q13</td>
<td>How much do you know about the green places (e.g., park, lake, forest, etc) near your home and work place in (around) Eindhoven? 1: not at all... 7: very much</td>
</tr>
<tr>
<td>Q14</td>
<td>How often do you go to those green places? 1: not at all...7: very often</td>
</tr>
</tbody>
</table>

Perceived control (Q5, Q6), perception of ease or difficulty of performing a particular behavior (Ajzen, 1991). Two questions ask how confident and autonomous they feel about meeting the standard.

Intention (Q7), indication of the readiness to perform a behavior, immediate antecedent of behavior (Ajzen, 2002a). It is determined by attitude, subjective norm and perceive control. One question asks about the intention in 3 months of meeting the standard.

Past behavior (Q8), may reflect the impact of factors that influence later behavior, but not be considered as a causal factor (Ajzen, 1991). One question asks the past behavior in the last 3 months.

The other 6 questions asked some related aspects such as the awareness of activity level (Q9), knowledge and ideas about how to stay active (Q10, Q11), difficulty of fitting PA into daily life.
(Q12), knowledge about green places (Q13) and the frequency of going to green places (Q14). The similar questions were asked in the two previous experiments and were adapted in this questionnaire (section 4.3.2; section 5.4.2). The motivation of constructing these questions is to find out whether the usage of the application can influence users to be more aware of their PA behavior, to give them more ideas of staying active, to help them easily fit daily activities in everyday life and to trigger them to go to green places more often.

The details of the questions are listed in Table 6.1. In addition to these questions participants were also asked whether they have decided on any behavior change during the usage of Motivate.

**Usage data**
We logged the information of every message that was created and sent to the users. The moments of a message being created, sent, received and responded by a user were recorded. The user responses and self-reported actions were collected for analysis. In addition, user location coordinates sent by mobile phones every 15 minutes were saved in the database. When a message was created, the weather condition of that moment was logged into the database as well.

**6.2.3 Participants**
From the mid of April till the end of June 2011, in total 42 Android users registered for the Motivate program through our Motivate website. 23 people were received the information through social media, public information, newsletters and newspapers, while 19 people were informed by personal contact.

Half of the participants were employees of the TU/e. 10 people did not finish the installation and configuration. After registration, 32 of them (17 from TU/e and 15 from outside of TU/e) installed the software and finished the setup. 2 potential participants only sent a few days of traces without responding to advices. One potential participant mentioned some phone setting of GPS which did not work. 4 other potential participants did not use the Motivate for required time. All the participants were not involved in the previous experiments before.

In the end, 25 (15 from TU/e, 10 from outside of TU/e) participants finished the user test by using the Motivate application for more than 5 weeks. Among them 16 participants were approached by personal contact while the other 9 people were attracted by media information and shared no acquaintance of any employee of the DS group of the TU/e.

They (8 females and 17 males) aged between 21 and 54 years of old with an average age of 34. According to the BMI calculation seven of them were overweight while 18 had normal body weight. Eleven participants were married and nine of them had children. 24 out of all 25 participants had higher education. Their Android devices include 17 Samsung Galaxy S, 5 HTC series, 2 LG and 1 Samsung Tablet. Most participants (expect for 4 of them) only purchased the Smartphone within the last 3 months.

According to the profile that they filled in, 19 participants considered themselves to be physically active (11 as “I am quite active” and 8 as “being just active enough”) and the other 6 considered
themselves to be rather inactive. Seventeen respondents intended to be more active. All participants thought “being physically active” was “very important” (15 people) or “modest important” (10 people). According to their self-report, most participants considered themselves to be quite active and were aware of the importance of being active.

6.2.4 Procedure

We offered a face-to-face initial set-up meeting with all participants, during which instructions of how to install the software and use the application were given. All detailed instruction videos and descriptions were also available online (Figure 6.1). Most participants who worked at the TU/e (14 out of 15) chose to meet up for the setup while the rest installed and configured the application themselves by watching the tutorial movies online. After installation, participants received a link to fill in the questionnaire for the first time. We enclosed a privacy disclosure agreement to ensure that the information of the participants was used only for this research (see Appendix C).

Each participant was required to use Motivate for at least 6 weeks in total. During the experiment, the Motivate application running on each participant’s phone sent the location every 15 minutes to the Motivate Server. In the first week, we observed the performance of the Motivate application, to make sure that the user location was sent to the server. After several days of observation, we added their home and work location to the database. During this one week of assessment period, no message was created. Afterwards, the Motivate Service started to generate advices automatically based on user location, agenda, weather, profile and If-then rules (section 5.3, section 4.2.2). The created messages were sent to participants’ mobile phones through the “Motivate” application. As we described in section 5.5.6, some changes have been made compared to the previous version of the application. During the experiment period, most of the if-then rules and the advice in the database did not change, expect for the event advice. During the experiment period, we sent different event advices every weekend. Due to the fact that the participants started the experiment from different date, they received messages accordingly based on their activities and various weather conditions. The average temperature in May, June and July 2011 are 14 (min: 8, max: 23), 16 (min: 11, max 26), 16 (min: 12, max 20) degrees (weather underground website). They first gave their initial response of whether they would like to follow the advice. Later they must report their actions of whether they actually followed the advice or not. They were required to use the Motivate for 5 weeks and could stop anytime afterwards. In the end they were asked to fill in the same online questionnaire and invited for a face-to-face interview after they stopped using Motivate. The interview lasted approximately 20 minutes and we asked open-ended questions about their opinions about the content and of the advice, user experience about usability, comments, etc. From 1st May until 1st August 2011, a total of 25 participants finished the user test and 20 of them completed 2 online questionnaires. In total 21 of the participants took part in the end user interview.
6.3 Results

6.3.1 System performance

On average, Motivate was used for 45 days (varied from 30 to 70 days). Due to different user configuration and phone internet connection, the Motivate application was used actively (sending their location and receiving messages on average for 38 days (varied from 16 to 70 days for each individual). In total, 3548 messages were sent to participants, equaling an average of 3-4 messages per day per person. The number of messages per day varied between individual participants from 1.4 to 5.5.

The distribution of messages throughout the day is shown in Figure 6.2. It shows that for weekdays during the hours of 10-11am, 18-19pm and 20-21pm, more messages were sent. While during weekend, most advices were sent in the morning from 9am to 12am. The distribution of messages sent in the morning, afternoon and evening is shown in Figure 6.3. More messages were sent in the morning during weekend compared to weekdays. On the other hand, more advices were sent in the evening during weekdays (after work). In general the messages were distributed evenly during the day.

Figure 6.2 Percentage of messages sent per hour
The percentages of different advice types are shown in Figure 6.4. The most frequently sent messages suggested outdoor activities such as a lunch walk during work or a leisure walk to a green place in the weekends. The secondly most frequently sent messages were about a small break during work or at home. Those are small activities which require only little effort. The difference with the pilot was that more outdoor activities and weekend activity suggestions rather than housework were sent.

Figure 6.4 Percentage of different advice types
6.3.2 Usage of Motivate

Missing rate
There were 2848 (83.3%) out of all 3421 messages that were given responses by users. We considered only those messages in the analysis. The response rate of individuals varied from 29.9% to 100%. 14 out of 25 users responded to more than 95% of the messages. 10 participants responded to 50-90% of the messages while the other one participant only responded to 29.9% of the advices.

Figure 6.5 Time of viewing message after receiving

Figure 6.6 Time between reporting action and responding to the message
Response speed
The time interval between a message arriving at the mobile phone and being viewed by a user for the first time was analyzed. The results (Figure 6.5) show that more than half of the messages were viewed within 30 minutes, while 31.1% of the messages were viewed almost immediately. The rest of the messages were viewed mostly with 12 hours.

After participants viewed the advice, in most cases (93.9%) they submitted their responses within 2 minutes. Sometime later participants reported their actions of whether they have followed the advices. We analyzed the time interval between responding to a message and reporting actions. The results are shown in Figure 6.6. The actions for round 15% of advices were reported within the first hour, while for 81% of the advices the actions were reported within 24 hours.

6.3.3 Reponses and actions for all advices
User response
In total 1361 messages (47.8%) were given a positive response (including “Yes now”, “Yes later” and “Yes already”), while 1488 messages were given a negative response (52.2%). The results of different responses are listed in Table 6.2.

<table>
<thead>
<tr>
<th>Positive responses (47.8%)</th>
<th>Yes now</th>
<th>696</th>
<th>24.4%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes later</td>
<td>355</td>
<td>12.5%</td>
</tr>
<tr>
<td></td>
<td>Yes already</td>
<td>310</td>
<td>10.9%</td>
</tr>
<tr>
<td>Negative response (52.2%)</td>
<td>No</td>
<td>1487</td>
<td>52.2%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2848</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Self-reported action
Participants reported their actions of whether they have followed the advice for 2288 (80.4%) out of the answered 2848 advices. Three participants chose “Yes, I did it” for all advices that they received due to their misunderstanding of the requirements. They thought it was a confirmation of responding to the advice. Thus their data of self-reported actions were excluded from the analysis. The self-reported actions of 22 participants (n = 2131) were analyzed. They reported “Yes, I did it” for 852 (40%) advices, and “No, I didn’t do it” to 1279 (60%) advices.

The NcNemar Chi-square test was applied to examine whether there is any change between the self-reported actions and their initial responses to the same advice. The responses and actions for the 2131 advices are shown in Table 6.3. The results indicate a significant difference between responses and self-report actions, \( \chi^2 = 88.688, p = 0.000, N = 2131. \)
Motivate: a Context-aware mobile application for physical activity promotion

### Table 6.3 Responses and Self-reported actions

<table>
<thead>
<tr>
<th>Response</th>
<th>Self-report action</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes, I did it</td>
<td>No, I didn’t do it</td>
</tr>
<tr>
<td>Positive</td>
<td>812 (81.8%)</td>
<td>181 (18.2%)</td>
</tr>
<tr>
<td>Negative</td>
<td>40 (3.5%)</td>
<td>1098 (96.5%)</td>
</tr>
<tr>
<td>Total</td>
<td>852 (40%)</td>
<td>1279 (60%)</td>
</tr>
</tbody>
</table>

When the users had no intention to follow the advice and gave a negative response, afterwards in most cases (96.5%), they indeed did not follow the advice according to their self-report. However, when they intended to follow the advice and gave a positive response, afterwards their reported actions were less consistent with their responses. Only 81.8% of the time, they reported that they indeed follow the advice after giving a positive response before.

The positive responses included “Yes now”, “Yes later” and “Yes already”. We further analyzed self-reported actions with respects to these three kinds of positive responses (Table 6.4). When they chose “Yes later”, they changed their mind more often than when choosing “Yes now” or “Yes already”.

### Table 6.4 User responses and their self-reported actions

<table>
<thead>
<tr>
<th>Actions</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counts</td>
<td>421</td>
<td>75</td>
<td>496</td>
</tr>
<tr>
<td>Percentage</td>
<td>84.9%</td>
<td>15.1%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Counts</td>
<td>193</td>
<td>62</td>
<td>255</td>
</tr>
<tr>
<td>Percentage</td>
<td>75.7%</td>
<td>24.3%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Counts</td>
<td>198</td>
<td>44</td>
<td>242</td>
</tr>
<tr>
<td>Percentage</td>
<td>81.8%</td>
<td>18.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Counts</td>
<td>40</td>
<td>1098</td>
<td>1138</td>
</tr>
<tr>
<td>Percentage</td>
<td>3.5%</td>
<td>96.5%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Counts</td>
<td>852</td>
<td>1279</td>
<td>2131</td>
</tr>
<tr>
<td>Percentage</td>
<td>40%</td>
<td>60%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

### Reasons for negative response

We analyzed the reasons for not following the advice (n = 1487). More than 75% of these advices were rejected because of 3 reasons: “I already have other plans”, “I don’t feel like doing it” and “I am busy and have no time”. Results were listed in Table 6.5.
Table 6.5 Reasons for negative response

<table>
<thead>
<tr>
<th>Reasons</th>
<th>Short term</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>I already have other plans</td>
<td>Other plans</td>
<td>29.7%</td>
</tr>
<tr>
<td>I am too busy and has no time</td>
<td>Busy</td>
<td>23.3%</td>
</tr>
<tr>
<td>I don't feel like doing it</td>
<td>Not feel like it</td>
<td>22.3%</td>
</tr>
<tr>
<td>Not feasible</td>
<td>Not feasible</td>
<td>11.0%</td>
</tr>
<tr>
<td>I don't like this kind of advice, I don’t want to get it again</td>
<td>Never again</td>
<td>2.5%</td>
</tr>
<tr>
<td>The location is not suitable</td>
<td>Location</td>
<td>2.0%</td>
</tr>
<tr>
<td>The weather is not suitable</td>
<td>Weather</td>
<td>3.6%</td>
</tr>
<tr>
<td>Other (not good timing, no need to do it, I am sick, etc)</td>
<td>Other</td>
<td>5.6%</td>
</tr>
</tbody>
</table>

We analyzed these reasons for negative responses for the 7 different kinds of advice with CHAID decision tree (Figure 6.7). For the outdoor, weekend, shopping and housework advices, the mostly mentioned reason for negative responses was “other plans”. Outdoor activity received negative responses due to the reasons of “other plans”, “not feel like it” and “busy”. It seems that not suitable weather or location was chosen as a reason in only 10% of the cases (66 cases out of 658 cases). For weekend advice, the reason for not going to events or cinema for more than half of the cases was “other plans”. For the shopping advice, we found that in 20 out of 134 cases, the reason was “there is no need” which was not chosen for any other advices. The reason for not doing housework was mainly “other plans”, “don’t feel like it” and “not feasible”. Take stairs, transportation and break messages that were more related to working hours were grouped together. The main reason for not following these advices were “busy”, “not feasible” and “don’t feel like”. The reason of “not feasible” was given to only 11.0% of the advices, and the advice types are mainly “take stairs”, “transportation”, “break”, and “housework”. There activities sometimes require that there is a stair to take at work, and a garden for “gardening” activity, for example.
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Differences during 5 weeks of usage

Responses

We analyzed whether the user responses to the advice differed during the 5 weeks of usage. From CHAID analysis we found some significant differences. In week 4 and 5, higher percentage of choosing “Yes now”, but lower percentage of choosing “Yes later” and “Yes already” were found compared with that in the first 3 weeks (Figure 6.8; Figure 6.9).
Chapter 6: Evaluation user study of Motivate Final Version

Figure 6.9 CHAID analysis of responses in 5 weeks

Self-reported actions
We are interested in how participants reported their actions during 5 weeks. First we analyzed the percentage of messages that users reported their actions after they gave their responses. The results of CHAID analysis shows that the percentage of the messages that were given self-reported actions by users increased significantly throughout the usage in 5 weeks (see Figure 6.10).

We further look into whether there is a difference of following-up rate according to the self-reported actions between weeks. Therefore, we only considered the valid reported-actions in the first 5 weeks (message number is 1600). We could not find any difference of self-reported actions between each week. The self-reported actions during 5 weeks are shown in Figure 6.11. The reporting of “Yes, I did it” was a bit higher for the last three weeks compared to the first two weeks, but not significantly.
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Figure 6.10 Percentage of messages given a reported action in 5 weeks

Figure 6.11 Self-reported actions in 5 weeks

Reminded messages
The participants responded “Yes, later” to 355 messages and they used “Reminder” function for 141 (39.7%) messages. As soon as the reminded messages were sent to them, positive responses were given to 107 messages of the reminded messages, 73 (51.8%) for “Yes”, 13(9.2%) for “Yes later” and 21 (14.9%) for “Yes already”.

Within 141 messages, the reminder has been set for all kinds of activities, and the most frequently remaineder messages are: “take a break at work” (n = 25), “Take stairs” (n = 12), “gardening at home” (n = 8), “a walk after dinner” (n = 8) and “go to an event” (n = 8).
Table 6.4 shows that there were 255 valid self-reported actions for the advice that were responded as “Yes Later”. To find out how the “Reminder” function worked, we compared the follow-up rate for the advices that were sent again to remind the users, with the rest that were sent to them only once. Table 6.6 shows that the “Remind later” advices were followed significantly less than the ones that “No reminder” was needed ($\chi^2 = 7.224, p< 0.05$). The reason could be that the users were less certain about whether they would follow the advice later, therefore they set the reminder. Still more than half of the “Remind later” advices were followed by the users.

Table 6.6 self-reported actions for the “Yes Later” advice

<table>
<thead>
<tr>
<th>“Yes Later”</th>
<th>Remind later</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>Count</td>
<td>Yes</td>
<td>No</td>
<td>Total</td>
</tr>
<tr>
<td>-------------</td>
<td>-------</td>
<td>-----</td>
<td>----</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>63</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>66.3%</td>
<td>33.7%</td>
<td>100.0%</td>
</tr>
<tr>
<td>No reminder</td>
<td>Count</td>
<td>130</td>
<td>30</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>81.3%</td>
<td>18.8%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Total</td>
<td>Count</td>
<td>193</td>
<td>62</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>75.7%</td>
<td>24.3%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

6.3.4 Utilitarian vs. Recreational advice

According to the activity type, we categorize advices into recreational and utilitarian activities. The utilitarian activities are the ones that can fit into daily activity, and together with other activities, sometimes with another purpose, such as going to supermarket, going to work by bike, taking stairs, etc. The recreational advices include the ones that suggest going for a walk or a cycling trip to a park, going to the city to meet friends, or going to an event in the spare time. The user responses to these 2 types of advices are shown in Table 6.7. The results indicate a significant difference in the user response to the utilitarian and recreational advices ($\chi^2 = 179,187, p = 0.000$). The advices suggesting utilitarian activities received more positive responses than the recreational activities.

Table 6.7 User responses to 2 types of advice

<table>
<thead>
<tr>
<th>Advice types</th>
<th>Responses</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>utilitarian</td>
<td>count</td>
<td>1067</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>56.8%</td>
</tr>
<tr>
<td>recreational</td>
<td>count</td>
<td>294</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>30.3%</td>
</tr>
<tr>
<td>Total</td>
<td>count</td>
<td>1361</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>52.2%</td>
</tr>
</tbody>
</table>

The same analysis of self-reported actions for these 2 types of advice is shown in Table 6.8 ($\chi^2 = 108.578, p = 0.000$). The same trend with the user responses in Table 6.7 is found in self-reported
actions, which indicates that more utilitarian activity advices were followed than recreational activity advices.

<table>
<thead>
<tr>
<th>Advice types</th>
<th>Self-reported action</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>utilitarian</td>
<td>count</td>
<td>681</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>47.8%</td>
</tr>
<tr>
<td>recreational</td>
<td>count</td>
<td>171</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>24.3%</td>
</tr>
<tr>
<td>Total</td>
<td>count</td>
<td>852</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>40%</td>
</tr>
</tbody>
</table>

**Green place advice**

*Validation of self-reported actions for green place advice*

The location coordinates (latitude and longitude) of the users was sent every 15 minutes to the server. With the knowledge of each location point and the localization accuracy (in meters) of that point, we define the range of a possible user location within a circle. The user coordinate (latitude and longitude) is the center and the accuracy is the radius (see Figure 6.12). In order to find out whether users went to the suggested green place after receiving the message, we analyzed the user location points recorded during the time period between responding to a message and reporting their actions. If they have been to that green place, the circle of user activity range and the green place geometry should intersect with each other (see Figure 6.12).

In total 859 advices suggested a green place for outdoor activities. Among them 297 messages (27.7%) were given positive response and 194 messages were self-reported later as “Yes, I did it.” We analyze these 194 cases, and found out in 99 (51.0%) cases, the participants’ location range intersected with the green place. Approximately in half of the cases, the participants indeed came to the suggested location when they reported “Yes, I did it”. The time that they first visited the green place was 1 hour after receiving the message on average. The average distance from their initial location to these suggested green places was 403 meters.
For the rest of the 95 messages, the user location coordinates were not found across the green place within that time period. On average the distance between these suggested green places from the users was 2217 meters. Out of these 95 messages 31 messages were given the responses of “Yes already”, which could be one possible reason for the user location not being found near the green place.

The validity of the validation method is dependent on the accuracy of the user location detected by the mobile phone and the frequency of recording user location (every 15 minutes). This validation can only indicate to some extent whether users have actually followed the green place advice, but it should be emphasized that many uncertainties are involved (section 6.4.4).

**Distance**

Among 859 advices that suggested a green place for outdoor activities, the distance from a user to the green places differed from less than 200 meters to more than 5km. For all these green place advices, no significant difference was found in user response due to the difference distance to a green place (p>0.1).

We further looked into each green place advice, including going to a green place nearby, a lunch walk at work, a walk or a cycling trip in the nature, and taking a detour to a green place on the way home. The distance of a green place from the user when receiving the advice, and the percentage of positive user responses are listed in the table below. No significant difference of user response has been found for each type of advice, with respect to the difference in distance (p>0.1).

<table>
<thead>
<tr>
<th>Advice</th>
<th>Distance to the suggested green places</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;200m</td>
</tr>
<tr>
<td>Close nature</td>
<td>27.9%</td>
</tr>
<tr>
<td>Lunch walk</td>
<td>24.2%</td>
</tr>
<tr>
<td>A walk in the nature</td>
<td>33.3%</td>
</tr>
<tr>
<td>Cycling in the nature</td>
<td>-</td>
</tr>
<tr>
<td>Detour to green</td>
<td>12.5%</td>
</tr>
</tbody>
</table>

**Advice suggesting a specific location vs. general advice**

We are interested in whether the suggestion of a specific green place can trigger more intention to follow the advice compared to the same advice suggesting a general location. For example, one advice suggested a walk after dinner either to a specific green place or just “around your neighborhood”. The response to the advice is show in Table 6.10. The positive responses to a walk to a green place was slightly less, but not significantly (p > 0.1). The specified green place with indication of the map did not trigger more intention to follow the advice.
Motivate: a Context-aware mobile application for physical activity promotion

Table 6.10 Responses to an advice with or without specific location

<table>
<thead>
<tr>
<th>Walk after dinner</th>
<th>Count</th>
<th>%</th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>around your neighborhood</td>
<td>44</td>
<td>37.3%</td>
<td>74</td>
<td></td>
<td>118</td>
</tr>
<tr>
<td>to a green place</td>
<td>80</td>
<td>31.5%</td>
<td>174</td>
<td></td>
<td>254</td>
</tr>
<tr>
<td>Total</td>
<td>124</td>
<td>33.3%</td>
<td>248</td>
<td></td>
<td>372</td>
</tr>
</tbody>
</table>

6.3.5 Different types of advice

![User responses to different types of advice](image)

Figure 6.13 User responses to different types of advice

![Self-reported action for different types of advice](image)

Figure 6.14 Self-reported action for different types of advice
First we analyzed the user responses to 7 different types of advices. The results shown in Figure 6.13 describe the responses to each type of advices. The advices of taking a break and taking stairs were given the most positive responses (76.9% and 60.5%).

The self-reported actions (N = 2131) for different kinds of advices were analyzed. The results shown in Figure 6.14 describe the self-reported actions to each type of advices. Comparing Figure 6.13 with Figure 6.14, a lower percentage of positive self-reported actions than the positive responses was found.

In section 6.3.3, pp.103 we have shown a significant difference between responses and self-report actions to all advices by McNemar Chi-square test. For each type of advice, the same analysis was performed and the results show higher percentages of negative self-reported actions than negative responses significantly for 5 out of the 7 types of advice, except for “housework” and “transportation”.

**Responded messages frequency**

In Chapter 4 section 4.2.2, pp. 57, the configuration of the frequency of each group of advices has been described. The number and frequency of messages of each group that were responded by users are described in Table 6.11. About half of the advices suggested small activities at work or at home, such as taking a break, taking stairs, a lunch walk (approximately 1.5 messages of these types per day). Besides, the advice of recreational activities such as activities in the nature for weekends, were sent quite often as well (2-3 messages per week on average). Other activities such as changing transport mode to commute to work, going to an event, social activities, etc were sent with a number between 100 and 200, approximately 1 message per week.

<table>
<thead>
<tr>
<th>Group</th>
<th>Advice</th>
<th>Percentage</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break at work</td>
<td>coffee break, take water /walk around,</td>
<td>16.6%</td>
<td>473</td>
</tr>
<tr>
<td>Activity at home</td>
<td>housework, gardening, indoor exercise , take break when watching TV</td>
<td>15.8%</td>
<td>450</td>
</tr>
<tr>
<td>Lunch</td>
<td>a lunch walk (to green place/canteen)</td>
<td>10.5%</td>
<td>299</td>
</tr>
<tr>
<td>Take stairs</td>
<td>take the stairs</td>
<td>7.5%</td>
<td>214</td>
</tr>
<tr>
<td>Dinner</td>
<td>wash dishes After, after dinner walk</td>
<td>5.6%</td>
<td>159</td>
</tr>
<tr>
<td>Transportation</td>
<td>go to work/home by bike, park your car further, take a detour, go to supermarket after work</td>
<td>5.9%</td>
<td>168</td>
</tr>
<tr>
<td>Shopping</td>
<td>weekend shopping/supermarket</td>
<td>8.0%</td>
<td>228</td>
</tr>
<tr>
<td>Nature weekend</td>
<td>walk to green places , cycling to green places</td>
<td>14.3%</td>
<td>407</td>
</tr>
<tr>
<td>Close nature</td>
<td>nature place to go (&lt;200m)</td>
<td>5.4%</td>
<td>154</td>
</tr>
<tr>
<td>Social weekend</td>
<td>visit friends, go to movie</td>
<td>6%</td>
<td>171</td>
</tr>
<tr>
<td>Event</td>
<td>weekend events</td>
<td>4.4%</td>
<td>125</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100%</td>
<td>2848</td>
</tr>
</tbody>
</table>
Motivate: a Context-aware mobile application for physical activity promotion

Detailed level advice analysis
In total 24 advices with different suggested activities were generated. The details of the messages are shown in Appendix B. Three individual advices were sent only few times (less than 10 times each), which were “getting off bus one or two stops before arrival (when going to work or going home)”, “go shopping to the closest shopping center on Saturday”, “go to the open market on Saturday”. The low occurrence of the advice of getting off the bus earlier was due to the profile of the users. Only one participant commutes to work by bus. Compared with the advices of “going to the supermarket” in the same category, the advices of “go shopping” and “go to open market” require conditions of female participants and rather good weather, which can be the reason for the low occurrence.

We further analyzed the user preference for each advice by looking into the detailed user responses (Table 6.12), the advices were arranged from top to bottom by positive response rate from highest to lowest.

<table>
<thead>
<tr>
<th>Advice</th>
<th>Number of messages</th>
<th>Positive response</th>
<th>Yes Now</th>
<th>Yes Later</th>
<th>Yes Already</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take a break while working at home</td>
<td>213</td>
<td>82.6%</td>
<td>62.3%</td>
<td>8.7%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Take a break (walk around or get water)</td>
<td>140</td>
<td>82.4%</td>
<td>54.7%</td>
<td>14.7%</td>
<td>13.0%</td>
</tr>
<tr>
<td>Stretch exercise at home</td>
<td>107</td>
<td>77.6%</td>
<td>61.7%</td>
<td>13.1%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Movement during watching TV</td>
<td>168</td>
<td>68.5%</td>
<td>41.1%</td>
<td>17.9%</td>
<td>9.5%</td>
</tr>
<tr>
<td>Go to a bathroom on another floor</td>
<td>120</td>
<td>68.3%</td>
<td>31.7%</td>
<td>17.5%</td>
<td>19.2%</td>
</tr>
<tr>
<td>Take stairs at work</td>
<td>215</td>
<td>60.5%</td>
<td>30.7%</td>
<td>14.0%</td>
<td>15.8%</td>
</tr>
<tr>
<td>Go out to visit friends</td>
<td>72</td>
<td>56.9%</td>
<td>15.3%</td>
<td>15.3%</td>
<td>26.4%</td>
</tr>
<tr>
<td>Housework</td>
<td>95</td>
<td>55.8%</td>
<td>28.4%</td>
<td>10.5%</td>
<td>16.8%</td>
</tr>
<tr>
<td>A walk to canteen to have lunch</td>
<td>42</td>
<td>52.4%</td>
<td>9.5%</td>
<td>23.8%</td>
<td>38.1%</td>
</tr>
<tr>
<td>Walk/bike to a supermarket</td>
<td>215</td>
<td>44.7%</td>
<td>17.0%</td>
<td>15.4%</td>
<td>12.3%</td>
</tr>
<tr>
<td>Garden work in a weekend</td>
<td>56</td>
<td>35.7%</td>
<td>8.9%</td>
<td>17.9%</td>
<td>8.9%</td>
</tr>
<tr>
<td>Park car a bit further when going home</td>
<td>54</td>
<td>33.5%</td>
<td>7.4%</td>
<td>14.7%</td>
<td>11.4%</td>
</tr>
<tr>
<td>A walk after dinner</td>
<td>372</td>
<td>33.3%</td>
<td>12.4%</td>
<td>12.4%</td>
<td>8.6%</td>
</tr>
<tr>
<td>Cycling in to the nature</td>
<td>88</td>
<td>31.8%</td>
<td>3.4%</td>
<td>10.2%</td>
<td>18.2%</td>
</tr>
<tr>
<td>A walk after lunch to a green place</td>
<td>258</td>
<td>30.2%</td>
<td>17.8%</td>
<td>5.8%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Go to the green place close by</td>
<td>154</td>
<td>27.9%</td>
<td>8.4%</td>
<td>11.7%</td>
<td>7.8%</td>
</tr>
<tr>
<td>A walk to the nature</td>
<td>62</td>
<td>24.2%</td>
<td>8.1%</td>
<td>6.5%</td>
<td>9.7%</td>
</tr>
<tr>
<td>Event in the city</td>
<td>124</td>
<td>21.8%</td>
<td>5.6%</td>
<td>12.9%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Walk to a cinema</td>
<td>98</td>
<td>16.3%</td>
<td>3.1%</td>
<td>9.2%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Go to work on foot</td>
<td>48</td>
<td>14.6%</td>
<td>10.4%</td>
<td>2.1%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Take a detour home</td>
<td>61</td>
<td>9.8%</td>
<td>4.9%</td>
<td>3.3%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>
The top 9 advices (n = 1159, 40.7% of all 2848 messages) were given positive responses for more than half of the time (in green color). The activities being suggested included some small breaks, take stairs, walk to the canteen and housework. The bottom 6 advices (n = 638, 13.8% of all 2848 messages) were given the least positive response (<30%, in red color). The rest of the 7 advices in the middle (n = 1199, 42.1% of all 2848 messages) were given positive response in between 30% to 50% of the time.

In particular for the most favorable advices, “visit friends” and “go to lunch” (in Italic style) advices were given the response of “Yes Already”, with higher percentage than “Yes now” and “Yes later”, indicating that the participants would have done the same activity without being influenced by the advice. For the other 7 top advices, the percentage of “Yes now” was much higher than “Yes later” (n = 1031, 36.2% of all 2848 messages). These 7 advices which suggested different small activities have triggered immediate compliance to the advice. Instead, for the bottom 12 less favorable advices, 5 of them (in Italic style) received higher percentage of “Yes later” rather than “Yes now”, indicating the participants considered to follow the advices possibility later, but not immediately.

6.3.6 Questionnaire results

Reported feeling of change of behavior
21 participants finished the questionnaires both before and after the usage of Motivate. Only 3 of them chose “No, I have not changed”. 15 participants chose that they have become “a little bit more active”; 3 of them chose that they became “a lot more active”.

Change before and after the usage
A paired-Sample T-Test was performed to analyze the answers to the questionnaire before and after using the Motivate. For each individual question, the average scores for 10 out of 14 questions after the usage were slightly higher than the scores before the usage. The average scores for each question before and after the experiment are shown in Table 6.13. No significant difference was found for score change of any individual question from before to after the experiment (p>0.05).

Awareness of PA level
When the participants first filled in their profile, they have been asked the same question as Question 9, considering their activity level (7 point Likert-scale), without comparing with the standard that was presented in the questionnaire (section 6.2.2., pp.96). The score of the judgment of PA level without considering the standard (Mean= 4.6) was significantly lower than the questionnaire (Mean = 5.76), t (20) = -2.758, p<0.05.
Table 6.13 Questionnaire results

<table>
<thead>
<tr>
<th>Question</th>
<th>Content</th>
<th>Before (M±SD)</th>
<th>After (M±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 Attitude</td>
<td>Meeting this standard for me would be (1: unimportant…7: Important)</td>
<td>5.19±1.07</td>
<td>5.71±0.96</td>
</tr>
<tr>
<td>Q2 Attitude</td>
<td>Meeting this standard for me would be (1: unpleasant…7: pleasant)</td>
<td>5.33±1.20</td>
<td>5.52±1.20</td>
</tr>
<tr>
<td>Q3 social norms</td>
<td>Most of my family and friends meet this standard (1:false…7:true)</td>
<td>4.24±1.45</td>
<td>4.19±1.44</td>
</tr>
<tr>
<td>Q4 social norms</td>
<td>Most people like me meet this standard (1:unlikely…7: likely)</td>
<td>4.33±1.45</td>
<td>4.52±1.57</td>
</tr>
<tr>
<td>Q5 Perceived control</td>
<td>I am confident that I can meet the standard for the next 3 months (1:false …7:true)</td>
<td>4.90±1.61</td>
<td>4.71±1.82</td>
</tr>
<tr>
<td>Q6 Perceived control</td>
<td>Whether I can meet the standard for the next 3 months is up to me (1:disagree…7:agree)</td>
<td>5.90±1.18</td>
<td>6.24±1.18</td>
</tr>
<tr>
<td>Q7 intention</td>
<td>I intend to meet this standard for next 3 months (1:false …7:true)</td>
<td>5.38±1.36</td>
<td>5.52±1.25</td>
</tr>
<tr>
<td>Q8 past behavior</td>
<td>In the past 3 months, I have met this standard (1:false …7:true)</td>
<td>4.29±1.65</td>
<td>4.43±1.89</td>
</tr>
<tr>
<td>Q9</td>
<td>How physically active do you think you are? (1: very inactive... 7: very active)</td>
<td>5.76±1.18</td>
<td>6.19±0.98</td>
</tr>
<tr>
<td>Q10</td>
<td>Do you know what you can do in order to stay active? (1:Not at all...7: yes, very much)</td>
<td>4.43±1.60</td>
<td>4.86±1.50</td>
</tr>
<tr>
<td>Q11</td>
<td>Do you have many ideas about what to do in order to stay active? (1: No idea…7: yes, many ideas)</td>
<td>4.71±1.59</td>
<td>4.86±1.10</td>
</tr>
<tr>
<td>Q12</td>
<td>How do you think about fitting physical activities into your daily life? (1:Very hard…7: very easy)</td>
<td>4.05±1.43</td>
<td>3.76±1.14</td>
</tr>
<tr>
<td>Q13</td>
<td>How much do you know about the green places (e.g., park, lake, forest, etc) near your home and work place in (around) Eindhoven? (1: not at all... 7: very much)</td>
<td>4.52±1.08</td>
<td>4.48±1.29</td>
</tr>
<tr>
<td>Q14</td>
<td>How often do you go to those green places? (1: not at all...7: very often)</td>
<td>5.14±1.59</td>
<td>5.71±0.85</td>
</tr>
</tbody>
</table>

Relationship between compliance and TPB variables

**Determinate of PA based on TPB model**

In this questionnaire, the variables of TPB model are related to the behavior of “being physically active”. We are interested in whether these variables can affect the behavior of complying with PA advices during the usage of Motivate. For example, whether the higher the intention to meet this standard, the more activity advices that participants would like to follow? To understand this relationship, we first group the 21 participants who have finished these two questionnaires into two groups. Based on the frequency of responding positively to all advices, we grouped them
into “group positive” and “group negative”, by Classification and Regression Trees (CRT). The percentages of positive responses to the advices of 2 groups are shown in table below. The participants who are in group positive responded positively to more than 50% of the advices, while the participants who are in group negative responded to less than 50% of the advices positively.

<table>
<thead>
<tr>
<th>Table 6.14 Participants groups based on responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group positive (11 participants)</td>
</tr>
<tr>
<td>On average</td>
</tr>
<tr>
<td>59.6%</td>
</tr>
<tr>
<td>Group negative (10 participants)</td>
</tr>
</tbody>
</table>

Between groups
An independent T-Test was conducted to analyze whether the scores for each question differ between group positive and group negative both before and after the experiment. Only the scores of Q14 after the experiment differed significantly between 2 groups. The positive group reported them going to green place (M = 5.36, SD = 0.67) less than Group negative (M = 6.10, SD = 0.88), t (19) = -2.171, p<0.05. This is a bit unexpected, and the explanation could be that the positive group may have followed more advices, although not green place advices in particular.

Within groups
For each group, a Paired-Sample T-Test was performed of each question to compare the score before and after the experiment. For the positive group, there was only one significant increase for Q1, from before (M = 5.09, SD = 0.94) to after (M = 5.90, SD= 0.83), t (10) = -2.764, p<0.05. This indicates that the participants who have responded more positively to advices showed a significant change of attitude towards “meeting the standard of being active”. The importance was rated more after using Motivate compared to the beginning. For the negative group no significant change of score was found for each question (p>0.05).

6.3.7 Interview

Preference of advice
More than half of the participants mentioned that their favorite advice suggested easy-to-do activities such as taking a break, taking stairs, or going to a supermarket, which they did not need extra planning and could follow immediately. The advice that they thought they followed least were the ones that needed extra effort, such as going to events or weekend outdoor activities. Their mostly mentioned reason for not following these kinds of advice was as “already have an initial plan”. When we asked participants about the green place and events advice in particular, most of them were enthusiastic about the ideas of exploring the green places and various activities in the city.
Almost all (18 out of 21) participants mentioned that the factors they considered first when making a decision of whether following the advice were “If I have enough time” or “If I do not have other plans”. Not enough time or having other plans was also the major reason for rejecting advices. Other concerns that were mentioned most were personal preference, mood, weather condition and opinions of other family members.

**Feeling of changes**

15 out of the 21 participants felt some changes during the period of using Motivate. They reported that they have conducted some activities more frequently such as taking breaks, taking stairs, or a small walk after dinner during the usage of Motivate.

Half of them also considered the advices to be useful for them, especially when they were too busy and forgot to move. The advice could change their habits such as sitting for too long during work. Some of them also mentioned that Motivate provided various ideas of what to do when they had some free time. The participants who felt no changes mentioned the main reasons for ignoring the advices were feeling lazy, being already quite active, or having a busy schedule.

**Usability**

All participants thought that the user interface of Motivate was “simple and easy to use”. Two participants who responded to the least percentage of the advice were asked for their reasons. One participant said she always set the phone to silent and missed many messages. The other participant complained that he received too many messages (on average 5 per day). Sometimes when he did not want to follow the advice, he just did not respond to it.

Only 2 participants mentioned the battery of their mobile phone drained faster than normal, possibly due to using Motivate.

**Reminder function**

We asked participants how they used the reminder function. They mentioned that they liked to use the reminder for small activities like taking a break or taking stairs. It was useful when they were occupied with something and knew exactly how long it would take. It was not very practical to set a reminded time if they were not sure when they would be free. Some people thought that it was not necessary to be reminded if they were already sure that they would follow the advice later.

**Ideas for improvements**

When being asked what could be improved with the Motivate application, participants mentioned the following points:

- More variety of advice
  
  Eight participants wished for more new advice. In the end, the advice was repeated more often and became predictable according to them.
- More personalized advice
Six participants mentioned that they expected more personalized advice based on a more extensive profile. For example, two participants with small children mentioned that many activities were appealing but difficult to fit in their schedule.

- Smarter advice
  Five participants hoped that the application could give suggestions based on their current activity level. Some people also mentioned it could be beneficial to suggest an activity for the time period when they had more free time.

- Interactive interface
  Four participants felt they were quite familiar with the text messages after some time and it was more interesting to present some pictures or animation of the activity.

- More information
  Three participants wished to have some information of how much calories being burned by doing that activity and possible health benefits. One participant mentioned it could help if the information of distance, time and route to go to a green place was also presented. Information about their performance compared with other people can also be motivating.

### 6.4 Discussions

#### 6.4.1 C-B-A change

According to the concept of a behavior change support system (Oinas-Kukkonen, 2010) there can be 3 categories of change, namely complying with the system requests (C-change), behavior change (B-change) and attitude change (A-change).

C-change: The basic goal of the Motivate application is to trigger C-change during usage. The responses to the messages reflected whether participants intended to comply with the advice and almost half of the messages were given a positive answer. The self-reported behavior of following the advice was not as positive as the initial intention. According to their self-reported actions, participants on average approximately followed 1-2 messages per day.

B-change: At least two thirds of the users have reported their feelings of changes towards being more active in the questionnaire and interview. They felt that they were conducting more small activities that can improve their PA level. Since we did not have a control group or measurement of the activity level of the users, we could not measure precisely how much behavior change was triggered by the Motivate advice. During the 5 weeks of the usage, the percentage of choosing “Yes already” did not increase as the usage time increased, which could not directly show that they already took the initiative to behave as being suggested. However, they indeed chose “Yes now” more after several weeks, which may indicate their willingness to immediately adapt their behavior.

A-change: the scores for the 2 questions that are related to the attitude of “being active”, showed no significant change after the intervention. Attitude is not always related to adherence to leisure
activity or fitness programs in adults (Dishman et al., 1985). The scores for Q1 and Q2 were higher than 5 on a 7-point scale, showing that the attitudes of users were already quite positive about “being active”. This “ceiling effect” may exist and explain no significant change after the intervention.

C-A change: A significant attitude change has been found for people who respond more positively to advices, which indicates a possible relation between C-change and A-change. More complying with the activity advice during the intervention is accompanied with considering “being active” as more important afterwards.

6.4.2 Determinants of PA based on TPB

In the experiment, the actual behavior of the compliance to the advices was studied and analyzed due to the self-report measurement. However, the target behavior of the Motivate application is to “become more physically active”, which was not able to be directly measured. Therefore, in the questionnaire the behavioral determinates of TPB was applied for a relevant behavior of “meeting the standard of being active” instead. By this approach the behavior of the general behavior of being physically active was studied to order to understand possible behavior and attitude change triggered by the intervention.

We measured the determinants of TPB model such as attitude, norms, perceived control, intention and past behavior for the behavior of “being active”. As a general rule, the more favorable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person’s intention to perform the behavior (Ajzen, 2012a). Consistently, the group of participants who has responded more positively to the advices, scored higher on these determinants of “being active” than other participants. We can argue that there exists a connection between users’ determinants of the behavior of “being active” with their behavior of complying with the advices that will help them achieve “being active”. The initial state of the participants may have some impact on the perception of the suggestions and the willingness to accept them. This suggests that the TPB can be used to study the behavior of “being active”.

6.4.3 Utilitarian vs. Recreational

From the user responses, actions and the interviews, we notice their preference for utilitarian activities, especially small ones such as taking stairs or a break at work or at home. Such utilization activities can easily fit into daily habits and are important for health promotion. Although the durations of these activities are rather short, their health benefits are no less than a single activity with long duration (Woolf-May et al., 1999; Jakie et al., 1999; Schmidt et al., 2001). The lifestyle interventions to promote small activities of “break”, “walking” or “taking stairs” were proven to have long-term effects on increasing PA and reducing sedentary activity (Dunn et al., 1998). Take “work break” as an example, the integration of PA into work breaks can reduce fatigue and improve mood (Pronk et al., 1995). Moreover, a “booster break” – organized, routine practice of various PA – can have the potential to improve workers’ well-being and health (Taylor, 2005). From this perspective, the Motivate application can be very
useful for people who are at the risk of sedentary lifestyle by sitting for long time during regular working hours. Indeed the usefulness of this intervention to remind them to do small PA during busy times is mentioned by half of the participants. We can expect long term health benefits of using this application as a gentle push for daily activities.

“Organizing activities means deciding on which activities to conduct where, when, for how long, by whom, with whom, which transport mode to use and how to get there” (Arentze & Timmermans, 2009). The theory states that activities are conducted to satisfy certain needs which build up or change over time (Arentze & Timmermans, 2006). The suggestions for utilitarian activities by Motivate are based on needs of daily lives, such as shopping, commuting to work, going to lunch, housekeeping, drinking water, etc. On the other hand, the recreational activities can satisfy the needs of leisure, relaxation, being in the open air, socializing, entertainment, and physical exercise as well. According to the need-based model proposed by Arentze and Timmermans (2009), the predication of the frequency of a certain activity is mainly dependent on the factors such as the target need of the activity, the potential of the activity to satisfy the need and a utility of time requirement of the individual (Arentze & Timmermans, 2009).

With the same fashion, the probability of following an advice can be influenced by how this suggested activity satisfy needs and also opportunity costs such as time and energy. This is supported by the major reason “Lack of time” for not following advice in the experiment. Besides, the first consideration when receiving an advice was the availability of time. This is in line with one frequently mentioned barrier to PA – “perceived lack of time” (Booth et al., 1997; Weinberg & Gould, 2007). The activities such as utilitarian activities takes less time and fulfill daily needs, therefore are preferred and followed more. The recreational activities may take more time and effort, and users need to consider how well this activity fits in their activity schedule and the needs of the other household members as well.

### 6.4.4 Validity and potential of measuring self-reported behavior

The Smartphone platform is ideal for collecting user opinions, since the phone can prompt users by sending them messages. The advantage is that user opinion can be collected at the moment when they are experiencing it, without recalling their memories. The self-report method adopted in our research is proven to be a good way to record behavior although it requires some user effort. More than 80% of the self-reported actions are given within 1 day, and more than half within 12 hours. There is little difficulty for people to record their behavior within this short period of time. As long as the moment to report the behavior is just after the happening of the behavior, self-reporting on mobile device can be reliable to measure report actual behavior.

However, the validity of self-report depends on whether people are honest about their choice. The validity of this self-reporting method to measure actual behavior of following the green place advices can be partly shown by the validation explained in section 6.3.4, pp. 110. It indicates that probably in half of the cases of reporting “Yes, I did it”, the participants indeed went to the suggested green place. However, we can't conclude the validity of the self-reporting method due to the uncertainties involved in this validation process. Because of the accuracy of the user
location detection and the frequency of recording user location (every 15 minutes), there were other possible factors which can influence the results of the analysis. For example, when the accuracy is 1km, there is a higher chance that the user location circle intersects with the green place nearby the user. The other possibility is that when a user remains his position nearby a green place for more than 15 minutes, his location point will intersect with the green place geometry. On the other hand, if a user went to a green place after receiving the advice but left in 15 minutes, his location circle probably would not intersect with that green place. In a word, this analysis can indicate to some extent whether users have actually followed the advice, but it should be emphasized that many uncertainties are involved.

6.4.5 Just in time persuasion

The participants viewed almost half of the messages half an hour after they received them. Although some users always view messages immediately, the others tend to view them a little later. For the advice that requires strict timing such as taking stairs, the response time of users is important. However, it is difficult to expect the time for users to interact with the advice. This raises the challenge of how to prompt users effectively by messaging on mobile devices.

On the other hand, the “right time” defined by the system design, is the moment that a user is more likely to follow the advice. But the determination of timing and the effect of persuasion are also related to the physical and psychological state of a person. The technology cannot identify other aspects of an opportune moment, such as the users’ state of mind, etc. (Fogg, 2003). They may be simply tired or not in the mood for exercise. In the experiment the participants mentioned one major reason for rejecting an advice was “I don’t feel like doing it”. This may be due to their “lack of motivation” or other unexpected factors, which may hinder the behavior of following advices. It suggests that “Just in time” is only one element for effective persuasion.

6.4.6 Location, more than location

Promoting outdoor activities at green places is one focus of the system design, thus we incorporate a geo database of green places in and around the city of Eindhoven. According to the end questionnaire the participants showed a change towards more visiting green places and know more about how to stay active (almost significantly). This shows evidently the benefit of such recreational advices. The selection of green places only depends on the distance of that place to a user, and we set this distance rather large in order to suggest various places. The distance to the suggested places did not make a difference in users’ willingness to follow the advice. This indicates there can be other factors besides the distance to the destination that can influenced their decisions, such as feasibility (time), accessibility and attractiveness of the green places, which are the environmental factors that may influence PA in the urban environment (Hoehner et al., 2005; Frank et al., 2003; Alfonzo, 2005). However, due to the limited information about the green places we could not include more attributes such as the suitability of the places for leisure activity to make a better selection. Besides, the presentation of the suggested place by Motivate is rather simple. It could help the users to judge how much effort they need to make in order to
follow the advice, by providing information of distance, possible route and time to reach the destination.

6.4.7 Agenda to plan activities

“I already have other plans” is the mostly mentioned reason for rejecting an advice in general, and also for outdoor, weekend, shopping and housework advices. Many daily activities and leisure activities are already scheduled. This is in line with the results of the questionnaire of Nijland et al. showing that in the case of sports activities, social activities and non-daily shopping activities, the activities are often planned more than a day before (Nijland, 2011).

We tried to solve this by sending recreational activities in the weekend one or two days before and implemented “Reminder” function to help them schedule their activity. This function is used in around 40% of the cases when the users would like to follow the advice later. As being mentioned in the interview, this function is used when they are busy, but would like to do it at a specific time later. More reminded activities are “break at work” instead of recreational activities. Since the reminder function is not systematically related to their agenda, they could not directly schedule an activity on their agenda by using the Reminder. Therefore, the Reminder is not effective on scheduling future activities in a longer term. The best solution is an accurate agenda that reflects every planned and current activity. Only with an extensive agenda the best empty time slot can be chosen for future activity scheduling. At the same time, information of weather forecast or future events should also be taken into account for leisure activity suggestion, for example. We can expect that synchronizing Reminder and Simple agenda together can help users set the reminder and update their agenda at the same time. In this manner, the performance of reminder and agenda can be both enhanced for scheduling and planning future activities.

6.4.8 Recruitment

Some difficulties were encountered during the recruitment. One practical reason can be the restriction that the participants need to own an Android phone, live and work in Eindhoven or surroundings. Only 42 people enrolled for the experiment. The other reason is that the requirement for participating in this research was not as simple as downloading a mobile application and use it. Therefore, 10 people did not complete the software setup and configuration. Another 7 people did not finish the whole experiment due to technical or other unknown reasons. The weeks of usage required a certain level of commitment. It might attract more participants if they could just download the application from the Android app store (Google Play). However, from a technical and practical point of view, we have to control the user setup procedure carefully to avoid unexpected problems and check user profiles. For a prototype testing recruiting a sufficient number of suitable participants was not easy considering a low budget.

6.4.9 Limitations

User profile that was taken into account for personalized advice generation was rather limited. Only gender, transportation mode and household type were considered for some advices such as
doing housework or changing transportation mode. The other profile such as user preferred activities, green places, shopping habit can be useful for generating advice that users are more likely to follow. The reason for a rather basic personalized level of advice is that we intend to provide individuals with a broad range of advice in order to get more data to extract their preferences.

The number of participants that were recruited during the experiment period was rather small. Therefore we could not afford a control group for comparison. We faced difficulties of recruiting people due to rather few Android users at that time. It was possible that people who were attracted to participate were initially interested in new technology and applications as well as already interested in PA promotion. According to the participants themselves, they were indeed quite active and already aware of the importance of being physically active, which may indicate a biased group. Besides, the participants consisted of rather high educated people who worked in high tech or academic work environment, and they were prone to be more active according to the findings that well-educated people are more likely to exercise (Dishman et al., 1985).

Although people who are not active enough and not aware of the importance of being active should be the ideal target of such a healthy living promotion interventions, we did not reach this exact group of participants. Half of the participants were working in the same academic environment which could bias the user group.

There are quite some researches that take interests in the effect of interactive design or feedback on persuasion (Consolvo et al., 2009b). From a persuasive design point of view, there are many ways to achieve a better persuasion. In the interview some users mentioned their desire of getting more feedback about their performance, or various interactions to make the application more fun and interesting to use. Due to our research scope, in the interface design process we focused on the effectiveness of usage. Thus, few efforts were made to achieve different interactive designs to interest users more. This leaves space for future development.

6.5 Conclusions

In this chapter we described the results of a user evaluation experiment of the final version of the Motivate application. The performance of the Motivate application has been proven to be stable during the time period of the user evaluation. The participants responded positively to approximately more than half of the advices and followed a slightly less of them according to their self report. Most users have felt behavioral change of towards being more active after weeks of usage. After the experiment, tendencies of positive attitude change, feelings of being more active, visiting more green places and knowing more about how to stay active have been found. These results all show that the Motivate application has the potential to change behavior and attitude towards an active life.

The utilitarian advices were preferred and followed more than recreational advices; in particular simple-to-do activities that required less effort received most positive responses. These small activities could trigger more behavioral change and following them is beneficial for people who
want to pursue a healthy lifestyle, especially for those who have a regular job and participate insufficiently in physical activities. The recreational advices have triggered reporting more visits to green places (with an almost significance). The “Motivate” can be a gentle push and reminder for simple daily activities, as well as offering innovative activity ideas for their free time.

The determinants of TPB model are proven to be useful for understanding behavior change and designing effective interventions. We can also conclude that the interpersonal factors such as attitude may have fundamental impact on how users perceived and reacted to PA advices, while behavior change can trigger attitude change. However, the impact of personal and contextual factors on the compliance to advices in detailed level needs to be studied in the next chapter.
Chapter 7. Logistic Regression analysis

7.1 Introduction

We mentioned in the previous chapter a need to investigate how personal factors and contextual factors impact on reactions to PA advices in various situations. As we discussed in section 2.2.2, age, gender, weight, education are correlates of PA behavior (Trost et al., 2002). The cognitive factors of the TPB model such as attitude, intention and perceived control are also important for PA behavior change. In the advice generation process only a few user profiles are considered as input, while the others are not analyzed. Therefore, we aspire to find out how personal profile factors such as user gender, weight, age, activity level intention, etc., influence users’ reactions to the advices. The contextual factors that are considered in advice generation include user agenda, location, weather, time, etc. They may influence how the users perceive and feel about the current conditions and thus the willingness to comply with the advice as well.

Besides, the characteristics of activities such as purpose, duration and intensity may decide on user preference in the first place. For instance, utilitarian activities can fit into daily schedules easily and accomplish another purpose, while recreational activities normally take more leisure time and fulfill user needs of relaxation, fresh air and exercise. Therefore the impact of advice type on the decision making process of users should be analyzed together with context.

In this chapter, we use binary logistic regression to analyze the responses to particular advices and self-reported actions given by different individuals in different contexts. We expect to gain insight into how “activity type”, “context” and “user profile” together influence how people comply with these suggestions.

7.2 Model description

7.2.1 The theory of Binary Logistic Regression

Let the probability of an event vary between 0 and 1, and be denoted by P. The regression model predicts the Logit, which is the natural log of the odds of making one or the other decision (e.g., complying with the given advice or not). The equation is:

\[ \text{Logit}(P) = \log \left( \frac{P}{1-P} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \]

X is the set of predictor variables

β is the set of coefficients of the predictor variables. Each β adjusts how quickly the probability P changes with changing each predictor variable a single unit. It measures the contribution of each independent predictor variables to variations in the dependent variable.

n is the number of predictors

Based on the equation above the probability (P) becomes:
Logistic regression is suitable for predicting whether something occurs or not. In different situations, the user may response either positively or negatively; thus the outcome measure is binary. Binary logistic regression is used to predict the probability that the users would follow the advices. The predictors include user profile variables and contextual variables. The analysis is to find out how the probability of choosing to follow the advice is associated with the type of advice, user profile and context of the users.

7.2.2 Data preparation

The analysis of both the responses and self-reported actions for advices were conducted respectively. We collected the responses to 2848 messages in total. We treat the decision making of responding positively or negatively to a piece of advice as one case in the model estimation. For this model in total 2848 cases could be used for the analysis.

In addition, among 2848 messages the self-reported actions for 2131 messages were given. The options were either “Yes I did it” or “No, I didn’t do it”. Altogether 2131 valid cases were included for the analysis of self-reported actions.

Dependent variables

The dependent variables for this analysis are binary (Table 7.1). User responses to advices were “Yes now”, “Yes later”, “Yes already” and “No” (as described in section 5.5.2, pp. 89). We group three positive choices together as “positive” response for this analysis. The positive response was designated as 1, whereas the negative response was designated as 0. The action of “Yes, I did it” was designated as 1, whereas the action of “No, I didn’t do it” was designated as 0.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Levels</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responses</td>
<td>Yes Now</td>
<td>Yes, I will do it now</td>
</tr>
<tr>
<td></td>
<td>Yes Later</td>
<td>Yes, I will do it later</td>
</tr>
<tr>
<td></td>
<td>Yes Already</td>
<td>Yes, because I am already doing or have planned something similar</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>No, I will not do it</td>
</tr>
<tr>
<td>Self-reported actions</td>
<td>Yes, I did it</td>
<td>I followed the advice</td>
</tr>
<tr>
<td></td>
<td>No, I didn’t do it</td>
<td>I didn’t follow the advice</td>
</tr>
</tbody>
</table>

Predictor variables

In total 14 variables were included in the model estimation. They are 8 profile variables, advice type and 5 contextual variables. The 8 variables that related to user profile, the coding and the composition sample size of the participants were described in Table 7.2.
Table 7.2 Composition of the sample

<table>
<thead>
<tr>
<th>User Profiles Variables</th>
<th>Levels(code)</th>
<th>number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male :1</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Female : 0</td>
<td>7</td>
</tr>
<tr>
<td>Age</td>
<td>Young (&lt; 34 years old): 1</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Old (&gt;=34 years old): 0</td>
<td>9</td>
</tr>
<tr>
<td>Nationality</td>
<td>Non Chinese :1</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Chinese: 0</td>
<td>7</td>
</tr>
<tr>
<td>Household composition</td>
<td>Live alone :1</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Live with others: 0</td>
<td>16</td>
</tr>
<tr>
<td>Body weight</td>
<td>Normal :1</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Overweight: 0</td>
<td>7</td>
</tr>
<tr>
<td>Transport mode</td>
<td>By bike : 1</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>By car/bus: 0</td>
<td>8</td>
</tr>
<tr>
<td>Activity level</td>
<td>Active :1</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Inactive: 0</td>
<td>6</td>
</tr>
<tr>
<td>Intention</td>
<td>Yes(want to be more active) :1</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>No or I don’t know: 0</td>
<td>8</td>
</tr>
</tbody>
</table>

The other 6 variables are related to the advice type and the context when the advices were created. The advices are categorized as utilitarian and recreational advices (see section 6.3.4). The 5 context variables include user related context variables (user location and agenda) and environmental variables such as time of the day, day of the week and weather. The variables user location, user agenda, weather and time of the day are categorical variables, and the parameter coding is shown in Table 7.3. The variable level coded with value 0, indicates the reference level for comparison. Thus, the combination of unknown user location, unknown user agenda, bad weather, in the evening, weekend and recreational advice constitutes the reference.
Table 7.3 Variables of advice kind and context description (reference level in bold)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code</th>
<th>Parameter Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advice type</td>
<td>Utilitarian</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Recreational</td>
<td>0</td>
</tr>
<tr>
<td>User location</td>
<td>Work</td>
<td>(1,0)</td>
</tr>
<tr>
<td></td>
<td>Home</td>
<td>(1,0)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(0,0)</td>
</tr>
<tr>
<td>User agenda</td>
<td>Go to work</td>
<td>(1,0,0,0,0)</td>
</tr>
<tr>
<td></td>
<td>Lunch break</td>
<td>(0,1,0,0,0)</td>
</tr>
<tr>
<td></td>
<td>Go home</td>
<td>(0,0,1,0,0)</td>
</tr>
<tr>
<td></td>
<td>Dinner</td>
<td>(0,0,0,1,0)</td>
</tr>
<tr>
<td></td>
<td>Work</td>
<td>(0,0,0,1)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>(0,0,0,0,1)</td>
</tr>
<tr>
<td>Weather</td>
<td>Good</td>
<td>(0,1)</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>(1,0)</td>
</tr>
<tr>
<td></td>
<td>Bad</td>
<td>(0,0)</td>
</tr>
<tr>
<td>Time of the day</td>
<td>Morning (7-12AM)</td>
<td>(1,0)</td>
</tr>
<tr>
<td></td>
<td>Afternoon(12-18PM)</td>
<td>(0,1)</td>
</tr>
<tr>
<td></td>
<td>Evening(18-24AM)</td>
<td>(0,0)</td>
</tr>
<tr>
<td>Day of the week</td>
<td>Weekday</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Weekend</td>
<td>0</td>
</tr>
</tbody>
</table>

7.3 Results

Binary logistic regression analysis was conducted to estimate models. The coefficient (B) of each 14 variable and the odds ratio (Exp(B)) values are described as results. All the significant (p<0.05) coefficients are in bold as presented in all tables.

7.3.1 Response to all advices

Main effects model

A binary logistic regression analysis was conducted with the user response to all advices, and the predictor variables. A positive response was designated as 1, whereas a negative response was designated as 0. The analysis results of the main effects model of user responses to all advices (n = 2848) are described in Table 7.4.

Nine out of the 14 variables contribute to the model significantly, $\chi^2 (21) = 512.854$, $R^2 = .165$ (Cox&Snell), .220 (Nagelkerke), and the percentage of correct prediction is 68.6%. The variables advice type and agenda have the highest absolute B value, which shows their highest association with the decision of how to respond to the advices made by users.

The signs of the B values of the significant variables show that the probability of a positive response to advices increases when:

- Participants are male, younger than 35 years old, commuting to work by car, Chinese, overweight, or have no obvious intention to become more active. In the case of the
negative B, the Exp(B) values of the variable transpiration, nationality, weight and intention are inversed into 1/0.619 = 1.62, 1/0.717 = 1.39, 1/0.590 = 1.69, 1/0.800 = 1.25. It indicates that the profile change in gender, age, transportation, etc of the participants increase or decrease the possibility of responding positively by factors ranging between 1 to 2.

- The advice type is utilitarian rather than recreational. Exp(B) value shows that utilitarian advices were 2.774 times more likely to receive a positive response compared to recreational advices.
- Users are at work, at home, rather than at other unknown locations.
- User agenda is at work time (exclusive of lunch break), or have nothing specific (unknown) rather than “go to work”, “lunch” and “go home”. The inversed Exp(B) of the variable “go to work” and “lunch” are 1/0.123 = 8.13, 1/0.366 = 2.73. These values show that when participants were about to go to work or during lunch time, they are much more negative towards advices compared to when they have no specific agenda.

Table 7.4 Main effects model of responses to all advices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code</th>
<th>B</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>male</td>
<td>.435</td>
<td>1.546</td>
</tr>
<tr>
<td>Age</td>
<td>young</td>
<td>.339</td>
<td>1.403</td>
</tr>
<tr>
<td>Transportation</td>
<td>by bike</td>
<td>-.480</td>
<td>.619</td>
</tr>
<tr>
<td>Nationality</td>
<td>non_Chinese</td>
<td>-.333</td>
<td>.717</td>
</tr>
<tr>
<td>Household composition</td>
<td>live alone</td>
<td>.087</td>
<td>1.091</td>
</tr>
<tr>
<td>Weight</td>
<td>normal</td>
<td>-.527</td>
<td>.590</td>
</tr>
<tr>
<td>Activity level</td>
<td>active</td>
<td>.070</td>
<td>1.072</td>
</tr>
<tr>
<td>Intention</td>
<td>yes</td>
<td>-.224</td>
<td>.800</td>
</tr>
<tr>
<td>Advice type</td>
<td>utilitarian</td>
<td>1.020</td>
<td>2.774</td>
</tr>
<tr>
<td>Location</td>
<td>work</td>
<td>.688</td>
<td>1.990</td>
</tr>
<tr>
<td></td>
<td>home</td>
<td>.460</td>
<td>1.584</td>
</tr>
<tr>
<td>Agenda</td>
<td>go to work</td>
<td>-2.098</td>
<td>.123</td>
</tr>
<tr>
<td></td>
<td>lunch</td>
<td>-1.005</td>
<td>.366</td>
</tr>
<tr>
<td></td>
<td>go home</td>
<td>-.651</td>
<td>.522</td>
</tr>
<tr>
<td></td>
<td>dinner</td>
<td>-.171</td>
<td>.843</td>
</tr>
<tr>
<td></td>
<td>work</td>
<td>.634</td>
<td>1.885</td>
</tr>
<tr>
<td>Weather</td>
<td>good</td>
<td>-.142</td>
<td>.868</td>
</tr>
<tr>
<td></td>
<td>fair</td>
<td>-.129</td>
<td>.879</td>
</tr>
<tr>
<td>Time of the day</td>
<td>morning</td>
<td>.107</td>
<td>1.113</td>
</tr>
<tr>
<td></td>
<td>afternoon</td>
<td>-.034</td>
<td>.966</td>
</tr>
<tr>
<td>Day of the week</td>
<td>weekday</td>
<td>.276</td>
<td>1.317</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>-.524</td>
<td>.592</td>
</tr>
</tbody>
</table>

Note: significant estimates in bold
Interaction effects model
The advice generation process considered various contexts. The effect of context can be analyzed by including main effects plus interaction effects between the context and advice type in the logistic regression analysis. The interactions of the advice type with 5 context variables are added as a second step in the binary regression analysis. After selecting the 14 variables as the first step, we add 5 interaction terms at once: “Advice type * location”, “Advice type * agenda”, “Advice type * time of the day”, “Advice type * weather” and “Advice type * day of the week”.

Compared with the main effects model in Table 7.4 the effects of profile variables are almost the same as in the main effects model. The major difference is that all 5 context variables contribute...
to this interaction effects model significantly, $\chi^2 (29) = 551.852$, $R^2 = .176$ (Cox&Snell), .235 (Nagelkerke), the percentage of correct prediction is 69.2%. All these values are higher than the main effects model, indicating a slightly better prediction. The effects of the variables are shown in the two columns on the right of Table 7.5.

The variables advice type and agenda still have the highest main effects in the model; especially the B value and Exp (B) of advice type becomes much higher than that in the initial main effects model. Besides, the other three context variables “weather”, “time of the day” and “day of the week” also contribute to the main effects significantly. The positive B values show that the contexts of good weather, in the morning and weekdays are associated with a higher chance of responding positively to an advice.

The interactions of advice type with user agenda, weather and time of the day contributes to the model, with all negative B values. When the advice type is “utilitarian” and a user is at dinner time, with fair weather or in the morning /afternoon are associated negatively with the probability of positive responses, considering the interaction effects. When the advice type is recreational, the same conditions are associated positively with the chance of positive responses instead.

There are no interaction effects between advice type and user location or day of the week. This indicates that no matter what kinds of advice that is, when users are at home, or the day is weekday, there is higher probability of positive responses.

7.3.2 Self-reported actions for all advices

Main effects model

A binary logistic regression was conducted with user self-reported actions and the predictor variables. An action of “Yes, I did it” was designated as 1, whereas an action of “No, I didn’t do it” was designated as 0. The analysis results of the main effects model of self-reported actions to for all advices (n = 2131) are described in Table 7.6.

Seven out of the 14 variables contribute to the model with significant effects, $\chi^2 (21) = 333.030$, $R^2 = .145$ (Cox&Snell), .196 (Nagelkerke), and the percentage of correct prediction is 70.1%. Compared to the model of user responses to all advices (Table 7.4), the effects of the significant context variables are very similar with this model of actions. The self-reported actions to the advices are also mostly associated by the variables advice type and agenda, which have the highest B values.

The signs of the B values of the significant variables show that the probability of an action of “Yes, I did it” increases when:

- Participants are younger than 35 years old, live alone, overweight, commuting to work by car.
- The advice type is utilitarian rather than recreational. Exp(B) value shows that utilitarian advices were 2.819 times more likely be followed according to the self-report.
Users are during work time (exclusive of lunch break time), or when they are having no specific activity on their agenda (unknown) rather than “go to work”. The inversed Exp(B) value of the variable go to work is $1/0.154 = 6.49$. They are much more unlikely to follow an advice when about to go to work according to the self-report.

Users are at work, at home, rather than at other unknown location

The main effects of profile variables of gender, nationality, intention were not found in the model of actions compared to the model of responses. When the participants live alone, they are more likely to follow advices than those who live with others, but this difference was not shown in their response to the advices.

Table 7.6 Main effects model of self-reported actions for all advices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code</th>
<th>B</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>male</td>
<td>.096</td>
<td>1.100</td>
</tr>
<tr>
<td>Age</td>
<td>young</td>
<td>.300</td>
<td>1.350</td>
</tr>
<tr>
<td>Transportation</td>
<td>by bike</td>
<td>-.661</td>
<td>.516</td>
</tr>
<tr>
<td>Nationality</td>
<td>non_Chinese</td>
<td>.042</td>
<td>1.043</td>
</tr>
<tr>
<td>Household composition</td>
<td>live alone</td>
<td>.358</td>
<td>1.430</td>
</tr>
<tr>
<td>Weight</td>
<td>normal</td>
<td>-.403</td>
<td>.668</td>
</tr>
<tr>
<td>Activity level</td>
<td>active</td>
<td>.099</td>
<td>1.104</td>
</tr>
<tr>
<td>Intention</td>
<td>yes</td>
<td>-.011</td>
<td>.989</td>
</tr>
<tr>
<td>Advice type</td>
<td>utilitarian</td>
<td>1.036</td>
<td>2.819</td>
</tr>
<tr>
<td>Location</td>
<td>work</td>
<td>.400</td>
<td>1.491</td>
</tr>
<tr>
<td></td>
<td>home</td>
<td>.310</td>
<td>1.363</td>
</tr>
<tr>
<td>Agenda</td>
<td>go to work</td>
<td>-1.874</td>
<td>.154</td>
</tr>
<tr>
<td></td>
<td>lunch</td>
<td>-.463</td>
<td>.630</td>
</tr>
<tr>
<td></td>
<td>go home</td>
<td>-.351</td>
<td>.704</td>
</tr>
<tr>
<td></td>
<td>dinner</td>
<td>-.138</td>
<td>.871</td>
</tr>
<tr>
<td></td>
<td>work</td>
<td>.969</td>
<td>2.636</td>
</tr>
<tr>
<td>Weather</td>
<td>good</td>
<td>-.110</td>
<td>.896</td>
</tr>
<tr>
<td></td>
<td>fair</td>
<td>.033</td>
<td>1.033</td>
</tr>
<tr>
<td>Time of the day</td>
<td>morning</td>
<td>-.239</td>
<td>.787</td>
</tr>
<tr>
<td></td>
<td>afternoon</td>
<td>-.386</td>
<td>.680</td>
</tr>
<tr>
<td>Day of the week</td>
<td>weekday</td>
<td>-.058</td>
<td>.944</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>-.766</td>
<td>.465</td>
</tr>
</tbody>
</table>

Note: significant estimates in bold

*Interaction effects model*

The interactions of the advice type with 5 context variables are added as a second step in the binary logistic regression analysis. After selecting the 14 variables as the first step, we add 5 interaction terms at once: “Advice type * location”, “Advice type * agenda”, “Advice type * time of the day”, “Advice type * weather” and “Advice type * day of the week”. Compared with the main effects model, the effects of profile variables do not change much when considering interaction effects. Only advice and agenda significantly have main effects, $\chi^2 (29) = 363.523$, $R^2 = .156$ (Cox&Snell), .211 (Nagelkerke), the percentage of correct prediction is 70.2%. All these
values are a bit higher than the main effects model, indicating a slightly better prediction. The effects of the variables are shown in the two columns on the right of Table 7.7.

When considering the interaction effects, the variable age does not have significant effects. The variables of advice type and agenda still have the highest main effects; especially the B value and Exp(B) of advice type becomes much higher than those values in the initial main effects model.

The interactions of advice type with user agenda and time of the day contributes to the model, with all negative B values. When the advice type is “utilitarian”, conditions of user at dinner time, or in the morning/afternoon are associated with less following advices, considering the interaction effects. When the advice type is recreational, the same conditions are associated with a higher chance of following advices instead.

Table 7.7 Interaction effects model of self-reported actions for all advices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code</th>
<th>B</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>male</td>
<td>.031</td>
<td>1.031</td>
</tr>
<tr>
<td>Age</td>
<td>young</td>
<td>.256</td>
<td>1.292</td>
</tr>
<tr>
<td>Transportation</td>
<td>by bike</td>
<td>-.664</td>
<td>.515</td>
</tr>
<tr>
<td>Nationality</td>
<td>non_Chinese</td>
<td>.046</td>
<td>1.047</td>
</tr>
<tr>
<td>Household composition</td>
<td>live alone</td>
<td>.383</td>
<td>1.267</td>
</tr>
<tr>
<td>Weight</td>
<td>normal</td>
<td>-.382</td>
<td>.683</td>
</tr>
<tr>
<td>Activity level</td>
<td>active</td>
<td>.041</td>
<td>1.042</td>
</tr>
<tr>
<td>Intention</td>
<td>yes</td>
<td>.036</td>
<td>1.037</td>
</tr>
<tr>
<td>Advice type</td>
<td>utilitarian</td>
<td>2.329</td>
<td>10.272</td>
</tr>
<tr>
<td>Location</td>
<td>work</td>
<td>.287</td>
<td>1.332</td>
</tr>
<tr>
<td></td>
<td>home</td>
<td>.204</td>
<td>1.226</td>
</tr>
<tr>
<td>Agenda</td>
<td>go to work</td>
<td>-1.837</td>
<td>.159</td>
</tr>
<tr>
<td></td>
<td>lunch</td>
<td>-.521</td>
<td>.594</td>
</tr>
<tr>
<td></td>
<td>go home</td>
<td>-.374</td>
<td>.688</td>
</tr>
<tr>
<td></td>
<td>dinner</td>
<td>.647</td>
<td>1.911</td>
</tr>
<tr>
<td></td>
<td>work</td>
<td>.925</td>
<td>2.521</td>
</tr>
<tr>
<td>Weather</td>
<td>good</td>
<td>.253</td>
<td>1.288</td>
</tr>
<tr>
<td></td>
<td>fair</td>
<td>.629</td>
<td>1.876</td>
</tr>
<tr>
<td>Time of the day</td>
<td>morning</td>
<td>.537</td>
<td>1.710</td>
</tr>
<tr>
<td></td>
<td>afternoon</td>
<td>.491</td>
<td>1.634</td>
</tr>
<tr>
<td>Day of the week</td>
<td>weekday</td>
<td>-.153</td>
<td>.858</td>
</tr>
<tr>
<td>Advice type * location</td>
<td>utilitarian* work</td>
<td>.084</td>
<td>1.088</td>
</tr>
<tr>
<td></td>
<td>utilitarian* home</td>
<td>-.127</td>
<td>.881</td>
</tr>
<tr>
<td>Advice type * agenda</td>
<td>utilitarian* dinner</td>
<td>-1.531</td>
<td>.216</td>
</tr>
<tr>
<td>Advice type * weather</td>
<td>utilitarian* good</td>
<td>-.365</td>
<td>.694</td>
</tr>
<tr>
<td></td>
<td>utilitarian* fair</td>
<td>-.685</td>
<td>.504</td>
</tr>
<tr>
<td>Advice type * time of the day</td>
<td>utilitarian* morning</td>
<td>-1.213</td>
<td>.297</td>
</tr>
<tr>
<td></td>
<td>utilitarian* afternoon</td>
<td>-1.339</td>
<td>.262</td>
</tr>
<tr>
<td>Advice type * day of the week</td>
<td>utilitarian* weekday</td>
<td>.422</td>
<td>1.525</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>-1.733</td>
<td>177</td>
</tr>
</tbody>
</table>

Note: significant estimates in bold
7.3.3 Responses to 2 types of advices

The significant interaction effects indicate that the combination of different type of advices with various contexts can influence how users react to the suggestions. Therefore, to understand the difference in reactions to utilitarian and recreational advice in details, we analyze user responses to these two types of advice separately with the binary logistic regression method. A positive response was designated as 1, whereas a negative response was designated as 0. The model estimations of the user responses to both utilitarian advices (n = 1879) and recreational advices (n = 968) are described in Table 7.8 for easy comparison.

Table 7.8 Model of user responses to utilitarian advices (column 3-4)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code</th>
<th>Utilitarian advice</th>
<th>Recreational advice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>Exp(B)</td>
</tr>
<tr>
<td>Gender</td>
<td>male</td>
<td>.545</td>
<td>1.725</td>
</tr>
<tr>
<td>Age</td>
<td>young</td>
<td>.284</td>
<td>1.329</td>
</tr>
<tr>
<td>Transportation</td>
<td>by bike</td>
<td>-.446</td>
<td>.640</td>
</tr>
<tr>
<td>Nationality</td>
<td>non Chinese</td>
<td>-.310</td>
<td>.733</td>
</tr>
<tr>
<td>Household composition</td>
<td>live alone</td>
<td>.521</td>
<td>1.683</td>
</tr>
<tr>
<td>Weight</td>
<td>normal</td>
<td>-.463</td>
<td>.629</td>
</tr>
<tr>
<td>Activity level</td>
<td>active</td>
<td>-.178</td>
<td>.837</td>
</tr>
<tr>
<td>Intention</td>
<td>yes</td>
<td>-.341</td>
<td>.711</td>
</tr>
<tr>
<td>Location</td>
<td>work</td>
<td>.629</td>
<td>1.875</td>
</tr>
<tr>
<td></td>
<td>home</td>
<td>.297</td>
<td>1.346</td>
</tr>
<tr>
<td>Agenda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>go to work</td>
<td>-.2005</td>
<td>.135</td>
</tr>
<tr>
<td></td>
<td>lunch</td>
<td>-.835</td>
<td>.434</td>
</tr>
<tr>
<td></td>
<td>go home</td>
<td>-.456</td>
<td>.634</td>
</tr>
<tr>
<td></td>
<td>dinner</td>
<td>-.830</td>
<td>.436</td>
</tr>
<tr>
<td></td>
<td>work</td>
<td>.823</td>
<td>2.278</td>
</tr>
<tr>
<td>Weather</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>good</td>
<td>-.280</td>
<td>.756</td>
</tr>
<tr>
<td></td>
<td>fair</td>
<td>-.311</td>
<td>.732</td>
</tr>
<tr>
<td>Time of the day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>morning</td>
<td>-.447</td>
<td>.639</td>
</tr>
<tr>
<td></td>
<td>afternoon</td>
<td>-.610</td>
<td>.543</td>
</tr>
<tr>
<td>Day of the week</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>weekday</td>
<td>.413</td>
<td>1.511</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>-.524</td>
<td>2.618</td>
</tr>
</tbody>
</table>

Note: significant estimates in bold

In principle, the timing of sending a recreational advice is set as free agenda without scheduled activities agenda, expect for that a walk after dinner advice was suggested around dinner time. Therefore, there are only 2 levels of user agenda variables: “dinner” (1) and “unknown” (0).

The results of the regression analysis of user response to utilitarian advices show that nine variables contributes to this model with significant effects, $\chi^2(20) = 350.240$, $R^2 = .170$ (Cox&Snell), .228 (Nagelkerke), and the percentage of correct prediction is 70.9%. While also nine variables contributes to the model of user responses to recreational advices, $\chi^2(16) = 63.175$, $R^2 = .063$ (Cox&Snell), .089 (Nagelkerke), and the percentage of correct prediction is 70.1%. These low values of $R^2$ indicate a poor prediction, which may be due to the small amount of data.
The associations between the significant context variables (agenda, weather and time of the day) with the two types of advices differ according to the signs of the B values. The situations of users at dinner time, fair weather, or in the afternoon are associated with lower probability of a positive response to utilitarian advices but higher probability of a positive response to recreational advices.

When users are at the moment of going to work, having lunch or dinner, they are more likely to reject utilitarian advices. Especially the very negative B value and inversed Exp (B) show that when people are about to go to work, the utilitarian advices are 7.41 times \((1/0.135 = 7.41)\) more likely to be rejected.

Only when they are working at their work location, they are more likely to respond positively to utilitarian advices, due to that the B values for variables location (work) and agenda (work) are both positive. This is probably due to their positive reactions to the small break advices during work.

On the other hand, the responses to the recreational advices are associated more with the time of the day. The probability of a positive response increases when the advices are sent either in the morning or afternoon compared to in the evening. Normally the recreational advices sent in the morning and afternoon suggest leisure activities for the weekend. Besides, when users are at home, around dinner time, or during weekdays, they are more likely to respond positivity to a recreational advice. In this case, it is mostly likely that the advice is “a walk after dinner” sent at dinner time of a weekday.

Consistently people who commute by bike or have normal weight respond more negatively to both utilitarian and recreational advices. It is noticeable that participants who live alone are more likely to respond positively to utilitarian advices 1.683 (Exp (B)) times rather than those who live with others, while for recreational advices, the trend is opposite. They are about 2 times \((1/0.479 = 2.08)\) unlikely to respond positively to recreational advices compared to those who live with others. The reason can be that recreational activities can normally fulfill the needs of social contact. Therefore, for people who have other people in the surroundings, it is easier to schedule activities of going for a walk after dinner, for instance, than for the people who need to find company.

### 7.3.4 Self-reported actions for 2 types of advice

The self-reported actions to both utilitarian and recreational advice are analyzed separately with binary logistic regression method. An action of “Yes, I did it” was designated as 1, whereas an action of “No, I didn’t do it” was designated as 0. The model estimations of the user self-reported actions for both utilitarian advices \((n = 1426)\) and recreational advices \((n = 705)\) are described in Table 7.9 for easy comparison. As described in the analysis of user responses to these 2 types of advices in section 7.3.3, there are only 2 levels of user agenda variables: “dinner” (1) and “unknown” (0) for recreational advices.
Table 7.9 Model of user self-reported actions for utilitarian advices (column 3-4)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code</th>
<th>Utilitarian advice</th>
<th>Recreational advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>male</td>
<td>.431</td>
<td>-.940</td>
</tr>
<tr>
<td>Age</td>
<td>young</td>
<td>.068</td>
<td>.875</td>
</tr>
<tr>
<td>Transportation</td>
<td>by bike</td>
<td>-.641</td>
<td>.527</td>
</tr>
<tr>
<td>Nationality</td>
<td>non_Chinese</td>
<td>-.150</td>
<td>.860</td>
</tr>
<tr>
<td>Household composition</td>
<td>live alone</td>
<td>.942</td>
<td>2.565</td>
</tr>
<tr>
<td>Weight</td>
<td>normal</td>
<td>-.434</td>
<td>.648</td>
</tr>
<tr>
<td>Activity level</td>
<td>active</td>
<td>.046</td>
<td>1.048</td>
</tr>
<tr>
<td>Intention</td>
<td>yes</td>
<td>-.161</td>
<td>.851</td>
</tr>
<tr>
<td>Location</td>
<td>work</td>
<td>.323</td>
<td>1.381</td>
</tr>
<tr>
<td></td>
<td>home</td>
<td>.064</td>
<td>1.066</td>
</tr>
<tr>
<td>Agenda</td>
<td>go to work</td>
<td>-2.089</td>
<td>.124</td>
</tr>
<tr>
<td></td>
<td>lunch</td>
<td>-.531</td>
<td>.588</td>
</tr>
<tr>
<td></td>
<td>go home</td>
<td>-.404</td>
<td>.668</td>
</tr>
<tr>
<td></td>
<td>dinner</td>
<td>-.860</td>
<td>.423</td>
</tr>
<tr>
<td></td>
<td>work</td>
<td>.922</td>
<td>2.514</td>
</tr>
<tr>
<td>Weather</td>
<td>good</td>
<td>-.130</td>
<td>.878</td>
</tr>
<tr>
<td></td>
<td>fair</td>
<td>-.086</td>
<td>.917</td>
</tr>
<tr>
<td>Time of the day</td>
<td>morning</td>
<td>-.610</td>
<td>.544</td>
</tr>
<tr>
<td></td>
<td>afternoon</td>
<td>-.824</td>
<td>.439</td>
</tr>
<tr>
<td>Day of the week</td>
<td>weekday</td>
<td>.335</td>
<td>1.398</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>-.169</td>
<td>.844</td>
</tr>
</tbody>
</table>

Note: significant estimates in bold

For the model of the self-reported actions for utilitarian advices, six variables contribute to this model with significant effects, $\chi^2(20) = 350.240$, $R^2 = .161$ (Cox&Snell), .215 (Nagelkerke), and the percentage of correct prediction is 68.4%. While eight variables contributes to the model of the self-reported actions for recreational advices, $\chi^2(16) = 61.071$, $R^2 = .083$(Cox&Snell), .124(Nagelkerke), and the percentage of correct prediction is 75.9%. These low values of $R^2$ indicate a poor prediction, which may be due to the small amount of data.

The significant variables “household composition” and “agenda” have opposite signs of B values for the self-reported actions for 2 different types of advices, which is the same trend as in the model of user response described in Table 7.8. In addition, the significant variable gender appears to be associated with the self-reported actions of 2 types of advices differently. Female participants are more likely to follow recreational advices but less likely to follow utilitarian advices. Compared to the negative B of “nationality” for the responses to the recreational advices (Table 7.8), the B value “nationality” becomes positive for self-reported actions for recreational advices. This indicates that Chinese respond at first more positively while non Chinese follow recreational advices more often according to their self-report.
Only the variable “agenda” and “time of the day” contribute to the models of self-reported actions for both utilitarian and recreational advices. The signs of the B values of these variables are consistent with the models of the user response to the 2 types of advices (Table 7.8).

7.4 Discussions

7.4.1 Impact of context

The variables advice type and user agenda are consistently strongly associated with the user responses and actions. The utilitarian advice compared to the recreational advice is more likely to be responded positively and followed by participants. At a certain moment such as the time to go to work, they are least likely to follow any advices. But when they are at work (exclusive of lunch time), they are more likely to follow advices. User agenda seems to have higher impact than user location on the reactions to the advices.

The existence of significant interaction effects show us the difference made by the combination of advice type and various contexts such as weather, user agenda and time of the day. Considering the different advice types, the context can influence user intention and actions of complying with the suggestions in different ways. For instance, the chance of appreciating a recreational advice is higher when the weather condition is good, but this same context will not help in case of a utilitarian advice.

Furthermore, we analyzed the user responses and actions for two types of advices separately to find out the impact of context in details. The results show opposite associations of the context variables (user agenda, time of the day and weather) and how the users comply with these two types of advices, which has been also indicated by the interaction effects. The other two context variables of user location and day of the week are associated with the user response to utilitarian or recreational advices. In both cases, when the participants are at an unknown location, they responded rather negatively to suggestions. The explanation can be that their activities can be hard to predict, thus their behavior is more difficult to be influenced.

More context variables are significantly associated with the user responses than self-reported actions. This is probably because the context is the moment when the advice is generated and may differ when the actions take place. The other reason can be that a less amount data is available for actions than responses for the analysis. The signs of the B values of the significant variables do not change, indicating a consistent association between the context and the reactions to the advices.

7.4.2 Impact of profile

The absolute B values of the most significant profile variables are smaller than the context variables, indicating a weaker association with the reactions to the advices. Looking into the main effects models of user response and actions for all advices, the variables age, transportation and weight consistently have contributions. The participants who are overweight, younger than 35 years old or commute by car are more likely to respond positively to the advice and also
follow more advices. While looking into the association of the profile variables with the reactions to two different kinds of advices, some reversed associations have been found. Male participants are more likely to respond positively to utilitarian advices and also follow more utilitarian advices according to their self-report, while female participants followed more recreational advices rather than male participants. This may be explained by the research of Nijland, who showed that the demographic variable of gender have impact on needs. Females tend to have higher needs for physical exercise, new experience and entertainment (Nijland, 2011), which can be fulfilled by recreational activities.

The studies about the determinants of PA shows that the association of demographics of people with PA behavior. For example, age and overweight both have consistent negative influences on PA, meaning people who are older or overweight do less PA (Trost et al., 2002). However, these research findings can only indicate some possible explanations for our models studying the behavior of the compliance to PA advices and the demographic variables. The behavior we looked into is how people respond to PA advices and whether follow the advice accordingly, instead of the general behavior of conducting PA. Nevertheless, the response to the advices may be influenced by their actual PA level. Since we did not have actual behavior measurement, we only asked for the activity level of people. However, in view of all variables, only the variable of activity level does not contribute to any of the models. It seems that whether the participants are physically active seems to be not directly related to their willingness to follow the activity advices.

The number of profile variables with significant associations with actions reduced from six to four of the model of user responses. The signs of all the B values remain the same, which indicates that the consistency in the associations of user profile variables with how they react to the advices. However, the sign of the coefficient of some profile variables (gender, nationality) become opposite on user actions with initial responses for recreational advices. This indicates some possible influence of user profile on actual behavior of complying with certain suggestions.

### 7.5 Conclusions

In this chapter, we applied binary logistic regression analysis to predict user responses and self-reported actions, with respect to advice type, context and profile variables. The main effects and interaction effects models for user responses and actions for all advices were first generated. Separate analyses of utilitarian and recreational advices were conducted as well. The results provide us with insight into how environmental factors and personal factors influence people’s reactions to various kinds of suggestions.

Considering all advices in general, advice type and user context are most consistently associated with both user responses and actions. Taking utilitarian and recreational advice individually into account, the variables that are related to time (user agenda and time of the day) have significant impacts on both responses and actions. Moreover, the impacts of agenda and time of the day variables may be opposite on different kinds of advices. We can conclude that the current activity
of users and the current time is very important for the decision making of whether to follow the advice and the actual behavior.

Profile variables have weaker associations than those context variables with the reactions to advices. Only a few profile variables consistently have their significant effects on the models. Considering the small number of participants, the analysis results of profile variables can indicate to a certain extent the role that a user profile may play, but without any definite conclusion.

In conclusion, the regression analysis results indicate that the decision making process of whether complying with the PA advices is mainly associated with the advice characteristics and contextual factors. The associations with some profile variables are weaker and less conclusive.
Chapter 8. Conclusions

In the previous chapters, the development and evaluation of the Motivate application are described. In this chapter, the main findings are summarized to answer the research questions formulated in the introduction. In addition, we reflect on the achievements and limitations of this work and identify avenues of further research.

8.1 Thesis Summary

The goal of this research has been to explore the potential and feasibility of LBS on mobile platform in the field of healthy living promotion. The suggestion on physical activity that is aware of user context and sent “just-in-time” has the advantage to intervene at the right time and location. We are interested in the user acceptance of these technologies and whether a mobile application providing advices can motivate people to be more active. Therefore we aim at developing a mobile adviser application (Motivate) that provides context-aware PA advices to promote healthy living. To design and develop the Motivate mobile application, an incremental approach, consisting of collecting user feedback to different stages of the development, was followed.

Our endeavor began with a literature review study, from which we gained insight into the fields of PA, interventions, context-aware persuasion, and state-of-the-art mobile applications. It was concluded that our system design should motivate people to be more physically active by providing personalized and context-aware messages at an appropriate time and place. With a simple concept of a location and physical activity-based adviser system in mind, we first conducted a questionnaire study. The results showed satisfactory user acceptance of the concept of the adviser system and indicated some design rules such as involving advices about daily life and recreational activities. Based on these results we detailed the concept design and tested the design in a Wizard-of-Oz experiment with GPS loggers. The inputs user location data log, activity, geo information, weather, etc were proven to be sufficient to understand context and create motivating advices at the right location and time. Besides, user agenda was proposed as an important input to decide on a good timing for suggestions.

The design and development of the Motivate application went through several phases. The first attempt was developing the Motivate Service which generated advices based on user location data. Offline inputs data including geo information, user agenda, profile and weather were processed with simple rules to find a suitable advice from the PA advice database. To evaluate the advice quality we implemented the Motivate web application to interact with users by presenting PA advices based on their activity locations collected by GPS loggers. The users were asked to give their opinions about the acceptance, timing of the advice and their reasons. The feedback to the advices was obtained in a user evaluation study, and the results gave us the confidence to proceed with implementing the real-time mobile application.
The first version of the Motivate mobile application was implemented and evaluated in a small-scale user test. The user location was sent by the mobile phone and real-time inputs were integrated for advice generation. The user feedback was analyzed to improve the design of the application. The features such as reporting actions and Reminder were added to the final version of Motivate for a better data collection and user interaction. The final user experiment was conducted with 25 Android users for 6 weeks to evaluate the final Motivate application. The participants showed their intention to follow more than half of the advices and they followed a bit less of them according to their self report. Most users felt a behavior change towards being more active after weeks of usage. Some tendencies of positive attitude change have been found as well. These results all show that the Motivate application has the potential to change behavior and attitude towards an active life. In addition to the descriptive analysis of the final results, we applied a binary logistic regression analysis to predict models of user responses and self-reported actions, with respect to advice type, context and profile variables. Advice type and user context (especially time) are most consistently associated with both the responses and actions. Some weaker associations of several profile variables with the responses and actions are shown as well.

Based on both the design process of Motivate and the results of the user evaluation we deduce the answers to the research questions, which are presented in the following section.

8.2 Answers to Research questions

The answers to the following research questions are presented.

1. What is the feasibility of LBS on a mobile platform as a context-aware adviser?

2. How strong is user acceptance of such technologies and what are the reactions to the context-aware advices?

Mobile localization method of the Smartphone is proven efficient for real-time location tracking. A mobile device is an ideal platform to interact with people. Location-aware devices, GIS, Internet, and telecommunication are integrated in this project to create a location-based mobile application for healthy lifestyle promotion. The performance of this multi-inputs mobile application is proven to be stable. Inputs of user location, simple user agenda of major activities and current time are processed to roughly anticipate on user activities. More than half of the advices were considered as “just on time”, which indicates the adequacy of these inputs for deciding on a satisfactory timing for suggestions. The simple If-Then rules also take weather and geo information into account in order to find opportunities of activities in the surroundings. “Not suitable location” or “not suitable weather” was not mentioned as major reasons for rejecting the advices in all three user evaluation experiments (section 4.3.3, 5.4.3, 6.3.3), which indicates that the users were rather satisfied with the suggested locations and the suitability of outdoor advices considering the weather condition.

In the beginning of this research, when Smart phones were not yet widely used, most of the respondents of the questionnaire already stated that they would like to give this new concept a try.
During the user evaluation tests the participants were quite positive about the usage of the mobile application. With the technology development in these years, location-based mobile applications become prevalent for all kinds of purposes. We feel that the acceptance of such systems is sufficient.

Since the ultimate goal of this application is for behavior change towards “more active”, we looked into both the users’ intentions to follow the advice and their self reported actions of whether following the advice. The users intended to comply with almost half of the messages and reported the behaviors of following the advice slightly less positively than the initial intentions. Encouragingly, most users have reported their feelings of changes towards being more active after the usage. These evidences show the positive effects of using the Motivate application.

8.3 Contributions

Although we are not the first to explore the potential of LBS on mobile platform for healthy lifestyle promotion, we have implemented a working application that generates “just-in-time” messages and interacts with users. This research shows the potential of mobile applications that provides context-aware advices to stimulate behavior change and gathers real-time user feedback. Compared with other interventions for health lifestyle promotion, the suggestions of Motivate are designed for different moments of a day to fit in a person’s daily settings. The research provides evidence of people’s willingness to use the new technology and the acceptance for real-time suggestions. The effective real-time interaction minimizes user effort as it does not require uploading data to a PC or web application. In practical terms our experience gained by trying out different localization methods can be useful for researchers and mobile application developers who would like to apply location-based technologies for developing context-aware applications.

When urban design adaptation needs a certain amount of effort and it takes time, such LBS that provides information about the environment and suggests healthy places can optimize the usage of existing facilities. It can also function as a platform to engage citizens with the changing environment of the city in order to make the best use of their surroundings. From another point of view, our application can be useful for urban planners to understand citizens’ activity pattern and perception of the urban environment. If we collect higher quality location data with a larger participant sample over a longer period, we can also derive their “activity map”, which presents their activities and frequently visited places. The suitability of green places for physical activities can be useful for urban planners to find out citizens’ preference and needs in order to improve the urban design.

8.4 Main findings and suggestions

This research adopts a rather explorative approach during the design and development of the application. In the user evaluation process we have discovered some interesting points. Some main findings and suggestions are summarized as follows.
8.4.1 Determinants of PA behavior

The conceptual models of PA behavior, individual/social/environmental determinants provide some guidelines for the system design. In our research, since individual and social determinants of PA are not the main focuses of the design, the design of the advices is not targeted at specific determinants. In the advice design, we considered only a few user profiles and added some social features to the advices for leisure activities (e.g., go to a park with your family, lunch break walk with colleagues). However, we did not look into whether this social feature can stimulate more compliance. The logistic regression analysis results indicated some consistent association of several personal factors (weight and transport mode) with compliance to suggestions on physical activities. As being indicated, people who live with others would like to follow more recreational advices. We can conclude that the companionship with others may influence people’s willingness to participate in certain types of activities.

The impact of the environmental factors (weather, distance, green place, user location) on compliance to advices has been studied (section 6.3.4; section 7.3). The results show that the distances to green places did not make a difference on user reactions. However, the user location and weather condition may influence on the compliance to advices, and differently on recreational and utilitarian activity advices, as indicated in the regression analysis results. It suggests that the combination of advice type and environmental factors can impact on how users perceive their context and their behavior of compliance.

Therefore, the characteristic of PA behavior advice and the context of receiving the suggestion can be interesting for PA promotion intervention design. The attempt and findings in this research can provide some design guidelines of how to incorporate context variables into different types of advices.

8.4.2 Time and agenda

The user evaluation results show that one major reason for rejecting advice was “I am busy and have no time” (section 4.3.3; 5.4.3; 6.3.3). “Lack of time” is one frequently mentioned barrier to PA. Available time is one basic requirement for following PA advices. This confirms the consideration of including user agenda as a system input for advice generation in our design. Assuming users updated their agenda by adding “busy” time slot to indicate unavailable time, they should be free for the suggestions. However, the users tended to forget to update their agenda when they were occupied with other activities.

The simple agenda including major daily activities has proven to be a good way of deriving activity patterns with the assumption that people follow a rather fixed schedule. Nevertheless, it is not practical to require users to adapt their agenda whenever any change of schedule occurs. Our first attempt of using Google calendar was proven to be even more troublesome due to the amount of user effort and difficulties of data interpretation. Therefore it is suggested that the challenge to achieve a smart agenda that requires the least user effort still remains.
We feel that designing interventions requiring real-time updated agenda needs more exploration and better solutions. An intervention that helps people utilize their time better by integrating physical activities into a daily agenda can be a good alternative, if they can optimize their agenda and stay active at the same time.

### 8.4.3 Timing for messages

The results of the regression analysis show that the user context concerning agenda or time of the day is a consistently important consideration of the users during the decision making. It indicates that the current activity at a certain time of the day may influence the willingness of following advices. A good timing to send an advice is an important feature of the system design. Based on the major daily activity on the user agenda, the timing of messages were satisfactory. It was also found that a message sent on time or a bit early received the same percentage of positive answers (section 5.4.3, pp.84). It indicates that the impact of the timing of the message may be not very critical for some advices and the best timing can be flexible. The definition of “just-in-time” should be adjusted according to different advice types.

In order to send perfect “just-in-time” messages, the user agenda should be accurate with always up-to-date data, which was not achieved in the experiment. Even if the extensive up-to-date agenda is ensured, it is still difficult to fully understand user context. Information of the physical and psychological state of people at a specific moment is hard to sense. Other uncertainties exist as well. For instance, the time to view the messages differed for participants (section 6.3.2, pp.103). It cannot be guaranteed that the users always read the message as soon as they receive it.

Therefore, we can conclude that a good timing is only one factor for context-aware advice, and it is difficult to fully capture user context due to these complexities. We suggest a good timing should be able to prompt immediate actions in some cases and give people sufficient time to schedule future activities in other cases. To design “just-in-time” message to trigger behavior change, factors such as behavior characteristics, delivering method, individual difference, etc should be taken into account.

### 8.4.4 Effects of recreational advice

Utilitarian advices were preferred more than recreational advices. The same trend has been shown consistently in all three evaluation experiments (section 4.3.3, 5.4.3, 6.3.3). Utilitarian advices require less checking on inputs than recreational advices, but yield more compliance. Effort is spent on implementing the geo database and applying GIS software to suggest good locations for outdoor activities. In fact outdoor advices to specific places based on the urban environment and city events are the main feature and uniqueness of our system. Compared to many utilitarian activities, these advices are followed less. However, our effort is not in vain, due to that a tendency of more frequent visits to green places was observed. Although these advices may be difficult to follow immediately, they trigger people to explore the surroundings and engage into the urban environment. Besides, following these advices takes more effort and time,
but also people can gain more benefits in terms of health, relaxation and enjoyment of fresh air and green.

It is suggested that interventions of providing citizens with useful information for healthy activities in their surroundings may promote PA in outdoor settings with good environment using mobile and LBS technology.

8.5 Reflections

8.5.1 Methodology

In this research we adopted an incremental approach to develop a mobile application. Every step of the design and development was based on the results of the user studies including questionnaires, interviews, prototype evaluations, etc. The advantage of the field testing with prototypes is that users reflect and report upon actual rather than hypothesized experiences (Khan, 2009). Before the development of the mobile application, a web based version was evaluated to test the advice generation (Chapter 4). The similar trends of user responses to the advices have been found in both the Motivate web applications (section 4.3.3) and the Motivate mobile applications (5.4.3, 6.3.3). The acceptance for the different types of advices in the web application evaluation and mobile application evaluation tests were almost the same (pp. 67, pp. 112). Despite of different experiment settings and participants, positive responses were given for approximately half of all advices. Utilitarian advices were preferred more than recreational advices. Even the judgment of the timing for all advices in general of the web application did not differ much from the results of the mobile application test. This consistency of user response indicates to some extent the reliability of reporting responses in “hypothesized context”. The participants need to imagine receiving an advice in a specific context and give their possible reactions. From this point of view, when technology is not available or not yet implemented, the approach of presenting hypothesized context can be applied to learn user feedback.

The Wizard-of-Oz experiment (Chapter 3) also gathered user opinions of the quality of advices and proved the concept design in a real setting without any technical implementation. However, the disadvantage that manually sending advices to simulate an automatic system require quite some work, and the participants number can only be rather limited. Therefore we can conclude that both the Wizard-of-Oz experiment method and the web application test are practical research approaches before the technical implementation. They can collect data about user needs and possible reactions during the development process in order to reduce the risk of design errors before the advanced technical implementation.

In this research, due to the restriction of technical requirements and cost, objective measures are not applied. The measurement of the compliance to physical activity advice is “self-report”. The method is proven to be practical to use mobile devices to collect self-report of the behaviors in the manner as in a feedback study. Although there is burden for participants, we can still collect rather accurate response to questions that depend on recall of the event. People may forget to enter information or make entries at the moments that have the time, rather than the ones of
interest to the researcher, which may lead to loss of data (Khan, 2009). The usage of the mobile
technology to collect feedback shortly after the event is an improvement for the traditional self-
report method. In a word, self-reporting method on mobile platform is a good alternative to
assess behavior when the objective measurement is not available.

8.5.2 Technology

In this research we have introduced different localization approaches: Bluetooth GPS receiver
together with a mobile phone (Sense of the city Eindhoven, 2011), GPS loggers, built-in GPS and
mobile localization (cell tower and Wi-Fi) for Android phone. The different methods have their
own advantages and disadvantages. The choice of which equipment to use depends on the
requirement and priority for accuracy, speed, battery life or costs. The GPS device has the
highest outdoor accuracy but is not ideal for indoor usage. The built-in GPS in Smartphone has
the problem of high battery consumption and low localization speed. This disadvantage can
deteriorate the performance of a mobile application. Therefore the mobile localization (cell tower
and Wi-Fi) method works better with faster speed and less power consumption, although the
accuracy is not as good as GPS.

The GPS loggers can record very detailed location and speed information with a high frequency
which is very useful for research purposes. If being transmitted to a mobile device by Bluetooth,
detailed real-time location data with high frequency can be obtained as an alternative. The
advantage is that the frequency of recording location data can be much higher and they can be
used for deriving activity patterns or user transportation mode. There is a clear potential of this
approach for real-time tracking research. The reason for not applying this method is that we did
not want to bother users with carrying extra devices.

8.6 Limitations and Future works

In this research, we only adopted activity monitors for the first proof of concept experiment, but
did not include PA level as a system input. Due to a limited access to data, we could not
synchronize the PA data with user location data as system inputs. For the evaluation of a PA
promotion intervention, objective measurements are most desirable. But there is a certain concern
about the effects of the activity monitoring devices. One disadvantage is that carrying the
monitoring devices every day requires extra user effort. The other concern is when users become
more motivated and active it is difficult to attribute the user changes to the usage of the mobile
application or monitoring device without a control group. On the other hand, mobile application
for activity monitoring is not practical and reliable so far, therefore we did not measure the
activity levels and no objective data was available to prove any PA change in terms of calorie
burning. Future work is needed to add the real-time PA assessment to the system design. The
data can be used for system inputs to decide on the opportune moment to give suggestions as
well. Meanwhile the direct feedback of the performance can be used to help users monitor their
behavior.
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The geo database of green places, lakes and parks includes geographic information without any indication of the suitability, safety and attractiveness of the places for leisure activities. To qualify as healthy places, the information of the noise level and air quality at that place should also be taken into account. In our development the lack of more detailed data source concerning the attributes of the places influenced the quality of location-based advices. However, the assessment of environmental conditions by mobile sensing devices is not yet applied. One future research direction can be an “environment-triggered adviser” that can sense the environment suitability and suggests physical activities at healthy places. The feasibility of measuring user comfort level such as temperature, humidity, wind speed and air quality by portable devices can be a challenge for research.

The rule-based system adopts simple If-then rules which are rather fixed during the usage. The user reactions to advices can reflect personal preferences for suggestions and locations, which make the user profile more extensive. This usage data can be analyzed with intelligent learning method to predict possible responses and make the If-then rules dynamic. We believe that the prediction models derived from the logistic regression analysis can also be used to optimize the simple If-then rules. How to create an interactive way of learning from user feedback to optimize the advice generation algorithm is what we intended to study in the future.

During the recruitment of the user tests, low response rate and high dropout rate has been observed. In the end only a rather small sample of participants was involved in our research, and most of them were highly educated, active enough and aware of the importance of being active. The highly selected number of participants weakens the generalizability of the conclusions. Due to the limited participants, we could not include a control group but tried to collect as much usage data as possible. Future works are needed to test the application with a much larger sample in a randomized controlled manner. The target group consisting of inactive people who are not aware of the importance of PA should be approached for participation.

Despite of the small sample in the evaluation we gathered quite a lot of location traces, and the ones collected by GPS loggers can be used to derive transportation modes and estimate PA level. The mobile location collected every 15 minutes can also be used to extrapolate movement patterns of people. If we observe movement patterns between, during and after the usage the Motivate application, we may find out whether a change of area of movements occurs due to following the suggestions. It is possible to fuse the location data with the timing of receiving advices, and analyze whether there is any change of movement patterns. Due to time constraint these analyses were not performed. Effort is required to analyze the activity patterns with the help of learning algorithms such as a Bayesian belief network.

So far the Motivate application is a good platform to interact with users by suggesting advices. We believe that some psychological elements for effective persuasion can easily be added and manipulated in the advice design as an extension. Features such as the possibility to compare performance, share experience and locations, compete or game with others for fun can be
effective components for behavior persuasion. Further research on the impact of these features can be conducted based on the existing application platform.
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Appendices

APPENDICES

Appendix A (a): Questionnaire part 1

Introduction

Dear Participants,

Thank you for your kind participation in this research.

This questionnaire is about health, and in particular exercise behavior. Some people say that a certain amount of physical activity is beneficial for their health, and others don’t feel the positive effect of exercise. What is your opinion? For the purposes of our scientific study, we would like you to answer some physical activity-related questions.

part 1

1. How many days a week do you practice moderate to vigorous activities of at least 20 minutes? (for instance: brisk walk, cycling, jogging, playing basketball, squash, football, swimming, dancing, gardening, etc)

   0 days   1 day   2 days   3 days   4 days   5 days   6 days   7 days

2. Which physical activities do you usually do? Choose the activities from the table below. How often do you do these activities, with whom?

3. Why do you do physical activities? (check as many as you like)
   - For health/fitness reasons
   - For physical appearance
   - For weight control
   - To enjoy the environment
   - For socialization
   - For fun/enjoyment
   - For mental stress relief
   - Other ___________

OR: Why don’t you exercise? Check one or more

   - Not enough time
   - Can’t stay motivated
   - I can’t get started
   - Exercise hurts
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- I dislike exercise
- Exercise doesn’t have any effect/benefit on me
- Can’t afford it
- Health problems inhibit me

4. Do you think you do enough physical activities?
   - Yes
   - No
   - I don’t know

5. How would you feel about getting personalized advice on physical activity?
   - Yes
   - No
   - I don’t know

6. Which circumstances would motivate you towards becoming more physically active?
   - There are more open areas in my neighborhood
   - There are safe walking paths in my area
   - There are areas with natural scenes nearby
   - There are easily accessible cycling lanes
   - There is a gym close to my home or my office
   - There is a good offer for registration at a local sports club
   - I (now) have enough time
   - I have someone to go sporting together
   - I am now more aware of my activity level
   - I am more concerned about my health
   - I am getting personalized advices on which activities work better for me

General information

Gender
- Male
- Female

Age
- 20-25
- 26-30
- 31-35
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- 36-40
- 41-45
- 46-50
- 56-60
- 61-65
- 65+

Marital Status
- Single
- In a long-term relationship (living with partner)
- Married

Work Status
- Full-time
- Part-time
- Student
- Not working

Highest level of education achieved
- Elementary school
- High school
- HBO
- University

Do you have any health problems?
- Yes
- No
- If your answer is “Yes”, what is your problem(s)?
Appendix A (b): Advices for questionnaire

There are 2 sets of advices, and each set includes 8 profiles.

Advises based on profile set 1 for Situation 1:

<table>
<thead>
<tr>
<th>Values for performance, advice, social feature, encouragement</th>
<th>Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,0,1,0</td>
<td>You have met 25% of your target. How about taking the stairs? If so, you will reach half of your target.</td>
</tr>
<tr>
<td>0,0,0,1</td>
<td>You have met 25% of your target. How about taking the stairs with your colleague?</td>
</tr>
<tr>
<td>1,0,1,0</td>
<td>You have met 50% of your target. How about taking the stairs? If so, you will almost reach your target.</td>
</tr>
<tr>
<td>1,0,0,1</td>
<td>You have met 50% of your target. How about taking the stairs with your colleague?</td>
</tr>
<tr>
<td>2,1,1,1</td>
<td>You have met 75% of your target. How about doing some exercise?</td>
</tr>
<tr>
<td>2,1,0,0</td>
<td>You have met 75% of your target. How about doing some exercise with your colleague? If so, you will reach your target.</td>
</tr>
<tr>
<td>3,1,0,1</td>
<td>You have met 100% of your target. How about doing some exercise with your colleague?</td>
</tr>
<tr>
<td>3,1,1,0</td>
<td>You have met 100% of your target. How about doing some exercise? If so, you will stay above your target.</td>
</tr>
</tbody>
</table>

Advises based on profile set 2 for Situation 1:

<table>
<thead>
<tr>
<th>Values for performance, advice, social feature, encouragement</th>
<th>Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,1,1,0</td>
<td>You have met 25% of your target. How about doing some exercise? If so, you will reach half of your target.</td>
</tr>
<tr>
<td>0,1,0,1</td>
<td>You have met 25% of your target. How about doing some exercise with your colleague?</td>
</tr>
<tr>
<td>1,1,1,0</td>
<td>You have met 50% of your target. How about doing some exercise? If so, you will almost reach your target.</td>
</tr>
<tr>
<td>1,1,0,1</td>
<td>You have met 50% of your target. How about doing some exercise with your colleague?</td>
</tr>
<tr>
<td>2,0,1,1</td>
<td>You have met 75% of your target. How about taking the stairs?</td>
</tr>
<tr>
<td>2,0,0,0</td>
<td>You have met 75% of your target. How about taking the stairs with your colleague? If so, you will reach your target.</td>
</tr>
<tr>
<td>3,0,0,1</td>
<td>You have met 100% of your target. How about taking the stairs with your colleague?</td>
</tr>
<tr>
<td>3,0,1,0</td>
<td>You have met 100% of your target. How about taking the stairs? If so, you will stay above your target.</td>
</tr>
</tbody>
</table>
## Appendices

### Advices based on profile set 1 for Situation 2:

<table>
<thead>
<tr>
<th>Values for performance, advice, social feature, encouragement</th>
<th>Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,0,1,0</td>
<td>You have met 25% of your target. How about walking to the park nearby? If so, you will reach half of your target.</td>
</tr>
<tr>
<td>0,0,0,1</td>
<td>You have met 25% of your target. How about walking to the park nearby with your friend?</td>
</tr>
<tr>
<td>1,0,1,0</td>
<td>You have met 50% of your target. How about walking to the park nearby? If so, you will almost reach your target.</td>
</tr>
<tr>
<td>1,0,0,1</td>
<td>You have met 50% of your target. How about walking to the park nearby with your friend?</td>
</tr>
<tr>
<td>2,1,1,1</td>
<td>You have met 75% of your target. How about doing some exercise?</td>
</tr>
<tr>
<td>2,1,0,0</td>
<td>You have met 75% of your target. How about doing some exercise with your friend? If so, you will reach your target.</td>
</tr>
<tr>
<td>3,1,0,1</td>
<td>You have met 100% of your target. How about doing some exercise with your friend?</td>
</tr>
<tr>
<td>3,1,1,0</td>
<td>You have met 100% of your target. How about doing some exercise? If so, you will stay above your target.</td>
</tr>
</tbody>
</table>

### Advices based on profile set 2 for Situation 2:

<table>
<thead>
<tr>
<th>Values for performance, advice, social feature, encouragement</th>
<th>Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,1,1,0</td>
<td>You have met 25% of your target. How about doing some exercise? If so, you will reach half of your target.</td>
</tr>
<tr>
<td>0,1,0,1</td>
<td>You have met 25% of your target. How about doing some exercise with your friend?</td>
</tr>
<tr>
<td>1,1,1,0</td>
<td>You have met 50% of your target. How about doing some exercise? If so, you will almost reach your target.</td>
</tr>
<tr>
<td>1,1,0,1</td>
<td>You have met 50% of your target. How about doing some exercise with your friend?</td>
</tr>
<tr>
<td>2,0,1,1</td>
<td>You have met 75% of your target. How about walking to the park nearby?</td>
</tr>
<tr>
<td>2,0,0,0</td>
<td>You have met 75% of your target. How about walking to the park nearby with your friend? If so, you will reach your target.</td>
</tr>
<tr>
<td>3,0,0,1</td>
<td>You have met 100% of your target. How about walking to the park nearby with your friend?</td>
</tr>
<tr>
<td>3,0,1,0</td>
<td>You have met 100% of your target. How about walking to the park nearby? If so, you will stay above your target.</td>
</tr>
</tbody>
</table>
## Appendix B: Example of messages

<table>
<thead>
<tr>
<th>Group</th>
<th>Advice</th>
<th>Example messages</th>
</tr>
</thead>
</table>
| Break | Take a break at work | -After sitting for a while, how about walking to the coffee corner to have a break?   
  -How about walking to the coffee corner to have a break?   
  -Water is good for health. How about walking to the coffee corner to get some water or tea? |
| Go to a bathroom on another floor | | If you need to use the bathroom, how about going to the one further, maybe at another floor? |
| Take a break while working at home | | At home today? Don't sit for too long. How about taking a break every hour to relax your body and get some water? |
| Stretch exercise at home | | -Sitting for too long is not healthy. How about walking around and stretching your body? Relax a bit   
  -You can roll your shoulder and arms and easily stretch yourself on a couch or chair. Then stand up and stretch your legs. Feel the blood flow and relax your muscles. |
| Movement during watching TV | | When you are watching TV or sitting in front of your computer, don't sit for too long. Get up to get some water and walk around in the house. |
| Move stairs | Take stairs at work | It's a good idea to take the stairs instead of elevator, maybe get out of the elevator two floors earlier and take the stairs? |
| Housework | Housework | -Do you know that doing housework is also a good physical activity. So, how about helping your wife with some housework?   
  -It's not very good weather outside. If you stay at home, you can also be active. How about some housework like vacuuming, mopping or tidying the house?   
  -You can be active at home as well. How about doing some dishes or cleaning up the kitchen after dinner? |
| Garden work in a weekend | | If you stay at home, you can also be active. If you have a garden, how about some gardening work? |
| Shopping | Walk/bike to a supermarket | -How about walking or cycling to supermarket for some grocery shopping on your way home?   
  -How about walking to the supermarket nearby for some fresh bread after dinner? |
| Go to city center for shopping | | -How about going to the shopping center with your family or friends Eindhoven Centrum for some shopping? |
| Outdoor | A walk to canteen to have lunch | -After working in the morning, it's time to get out of your office to breathe some fresh air. Let's walk to the canteen with your colleagues to have lunch? |
- It's lunch time. Although weather is not very good, it's nice to breathe some fresh air. Let's walk to the canteen close by with your colleagues to have lunch?

**A walk after lunch to a green place**
- How about going to Dommel for a short walk (with your colleagues) after lunch?
- How about taking a small walk around after lunch with your colleagues before you go back to work?

**A walk after dinner**
- How about a short walk around your neighborhood after dinner?
- How about going to park Anne Frankplantsoen for a short walk after dinner (with your family)?

**Cycling in to the nature**
- It's good to be outside and breathe some fresh air! How about cycling to Papenvoortsche Heide and enjoy the nature?

**Go to the green place close by**
- you are less than 200 meters from Dommel. If you have time, how about walking there to enjoy the nature?
- you are very close to Eindhovens kanaal. If you are already there, walk around, enjoy! If you are not yet, how about a small walk there?

**A walk to the nature**
- If you have some time, how about cycling or walking to 't Venneke with your family or friends? That will be a good exercise
- It's good weather outside. How about going to Dommel with your family or friends for a short walk to enjoy the nature?
- The weather is so nice right now!! How about going to Philips Van Lennepark with your family or friends for a short walk to enjoy the nature?

**Weekend activity**
**Go out to visit friends**
- It's relaxing weekend now. How about plan a visit to your family or friends? You can walk or cycle to their places or find a nice meeting point that you can have a nice walk together.

**Event in the city**
- You can walk different routes (2 to 8 km) around Gennepere Parken with the help of GPS device. It's fun to explore the nature and be active! Check <a href=http://www.mecehv.nl/?meivakantie-2011/>GPS wandel</a> for more information
- This Saturday 4th June, there will be Muziek op de Dommel festival from 13:00 to 22:00 near Van Abbemuseum. Go for a walk and enjoy live music performance for free!! Check <a href=http://www.muziekopdedommel.nl/>Website</a> for more information.

**Walk to a cinema**
- Instead of staying at home to watch TV or movie, how about walking or cycling to the cinema with your family or friends and have more fun?

**Transportation**
**Go to work on**
- Have you thought of going to work on foot today for a change?
Motivate: a Context-aware mobile application for physical activity promotion

<table>
<thead>
<tr>
<th>foot</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Take a detour home</td>
<td>How about taking a detour to forest Philips De Jongh Wandelpark on your way home?</td>
</tr>
<tr>
<td>Park car a bit further when going home</td>
<td>How about park your car a bit further from your office/home and walk more?</td>
</tr>
<tr>
<td>Get off bus earlier</td>
<td>How about getting off the bus one stop early and walk the rest of the way to work?</td>
</tr>
</tbody>
</table>
Appendices

Appendix C: Privacy Disclosure Statement

The Privacy Act

The application of Motivate is developed for the PhD research of Yuzhong Lin, working at the Design Systems group of the department of Architecture, Building and Planning of Eindhoven University of Technology. For the evaluation of this application we are collecting user feedbacks during their interaction with this application. It is important that you feel comfortable and secure with the information may be collected. The principles set out in this Privacy Policy and Disclosure Statement applies to any personal information you provide to us via the Motivate website or your personal mobile device.

Disclosure Statement

- We collect personal information for the following purposes to:
  - Location data is used to generate advice that is suitable for your location
  - Your profile data is used to generate personalized advice
  - Your daily time schedule is used to generate advice with good timing

If this information is not provided, the application can’t function properly. The analysis of all the data is anonymous and for scientific research only. When the results are presented, no personal information will be mentioned. All the information collected is used for the research purpose for this PhD research. We do not disclose personal information we collect to third parties without permission.

Security of Personal Information

Your personal information is stored in our computers server of our group. We take responsibilities to minimize the risk of any misuse or loss of personal information and to protect it from unauthorized access, modification and disclosure. Such care includes measures for controlling access to data systems using passwords, firewalls, and other data access permission control systems.
**SUMMARY**

**Motivate: a Context-aware mobile application for physical activity promotion**

The objective of this research is to explore the potential and feasibility of LBS on mobile platform in the field of healthy living promotion. The context-aware suggestion on physical activity intervenes at the right time and location. We are interested in the user acceptance of contextualized and personalized advices provided by a mobile application, and whether the users can be motivated to be more active. Therefore we aim at developing a mobile adviser application (Motivate) that provides context-aware physical activity advices to promote healthy living.

Our endeavor began with a questionnaire study and a Wizard-of-Oz experiment to design the concept of a location and physical activity-based adviser system. Insight was gained into the user acceptance of the concept design and technologies. User location data, activity, geo information, weather, agenda, etc were proven to be important factors to understand the context and create motivating advices at the right location and time.

The design and development of the Motivate application began with a web Service which generated advices based on user offline location data collected by GPS loggers. Information such as geo information, user agenda, profile and weather were processed with simple rules to find a suitable advice from the PA advice database. The feedback to the advices provided us with the confidence to proceed with implementing the real-time mobile application.

The first version of the Motivate mobile application generated advices based on the user location sent by the mobile phone and integrated real-time inputs such as weather, agenda, geo information and profile. A small-scale user test was conducted to evaluate and improve this application. The features such as reporting actions and Reminder were added to the final version of Motivate for a better data collection and user interaction. The final user experiment was conducted to evaluate the final Motivate application. The results show that the Motivate application has the potential to change behavior and attitude towards an active life. In addition to the descriptive analysis of the final results, a binary logistic regression analysis was applied to predict models of user responses and self-reported actions with respect to advice type, context and profile variables. Advice type and user context (especially time) are the most consistently associated with both the responses and actions. Some weaker associations of several profile variables with the responses and actions are shown as well.

This research shows the potential of mobile applications that provide context-aware advices to stimulate behavior change and gathers real-time user feedback. It provides evidence of people’s willingness to use the new technology and the acceptance for real-time suggestions. The attempt and findings in this research also provide some design guidelines of how to incorporate context variables into different types of advices to promote active behavioral change.
# CURRICULUM VITEA

## Personal data

Yuzhong Lin  
Date of birth: July 26th 1982  
Place of birth: Nanjing, China  
Nationality: Chinese

## Professional Education

2000 – 2004: Bachelor of Science in Psychology  
Bachelor of Engineering in Computer Science  
Chu Konchen Honors College, Zhejiang University, China  
2005 – 2007: Master of Science in Human-Technology Interaction (ICT Track)  
Industrial Engineering & Innovation Sciences  
Eindhoven University of Technology, the Netherlands

## Work experience

2004 – 2005: HR assistant/Market researcher at Yangsheng Tang Ltd, China  
2008– 2013: Ph.D. candidate, Eindhoven University of Technology, Department of Built Environment, Design Systems group.