AN INTERACTIVE HEALTH TECHNOLOGY SOLUTION FOR ENCOURAGING PHYSICAL ACTIVITY
A FIRST MODEL BASED ON A USER PERSPECTIVE

Anna Åkerberg

Anna Åkerberg holds a Master’s Degree in Public Health Science and has been working in the Health Technology area since 2011. As a Public Health Scientist, her goal is to promote health and prevent disease, and she is interested in how to use technical solutions that can promote physical activity. Her research focus is interdisciplinary, examining how to use technology to encourage and monitor physical activity from a user perspective.
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School of Health, Care and Social Welfare
School of Innovation, Design and Engineering
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Akademisk avhandling

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Akademin för hälsa, vård och välfärd
Akademin för innovation, design och teknik
Abstract

Globally, the level of physical inactivity is increasing. The overall aim of this thesis was to develop and test a first model of an interactive health technology solution (called App&Move) that should encourage physically inactive adults to be more physically active. App&Move was iteratively developed based on the user perspective, a so-called user-centered design. First, available technology was assessed; the validity and reliability of one smartphone pedometer application and one commonly used traditional pedometer were investigated. It was found that none of the investigated pedometers could measure correctly in all investigated situations. However, measurements by a smartphone application was identified to have high potential when aimed at monitoring physical activity in everyday situations. As the next step, a questionnaire was developed and distributed in central Sweden. The 107 respondents who answered the questionnaire were divided and analyzed in groups of users and non-users of physical activity self-monitoring technology. The results showed that users and non-users of such technology mainly had similar opinions about desirable functions of the technology. To gain further knowledge concerning how to design App&Move, the target group physically inactive non-users participated in focus group interviews. Important results were that the technology should focus on encouragement rather than measurements and that it preferably should be integrated into already existing technology, if possible already owned and worn by the person. A brainstorming workshop confirmed that the smartphone was a suitable platform, and a decision to develop a smartphone application was taken. A first draft of App&Move was developed, focusing on encouragement and measuring everyday activity and exercise in minutes per day. App&Move was based on available physical activity recommendations and strategies for successful behavior change. App&Move was positively received in a user workshop and thereafter iteratively refined and developed based on further user input. App&Move was usability tested in 23 physically inactive adults who used App&Move for four weeks and answered two questionnaires. Three usability aspects, effectiveness, efficiency and satisfaction, were assessed as follows: acceptable, high and medium, and slight increases in activity minutes were observed during the test period. To conclude, this thesis has investigated the user perspective of physical activity self-monitoring technology with a target group of physically inactive adults. Based on these findings, a behavior change application for smartphone, App&Move, was presented. The usability test indicated promising results with respect to usability and indicated an ability to encourage the users to physical activity to some extent.
Walking is a man’s best medicine

Hippocrates
Abstract

Globally, the level of physical inactivity is increasing. The overall aim of this thesis was to develop and test a first model of an interactive health technology solution (called App&Move) that should encourage physically inactive adults to be more physically active. App&Move was iteratively developed based on the user perspective, a so-called user-centered design. First, available technology was assessed; the validity and reliability of one smartphone pedometer application and one commonly used traditional pedometer were investigated. It was found that none of the investigated pedometers could measure correctly in all investigated situations. However, measurements by a smartphone application was identified to have high potential when aimed at monitoring physical activity in everyday situations. As the next step, a questionnaire was developed and distributed in central Sweden. The 107 respondents who answered the questionnaire were divided and analyzed in groups of users and non-users of physical activity self-monitoring technology. The results showed that users and non-users of such technology mainly had similar opinions about desirable functions of the technology. To gain further knowledge concerning how to design App&Move, the target group physically inactive non-users participated in focus group interviews. Important results were that the technology should focus on encouragement rather than measurements and that it preferably should be integrated into already existing technology, if possible already owned and worn by the person. A brainstorming workshop confirmed that the smartphone was a suitable platform, and a decision to develop a smartphone application was taken. A first draft of App&Move was developed, focusing on encouragement and measuring everyday activity and exercise in minutes per day. App&Move was based on available physical activity recommendations and strategies for successful behavior change. App&Move was positively received in a user workshop and thereafter iteratively refined and developed based on further user input. App&Move was usability tested in 23 physically inactive adults who used App&Move for four weeks and answered two questionnaires. Three usability aspects, effectiveness, efficiency and satisfaction, were assessed as follows: acceptable, high and medium, and slight increases in activity minutes were observed during the test period. To conclude, this thesis has investigated the user perspective of physical activity self-monitoring technology with a target group of physically inactive adults. Based on these findings, a behavior change application for smartphone, App&Move, was presented. The usability test indicated promising results with respect to
usability and indicated an ability to encourage the users to physical activity to some extent.

**Keywords:** physical activity, user perspective, user, technology, encourage, behavior change, application, smartphone
spektiv hos målgruppen fysiskt inaktiva, gällande fysisk aktivitetsmonitore-
ingsteknik. Utifrån dessa resultat har en beteendeförändringsapplikation ut-
vecklats och testats. Användbarhetstestet indikerade lovande potential gäl-
lande användbarheten, och tydde även på att appen till viss del kan uppmuntra
användarna till ökad fysisk aktivitet.

**Nyckelord:** fysisk aktivitet, användarperspektiv, användare, teknik, upp-
muntra, beteendeförändring, applikation, smartphone
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Therese Jagestig Bjurquist (former RECO), Per Hellström for the opportunity to participate in your PhD project, Gregory Koshmak for collaborating during the Linkura study and my office colleagues Ning Xiong and Peter Funk. I also want to thank Mats and Christina Björkman for their insightful lunch conversations and support, Maria Ehn for fruitful discussions, Rickard Lindell, Sara Lundahl and Carl Alhberg for providing important input into my studies, all the helpful girls in the IDT administration, all my colleagues in ESS-H and the department for Intelligent Future Technologies (IFT), and last but not least, Fredrik Ekstrand (IFT Head of Division), for providing support and wise words during my last year as a PhD student.

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Anna Åkerberg
Västerås, February 2018
List of Publications

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.


Published online: 27 Feb 2017


IV Åkerberg, A., Söderlund, A., Lindén, M. The development and usability evaluation of an interactive health technology solution, for encouragement of physical activity in inactive adults - based on the user perspective. [Submitted to Journal]

Reprints were made with permission from the respective publishers.
Author’s contribution

I The author’s contributions to this paper include planning the study, performing the data collection and analysis and writing the manuscript with supervision from the co-authors.

II The author developed the questionnaire and handled the distribution and statistical analysis of the questionnaire. The author wrote the manuscript with the supervision of the co-authors.

III In addition to writing the manuscript with the help of the co-authors, the author also performed preparations, moderation and analysis of the focus group interviews.

IV The author planned the different parts of this study, designed how the study was presented, developed the questionnaires, performed the workshops and the usability study, and analyzed the data. The author wrote the manuscript, supervised by the co-authors.
Related publications

The following publications are performed within the research field, but are not included in this thesis.


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### Abbreviations

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<th>Description</th>
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<tbody>
<tr>
<td>B-WS</td>
<td>Brainstorming Workshop</td>
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<tr>
<td>BCT</td>
<td>Behavior Change Technique</td>
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<tr>
<td>CUD</td>
<td>Combined User Dimension</td>
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<tr>
<td>EE</td>
<td>Energy Expenditure</td>
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<td>HR</td>
<td>Heart Rate</td>
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<tr>
<td>IPAQ</td>
<td>International Physical Activity Questionnaire</td>
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<tr>
<td>LIPA</td>
<td>Light Physical Activity</td>
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<td>MET</td>
<td>Metabolic Equivalent</td>
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<tr>
<td>MVPA</td>
<td>Moderate and Vigorous Physical Activity</td>
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<td>PA</td>
<td>Physical Activity</td>
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<td>PB</td>
<td>Physical Behavior</td>
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<td>PHYS-PRO</td>
<td>The Physical Activity Products Questionnaire</td>
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<tr>
<td>SB</td>
<td>Sedentary Behavior</td>
</tr>
<tr>
<td>SOC</td>
<td>Stages of Change</td>
</tr>
<tr>
<td>TTM</td>
<td>Transtheoretical model</td>
</tr>
<tr>
<td>TUD</td>
<td>Technical User Dimension</td>
</tr>
<tr>
<td>UCD</td>
<td>User-Centered Design</td>
</tr>
<tr>
<td>UID</td>
<td>User Input Dimension</td>
</tr>
<tr>
<td>UP</td>
<td>User Perspective</td>
</tr>
<tr>
<td>U-WS</td>
<td>User Workshop</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WS</td>
<td>Workshop</td>
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Preface

When I began to study Public Health Science at Mälardalen University in 2001, a completely new chapter in my life began. I learned extensively every day, and I was curious where these studies would lead. Maybe I had a feeling at that time that my curiosity and desire for new knowledge would lead me into research. I am very satisfied and proud to be a Public Health Scientist, and my vision is to provide tools that enable the population opportunities to live a long and healthy life with high quality. This work is extremely important and meaningful. In the year 2012, I had the opportunity to become an interdisciplinary PhD student, which was of course a chance and challenge too good to reject.

This thesis focuses on the use of technology as a means to promote physical activity. A sedentary lifestyle is related to health risks and has been identified as one of the main risks for global mortality. The level of physical inactivity is increasing in many countries and is therefore a global health problem. In contrast, today we know that physical activity generates positive health outcomes and also decreases the risk for certain diseases. Solely increasing the level of physical activity can generate such a tremendous change or improvement in health status, which has fascinated me for a long time. Additionally, a genuine interest in how technological solutions can be used to measure, motivate and encourage populations, and therefore promote physical activity, has inspired me to conduct research within the field of health technology.

I believe that interdisciplinary work – which can be defined as the combination of two or more academic fields, in this case referred to as the fields of care science (public health science), the technology field and also behavior medicine – can generate successful outcomes. Additionally, the development of technical solutions that meet needs – the users’ needs – is an important component of this work and the reason for involving the user in the research process.

My goal with this thesis is to provide a starting point for physical activity behavior change for physically inactive adults. Selection of the target group of physically inactive individuals is most beneficial for society from a health and welfare perspective. This interdisciplinary research work is expected to contribute to increasing the level of physical activity and, over the longer term, decrease the prevalence of lifestyle-related diseases and improve health.
1. Background

1.1 Central user concepts

This thesis focuses on the use of technology to promote physical activity. Users can be described in several ways, for instance, as persons who use a product or service. The end-user corresponds to someone who actually uses the product or service in the end. However, in addition to the end-user, there might be several other user groups, for instance, relatives or family, the caregiver, the developer, a support group and the employer. Finally, an important group to mention is also the non-users, who can be defined as persons who choose not to use the product or service. Herxheimer and Goodare (1999) claims that users of health services can be referred to as anyone who uses or has used some kind of health service, and this definition can be extended to include also potential future users. In this thesis, the potential users/future users are defined as physically inactive adults.

The users' perspective (UP) can be seen as involving the user in, for instance, the process or development and trying to describe their perspective, for instance as the users’ needs, demands and experiences. Several studies have been performed from the users’ perspective within healthcare (Paul et al. 2012; Ahme et al. 2017; Baim-Lance et al. 2016). Sarwar Shah and Robinson (2007) investigated benefits and barriers to user involvement in medical device technology development. They concluded that the main benefits of user involvement were increased accessibility to user ideas and needs and increased usability, functionality and quality of the developed devices. These results are in accordance with the findings of Bridgelal and colleagues (2008), who found that active participation of the users is important for developing usable and effective healthcare devices. Van der Weegen et al (2013) concluded that a user-centered approach generates valuable information that improves the fit between the user and the device, which is important for the acceptability of using the device. Bitterman (2011) discussed home medical device development in a wider perspective. They highlighted the increased need of involvement of both the end-user and the other user groups involved, such as engineers, care givers, designers and other user groups.
Involving the users in the development process is expected to increase the usability of a product or service. Nielsen (1993) defines usability as all aspects of a product, service or system with which a human can interact. The international standard ISO 9241-11 provides a more specific definition of the concept of usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (UsabilityNet, 2006). Usability as a concept has multiple components (Nielsen 1993) and includes three usability aspects; effectiveness, efficiency and satisfaction. These aspects can, however, be effected by the users, their goals and the usage situation (UsabilityNet, 2006).

To improve the usability of a product or a system, a user-centered design (UCD) is recommended (Nielsen 1993; Abras et al 2004). In a user-centered design process, the focus is on the product/system that is being developed when trying to ensure that the product/system meets the needs of the intended user. In UCD, the user is not a part of the developing team but is represented by the researcher that collects the data to learn about the user’s needs (Sanders, 2002).

To be able to develop products or health services that are useful, user involvement is essential, and the perspectives of non-users’ or potential future users’ need further investigation.

1.2 Health and welfare and its relation to physical activity

The research domain of health and welfare, which is the cornerstone for this thesis, can be described as a field of knowledge where health and welfare research are integrated (Mälardalen University, 2011). The concept of health can be defined in many ways, but according to the World Health Organization (WHO, 1998), health can be described as “a dynamic state of complete physical, mental, spiritual and social wellbeing and not merely the absence of disease or infirmity”. The process of enabling people to increase control over their health is described as “health promotion” according to the Ottawa Charter (WHO, 1986), which in turn can have an effect on people’s ability to participate and how they contribute to welfare, which is in line with the long-term goal of this thesis.
This thesis has its foundation in the *Social Ecological Theory of Health*, which describes the influence on health of different levels of society by identifying the relationships between the individuals, their environment and diseases (Dahlgren and Whitehead, 1991). According to this theory, all levels can more or less affect the health of the individuals (Figure 1).

There are several important *individual lifestyle factors* in people’s lives (Dahlgren and Whitehead, 1991), and one of the most important individual lifestyle factors is physical activity.

![Social Ecological Theory of Health](image)

Figure 1. Illustration of the Social Ecological Theory of Health, own processing and modification based on Dahlgren and Whitehead, 1991.

### 1.3 The concept of physical behavior

In this thesis, the concept of physical behavior (PB) is used. PB is a multidimensional construct (Bussman et al. 2013) and includes a wide range of physical activity behaviors that humans perform in their everyday life, including both sedentary behavior and physical activity (Granath, 2014). PB is illustrated in Figure 2.
Sedentary behavior can be defined as any waking behavior characterized by an energy expenditure $\leq 1.5$ metabolic equivalents (METs), in a sitting, reclining or lying posture (Trembley et al. 2017). Dishman et al (2004) defines physical inactivity as performing a small amount of physical activity. The Sedentary Behavior Research Network, SBRN, (Trembley et al. 2017) has recently proposed a new definition of physical inactivity as an insufficient physical activity level to meet present physical activity recommendations. Sedentary behavior and physical inactivity are sometimes used incorrectly as synonyms; however, these are separate concepts.

Physical activity can be regarded as a complex behavior (Peete Gabriel et al. 2012). Physical activity in general is defined by Caspersen and colleagues (1985) as "any bodily activity produced by the muscles that generates energy expenditure". WHO (2014) also adds a wider perspective to the definition of physical activity, namely, that it includes activities while working, playing, doing household chores, travelling and participating in recreational activities. This means that the concept of physical activity includes all kinds of physical activity, regardless of intensity.

The definitions of the different parts of the PB concept indicate that an individual can meet the present physical activity recommendation while simultaneously being sedentary. The borders between the intensities are unclear. The intensity of the activity can vary between different individuals depending on, for instance, body composition and how the activity is performed (Haskell, 2007).
Physical activity is commonly classified as light, moderate and vigorous intensity. **Light intensity** corresponds to routine activities of daily life, for example, casual walking, shopping or self-care. Activity that noticeably accelerates the heart rate for most people, such as a brisk walk, corresponds to **moderate intensity**. **Vigorous intensity** generates rapid breathing and a substantially increased heart rate, for example, jogging and running. Physical activity intensities can also be defined in METs, as light < 3 METs, moderate 3.0-6.0 METs, and vigorous > 6.0 METs (Haskell, 2007). MET corresponds to metabolic equivalent and can be described as the resting metabolic rate. MET can be calculated as the amount of oxygen consumed while resting/sitting/lying, which is approximately 3.5 ml O₂/kg/min (Jetté and Blumchen, 1990).

Physical activity can be classified in several dimensions and domains (Strath et al 2013), as presented in Table 1.

<table>
<thead>
<tr>
<th>Physical Activity Dimensions</th>
<th>Mode</th>
<th>Frequency</th>
<th>Duration</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples:</td>
<td>The activity performed, for instance walking or cycling</td>
<td>Number of sessions, for instance two sessions per week</td>
<td>Time of the activity during a specific time frame, for instance 30 minutes a week</td>
<td>The rate of energy expenditure during activity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Activity Domains</th>
<th>Occupational</th>
<th>Domestic</th>
<th>Transportation</th>
<th>Leisure time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples:</td>
<td>Work-related activity, for instance walking or carry things at work</td>
<td>For instance garden work, household chores, child care or self-care</td>
<td>Activity during transportation, for instance bicycling or standing in a bus</td>
<td>Recreational activities like performing hobbies, sports and exercise</td>
</tr>
</tbody>
</table>

1.3.1 Physical inactivity

Physical inactivity is one important risk factor for chronic morbidity and cause of death (Bull et al. 2004), and the level of physical inactivity is rising.
in many countries worldwide (WHO, 2005). According to the WHO (WHO, 2017), between 23-55% of the global adult population in 2010 was not sufficiently physically active, defined as not meeting the physical activity recommendation. Physical inactivity can therefore be regarded as a public health challenge.

1.3.2 Physical activity and its impact on health

It is well known that physical activity can reduce the risk of chronic disease (ISPAH, 2010) and has positive impact on several bodily functions (WHO, 2004; Van Praag, 2008; Nielsen et al. 2010; Hillman et al. 2008; Sibley and Etnier, 2003). In a Finnish study, Hassmén and colleagues (2000) concluded that regular physical activity was associated with enhanced psychological wellbeing. Currently, physical activity is used as a central component for the prevention and treatment of several diseases (WHO, 2004; U.S. Department of Health and Human Services, 1996), such as the treatment of depression (Searle et al. 2011), coronary artery disease and heart failure (Thomson et al. 2003) and the treatment or prevention of obesity (Brown et al. 2015).

1.3.3 Target group with the most health benefits from physical activity

In physical activity studies, there is scientific evidence that most benefits will be gained when selecting physically inactive or the least fit individuals in the population. Warburton (2006) stated that most health improvements are accomplished when the least fit part of the population becomes more physically active. Additionally, Hagströmer and Franzén (2017) concluded that greater health benefits are achieved when the physical activity level is increased among less physically active or physically inactive people. This conclusion is also in line with a public health perspective that recommends health efforts for the part of the population that will experience the most gain. A recent study concluded that inactive people and people who are not active according to physical activity recommendations should be stimulated to participate in physical activity of any intensity (Füzéki et al. 2017).

1.3.4 Recommendations regarding physical behavior

Since the 1970s, when the first physical activity recommendations were presented, these have included different statements regarding physical activity. In Table 2, available recommendations from WHO, the American Heart Association and YFA/Svenska läkaresällskapet in Sweden are presented.
Table 2. Presentation of available physical activity recommendations from WHO, American Heart Association and YFA/Svenska Läkaresällskapet in Sweden.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1. At least 150 minutes of moderate-intensity aerobic physical, or at least 75 minutes of vigorous-intensity aerobic physical activity during the week, or a combination of these intensities.</td>
<td>1. All adults should adopt a physically active lifestyle to promote and maintain good health.</td>
<td>1. To perform at least 150 minutes of PA at moderate intensity per week or 75 minutes of PA at vigorous intensity, or a combination of these. The activity should be performed during on least three days, and more PA can generate even more positive health effects.</td>
</tr>
<tr>
<td>2. Aerobic activity in 10-minute bouts.</td>
<td>2. They should perform a minimum of 30 minutes of moderate PA on five days or 20 minutes of vigorous PA three days/week.</td>
<td>2. Muscle strengthening activities should be performed at least twice a week.</td>
</tr>
<tr>
<td>3. For additional health benefits, increase moderate activity to 300, or vigorous activity to 150 minutes per week, or a combination of these.</td>
<td>3. Or a combination of moderate and vigorous activity (see above).</td>
<td>3. Adults over 65 years should also perform balance training.</td>
</tr>
<tr>
<td>4. Muscle strengthening activities should be performed 2 or more days a week.</td>
<td>4. The moderate and vigorous PA are in addition to the light intensity PA frequently performed in everyday life (for example washing dishes, walking to the parking lot, taking out the trash).</td>
<td>4. Long periods of time sitting should be avoided. For people with a sedentary occupation or who sit a lot during leisure time, regular short muscle activity breaks (leg stretches) are recommended.</td>
</tr>
</tbody>
</table>

The recommendations by the WHO can be regarded as the current globally adopted physical activity recommendations and include moderate and vigorous physical activity but not light physical activity. Additionally, the American Heart Association’s physical activity recommendation is generally...
used worldwide. This recommendation was developed before the WHO presented their recommendation and exhibits some similarities, for instance, it consists of both moderate and vigorous physical activity. The American Heart Association’s recommendation also includes light physical activity (section 4). However, it does not mention the total amount of light intensity physical activity that is required each day or week. As with the two other recommendations, the Swedish recommendations also include moderate and vigorous physical activity and can, in that aspect, be considered similar to the other two. However, the Swedish recommendations are the only ones that include a statement about sedentary behavior (section 4). There is no specific recommendation available about sedentary behavior. However, in 2016, the American Diabetes Association recommended that “all adults should besides engaging in regular physical activity, try to decrease their total amount of daily sedentary time, and to take regular breaks in the sitting time” (Colberg et al. 2016). However, there are no available limits regarding the amount of sedentary time that is normal or how much sedentary time is harmful to health.

1.4 Methods to assess or measure physical activity

Physical activity can be seen as a complex and multidimensional behavior (Petee Gabriel et al. 2012) and can be assessed or measured as a behavior or as the energy expenditure of the construct of body movement (Hagströmer, 2007). Energy expenditure can be measured by the doubled-labeled water method, or it can be described in metabolic equivalents (METs). The MET can be used to express the intensity of exercise. However, this parameter varies with age, sex and body composition. One MET represents the resting energy expenditure (EE) during quiet sitting, and the value increases with the intensity of the activity (Strath, 2013).

In this thesis, I have chosen to describe physical activity as a behavior. Two categories of methods can be used to assess physical activity. Strath (2013) mentions one method that relies on the individual him- or herself to recall earlier physical activities or to record them, as a subjective method. Examples of such methods are questionnaires (for example, the International Physical Activity Questionnaire, WHO 1998), interviews and activity logs (diaries).

In today’s society, it is common to use different measurement systems, for instance, sensor technology like different wearable monitors, to directly measure or assess physiological signals. According to Strath (2013), these can be described as objective methods. It is important to be aware, however, that an objective measure does not automatically indicate that the measured
data are correct (Haskell, 2012). Pedometry, accelerometry, heart rate monitoring and combined sensors can be organized as categories of objective methods. The most common purpose of a measurement system is to connect the user to the process (Bently, 2005), as shown in Figure 3. To explain Figure 3, an example can be made in relation to physical activity. The first step, physical conditions that are measured, can be walking. The input consists of the actual number of steps that an individual generates during a walk. The measurement system can be a pedometer, and the output is the number of steps that the pedometer measured during this walk. The user is the individual that performs the walk and uses the measurement system. The purpose, of this example is to connect the user to the walk by correctly measuring the steps with the measurement system (pedometer). An example of a measurement system is illustrated in Figure 3.

Figure 3. An example of a measurement system. Own processing and modification based on Bently (2005).

1.4.1 Different sensors that can assess physical activity

Several categories of wearable monitors are available to objectively measure physical activity, for instance, motion sensors, physiological measures, combined monitors and multiple sensor systems.

A sensor is a device that converts a physical measure into a signal that is registered by an instrument. A motion sensor can be defined as a mechanical and electronic device that depending on where it is attached to the body, registers motion or acceleration from the limbs or body trunk. There are several motion sensors available on the commercial market today, from simple to complex, and two examples of motion sensors are pedometers and accelerometers (Freedson and Miller, 2000). A pedometer is a device that counts steps taken per day while walking or running, and it is usually worn at the waist or on a belt. Pedometer devices can consist of different mechanisms (Bassett et al. 2008). The most simple is the pedometer with a spring-suspended horizontal lever arm, which has a horizontal lever arm that moves up...
and down to open and close an electrical circuit with each step when walking or running (Welk, 2002). An example of this kind of pedometer is the Yamax LS2000 (Yamax Corp., Tokyo, Japan; Yamax Health & Sports, San Antonio, TX, USA). The most common accelerometer today, the triaxial accelerometer, measures acceleration in the following three planes: vertical, horizontal and mediolateral (Freedson and Miller, 2000). Acceleration (a) can be defined as the time rate of change of velocity and is often expressed as feet per second per second (ft/s²) or as meters per second per second (m/s²) (McGraw-Hill, 2002). The accelerometer is often capable of capturing more output variables, for instance, activity intensity, and it often has several more options for wearing positions on the body. Accelerometers measure acceleration in raw acceleration signals, and most accelerometers converts these signals to counts per minute (CPM) to enable a measure of the physical activity intensity, in cutpoints, for different activity levels (Trost and O’Neil, 2014). An example of a three-axis accelerometer is the Actigraph wGT3X-BT, which records raw acceleration data and converts them to activity and sleep measures (Actigraph, 2018).

Heart rate (HR) monitoring is a physiological measurement method that can be used in different ways and has lately become more practical because of wireless methods. The heart rate varies during physical activity of any kind (Strath, 2013). HR monitoring can be defined as an indirect measuring method of physical activity because it aims to measure a physiological parameter that is affected by physical activity. Heart rate monitoring often consists of a sender and a receiver, as well as a chest strap around the chest.

A combined monitor is a device that often combines HR monitoring and accelerometry (Butte et al. 2012), such as an activity/fitness tracker. The fitness tracker is a more advanced accelerometer that can provide estimates of several parameters in addition to physical activity, such as distance, energy expenditure, heart rate and sleep. The fitness tracker can be connected to a smartphone application or personal computer, which helps the user keep track of his or her behaviors over longer periods of time (Sullivan and Lachman, 2017). Other examples of combined sensors are smartwatches and the Fitbit HR monitor.

A group of devices that is equipped with several sensors can be seen as multiple sensor systems. These systems use several sensors that are attached to the trunk and extremities. An example is the Intelligent Device for Energy Expenditure and Activity system, which uses five sensors (chest, thighs and feet) and records body and limb motions (Zhang et al. 2004; Zhang et al. 2003).
1.4.2 Strengths and limitations of the assessment methods

All methods that are used to assess physical activity have strengths and limitations. Subjective measures, also called self-reports, can both overestimate and underestimate the measured parameter in comparison to objective methods (Prince et al. 2008; Sallis and Saelens, 2015). It is common for people to overestimate time spent performing their favorite activity, or do not reflect on activity that can be seen as everyday activity, which leads to an underestimation. Because self-reports are dependent on the memory of the person reporting, memory recall can also be a possible reason for inaccurate results. However, almost all studies that have provided evidence for a link between chronic disease and regular physical activity, on which the physical activity recommendations are also based, are generated from self-reports (Haskell, 2012). In epidemiological studies, the questionnaire is the method most frequently used to assess physical activity (Pols et al. 1998).

Regarding objective measures, either motion sensors or heart rate monitoring reflects physical activity in a completely accurate way.

The small size of the pedometer is its main advantage, and the pedometer is useful as a motivational tool and is recommended for use in walking intervention studies with specific step goals (Freedson and Miller, 2000). The pedometer is most accurate for step counts (Schneider et al. 2003); however, it has some limitations. It only captures movement that is related to vertical acceleration (not horizontal or upper body movement) and is therefore not useful for habitual activity recognition. It does not provide information about activity patterns and has no memory for data storage. There may be high variability between different models and brands of pedometers (Melanson and Freedson, 1996); therefore, comparisons between pedometers are difficult (Schneider et al. 2003). The pedometer device is not accurate at very slow or very fast walking speeds (Bassett et al. 1996; Washburn et al. 1980).

The main advantage of the accelerometer is its small size with a large memory that allows the storage of data over longer periods. Other advantages of the accelerometer are that it measures both the amount and the intensity of the activity (Freedson and Miller, 2000), and it is suitable for measuring both sedentary time and physical activity. Most accelerometers convert raw acceleration signals to counts per minute (CPM) to enable a measure of the intensity of the physical activity, and the counts are classified into different levels using cutpoints. A major disadvantage of accelerometers is that the algorithms responsible for these counts vary between different brands and models of accelerometers (Trost and O’Neil, 2014). The lack of a standard for this conversion of accelerometer raw data to counts can also be seen as a weakness. The accelerometer is, however, not able to recognize
nonambulatory or static activities like lifting weights (Matthews, 2005), which can also be seen as disadvantages.

Measuring physical activity based on the **heart rate** also has some limitations. Other factors in addition to physical activity can affect the heart rate, for instance, emotional stress and a high ambient temperature (Melanson and Freedson, 1996). A major disadvantage of fitness trackers is that the algorithms for raw data transformation are often not available to the public, making it difficult to compare results between fitness trackers (Watson et al. 2014).

The **multiple sensor systems** are not wireless, the systems are expensive, complex and often require complex data processing programs to process the data, which can be seen as a weakness (Butte et al. 2012).

### 1.4.3 Psychometric characteristics of the assessments

When developing, refining and using measurement systems that aim to measure physiological parameters in humans, it is important to use a good measurement methodology. A requirement for this goal is to be able to consider and describe the psychometric characteristics of the measurement methodology.

The **validity** can be explained as the extent to which a device actually measures what it intends to, or as Welk (2002) states, as the extent to which the device measures the correct exposure of interest. For example, the requirement for high validity for a pedometer device is that it is cable of measuring steps and no other parameter. Measurement **accuracy** refers to the degree of agreement between the measured value and the true value (Jakobson and Öberg, 2003). The theoretical ideal is to have a perfectly accurate (total agreement) measurement system (Bently, 2005). In practice, this means that a pedometer device that measures 100 out of 100 possible steps (the true value) has total agreement. However, this might not be as likely for pedometer devices in real life. The degree of agreement between repeated measures with the same device can be defined as the measurement **precision**. If similar values are gained several times, the precision is high. High measurement accuracy requires high precision. However, the accuracy can be low even though the measurement precision is high (Jakobson and Öberg, 2003), for example, if the measurement device is adding a systematic error. If the pedometer device measures 100 out of 100 possible steps (the true value) ten times with the same device, the precision is high. Although, if it measures 50 out of 100 steps ten times with the same pedometer device, the precision is still high even though the accuracy is low. If the systematic error is known, it
can be compensated for in this example by adding 50 steps. This process can be done by calibration by first measuring the true value using a reference method and then adjusting the measurement device.

It is also important to consider possible errors. The difference between the measured value and the true value is often referred to as the *measuring error*. If the errors vary both up and down every time the data are read, even though the true value is the same, it is called the *standard error*. If the device has a small standard error, then the measurement precision is high (Jakobsson and Öberg, 2003). Thus, a pedometer device with a small standard error, for instance 1, will still have a high measurement precision. However, systematic errors occur when the measured value always points in a certain direction, too high or too low, compared with the true value (Jakobsson and Öberg, 2003). Possible reasons for *systematic errors* for a pedometer device could be that the pedometer was incorrectly attached to the body, which generates a skewed measurement because the measured values will probably be too low.

1.4.4 Evidence for using technology in physical activity interventions

To use technology in general has a positive impact on health. A review by Bort-Roig (2014) indicated the potential for technology to promote health. The smartphone was concluded to be an effective platform for influencing physical activity behavior (Fanning et al. 2012), and mobile phone interventions have been shown to be effective tools for promoting weight loss (Liu et al. 2015). The use of pedometers is associated with increased levels of physical activity and significant decreases in body mass index and blood pressure (Bravata, 2007). It is not recommended to use scientifically untested pedometers since they can lead to frustration and negative reactions towards the device (Clemes et al. 2010) and thus possibly also towards physical activity.

1.5 Behavior change

The transtheoretical model (TTM) describes a person's willingness to act on a new healthier behavior. The theory of Stages of Change (SOC), which is part of the TTM, can be used to identify the individual's current ability to change their behavior by mapping the different levels of behavior change in relation to how willing the individuals are to make the behavior change (Prochash & DiClemente, 1982; 1983; and 1986).
SOC is considered a non-linear process that develops in several stages over time. In the precontemplation stage, the individual is unaware of the consequences of a behavior. When he or she becomes aware of the problem and when the person intends to change his/her behavior in the next six months, the person has advanced to the contemplation stage. In the preparation stage, the person intends to take action soon, and in the action stage, the person has already taken specific actions. In the maintenance stage, the person is working to prevent relapse and is gaining confidence in his/her new, healthier behavior. Finally, reaching the termination stage means achieving 100% self-efficacy in the new behavior and having no temptation to regress to the old behavior (Prochasha & DiClemente, 1982; 1983; and 1986). Figure 4 illustrates the relationship between the individual lifestyle factor physical activity, the stages of the SOC and perspectives on physical activity. The individual lifestyle factor physical activity (on the left) can be applied in the SOC ladder (the ladder in the middle). The user is progressing and relapsing up and down, from the first step (precontemplation) until the last step (termination). The SOC ladder is climbing up the triangle (on the right), which illustrates the amount of physical activity that should be performed. The rectangle on the right (in the triangle) describes situations in which physical activity can be performed.

Figure 4. Illustration of the relationship between the individual lifestyle factor physical activity, the stages of the SOC and perspectives on physical activity. The individual lifestyle factor physical activity can be applied in the SOC ladder. The user is progressing and relapsing up and down, from the first step (precontemplation) until the last step (termination). The SOC ladder is climbing up the triangle, which illustrates the amount of physical activity that should be performed. The rectangle on the right describes situations in which physical activity can be performed. Own modification and processing based on Dahlgren & Whitehead, 1991; Prochasha & DiClemente, 1982; 1983; and 1986, Faskunger, 2001; and WHO, 2014.
1.5.1 Behavior change techniques and physical activity

Theory-based techniques that are effectively used in behavior change interventions can be referred to as behavior change techniques, or BCTs (Abraham and Michie, 2008). Michie and colleagues (2011; 2013) have identified 93 BCTs in the CALO-RE taxonomy, which is recommended to be used to identify BCTs (Direito et al. 2014). However, current physical activity self-monitoring technology lacks relevant and integrated BCTs that can stimulate the user to a successful behavior change.

Michie and colleagues (2009) concluded in a systematic meta-regression that self-monitoring was the most effective BCT for changing physical activity behavior. The most common BCTs mentioned in the CALO-RE taxonomy are feedback, social support, rewards, goal setting, action planning, coaching and identifying barriers/problem solving (Michie et al. 2011). Another meta-analysis concluded that interventions that had established and integrated BCTs, especially goal-setting, self-monitoring and social support, showed a greater increase in physical activity than studies that had no integrated BCTs (Greaves et al. 2011). Additionally, Gardner and colleagues (2016) concluded that interventions that integrated self-monitoring and environmental restructuring, persuasion or education, were the most effective.

The CALO-RE taxonomy mentions small goals (Michie et al. 2011), and successfully meeting smaller goals is associated with meeting larger goals over time (Fogg, 2009). Feedback and rewards are other BCTs that are effective for increasing physical activity (Conroy, 2014; Normand, 2008) and are often integrated in fitness apps as reminders, messages or alerts when meeting goals or having been sedentary for too long (Conroy, 2014; Mercer et al. 2016).

Social support has been reported to be especially effective for inactive or unmotivated adults (Rovniak et al. 2016) and is integrated in some fitness apps (Conroy, 2014; Mercer et al. 2016). Action planning is considered important for inactive people to make detailed plans about when and where to be active (Conroy, 2014; Mercer et al. 2016). Sullivan and Lachman (2017) recommend multiple behavior change strategies when the target group is inactive individuals, in which the strategies should suit the intended target group, and also to include strategies that are less used today. Such BCTs could be, for example, modifying environmental factors, action planning and identifying obstacles.

Physical activity applications consist of a limited number of BCTs, ranging from 1-21, with an average of 6.6 BCTs per application (Yang et al. 2018).
The most common BCTs in physical activity applications are educational and provide demonstrations or information about activities (Conroy, 2014). A study by Sullivan and Lachman (2017) indicated that technologies like smartphone applications and activity trackers were promising for encouraging and measuring physical activity. However, when these devices integrated BCTs, even greater benefits were achieved (Conroy, 2014).

1.6 Encouragement

The concept of encouragement is frequently used in everyday social life, for example, in relationships, in sport coaching and in family and parenting situations (Wong, 2015). Lamport (Lamport, 2011) defines encouragement as the act of supplying courage to someone by doing or saying something to inspire them. Research on encouragement over the past years has been inconsistent and performed across diverse fields. The conceptual boundaries of the concept remain unclear and are in need of clarification (Wong, 2015). Therefore, Wong suggested a narrower definition and discussed the concept further as the expression of confirmation through language or other symbolic illustrations to introduce courage, perseverance, confidence, inspiration or hope in a person, addressing a challenging situation. Encouragement as a concept has some unique aspects that differ from other similar concepts, such as the requirement that it needs to be communicated to someone else to qualify as encouragement. Additionally, encouragement consistently has a present or future orientation in the time perspective, meaning that it is possible to make a statement on a past success with the aim to provide courage or confidence for future achievements. Finally, encouragement is often provided to individuals who are involved in challenging situations, for example, general problems in life, illnesses, making life choices or other activities that require considerable effort (Wong, 2015).

Adlerian scholars have explained the concept in two ways: as a social phenomenon or as an individual’s way of being. A wide range of encouragement skills have been distinguished, for example, communicating faith in others, use of humor, pointing out others’ strengths, positive reframing, validating others’ goals and reflective listening (Wong, 2015). Wong (Wong, 2015) has also stated that encouragement has been identified as a form of social support. Many studies investigating social support involve encouragement to support health behaviors (Kratz, 2013). Encouragement can also be described as holistic because it affects human psychological wellbeing, as well as physical and spiritual health (Cheston, 2000). This leads to motivation, a term that is sometimes incorrectly used synonymously with encouragement. Motivation can be defined as the activation to action (Bandura, 1994). Although encouragement can lead to motivation, the two are different
concepts. This statement is confirmed by Sweeney (Sweeney, 2009), who claims that the goal of encouragement is not only to change behavior, but also to introduce courage and confidence to change and therefore focus more on modifying individual motivation rather than modifying behavior.

To be encouraged makes people feel good, and consequently people often respond positively to others’ words of confirmation. Being encouraged fulfills a desire that all humans have, namely, the desire and need to be confirmed or validated by others (Lamport, 2011). A key strength of the Adlerian theorizing on encouragement is its focus on refining individuals’ internal resources and increasing motivation (Cheston, 2000).

To my knowledge, the concept of encouragement has not been explicitly studied previously as part of any system that aims to increase physical activity. Therefore, I have chosen to study encouragement in relation to physical activity behavior change with the support of technology.
2. Rationale

Physical inactivity is increasing and can therefore be regarded as a global health problem. Today’s society is high tech, and the population is using technology in their everyday life, both at work and for leisure time. Currently, there are many physical activity self-monitoring devices available that can be used when being physically active; however, research has shown that these devices have limitations. Another important aspect is if or to what extend these devices are able to encourage to physical activity, which can motivate the user and thereby prompt a behavior change. There is a need for a self-monitoring measurement system that is able to encourage all intensities of physical activity during a longer period of time and that is developed and based on the user perspective. The user perspective is an important component when developing technology that should be used by specific target groups. It is essential to investigate the users’ opinions about the devices and how they think the technical devices should possibly function in the future. In addition to performing accurate measurements, the devices should be usable for all people independently of the situation or the environment in which they are applied.

There is a need to develop an interactive health technology solution that is able to encourage target users to be less sedentary and more physically active. By being encouraged, the users can thereby become motivated to be more physically active, which can eventually result in a behavior change.
3. Aims of the thesis

The overall aim of this thesis was, based on a user perspective, to develop a first model of an interactive health technology solution, usable to encourage physically inactive adults to become more physically active.

The specific aims were as follows:

- To investigate the validity and measurement agreement of a smartphone pedometer application and a traditional pedometer, both compared to the manual step count, in six environments, and also to examine the relative reliability of two positions of the smartphone pedometer application in the six environments (Study I)

- To investigate possible differences between users and non-users regarding their opinions about physical activity self-monitoring technologies, and to investigate differences in demographic variables between the groups (Study II)

- To investigate opinions in a group of physically inactive non-users regarding how, when and in what way technology possibly could measure and encourage to physical activity (Study III)

- To, based on a user perspective, develop an interactive health technology solution to encourage physical activity behavior change in physically inactive adults, and to evaluate the developed interactive health technology solution in a usability study (Study IV)
4. Method

4.1 Designs

To answer the overall aim of this thesis, I used both qualitative and quantitative methods. Table 3 presents an overview of the four studies that are included in this thesis.

Table 3. Presentation of the four included studies in the thesis regarding design, data collection and data analysis.

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Data collection</th>
<th>Data analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Cross-sectional comparative design</td>
<td>Physical measure (number of steps)</td>
<td>Descriptive statistics, ANOVA</td>
</tr>
<tr>
<td>II</td>
<td>Cross-sectional design</td>
<td>Questionnaire</td>
<td>Descriptive statistics, Chi2-test, Mann-Whitney U test</td>
</tr>
<tr>
<td>III</td>
<td>Qualitative explorative design</td>
<td>Focus group interviews</td>
<td>Qualitative content analysis</td>
</tr>
<tr>
<td>IV</td>
<td>Mixed methods design based on a user-centered approach (Phase 1 – User-Centered design, Phase 2 – Mixed methods design)</td>
<td>Workshops, Written notes, Questionnaires, Physical measure (activity data in minutes)</td>
<td>Qualitative content analysis, Descriptive statistics, Wilcoxon signed-rank test, Usability evaluation</td>
</tr>
</tbody>
</table>

4.2 Sample and setting

A total of 480 individuals were invited to participate in the studies in this thesis and 307 were excluded, resulting in a final sample of 173 participants (Figure 5).
All studies in this thesis were conducted with different user groups. However, these studies were all based on the user perspective, and the development of the interactive health technology solution was performed with a user-centered design in an iterative process. Thus, some participants were invited to participate in more than one part of a study or in several studies. Three of the studies (Study I, III and IV) were performed with participants from Västmanland, and the fourth study (Study II) was conducted in several municipalities in the Mälardalen region, Sweden.

4.2.1 Study I

The participants were recruited among the employees at a medium-sized university in central Sweden. The staff record, available at the university website, with names and contact information of the employees, was numbered in chronological order. Numbers were randomly selected using a computer. The randomly selected numbers were thereafter matched to the names on the staff record. An overview of the study sample and criteria for inclusion are presented in Table 4.
4.2.2 Study II

Participants were recruited in a region of central Sweden. The sample was drawn from the Swedish address register of persons (SPAR), owned by the taxes office in Sweden. Names and addresses of the selected persons were obtained from SPAR. The sample consisted of persons who were registered in one of seven municipalities in the region of Mälardalen (Västerås, Södertälje, Eskilstuna, Enköping, Strängnäs, Köping and Arboga). The criteria for inclusion were all based on random selection, except for the geographical parameter, which was based on the proportion of the sample in relation to the size of the municipality. An overview of the study sample and criteria for inclusion are presented in Table 4.

4.2.3 Study III

The participants were recruited via a purposeful selection method among the employees at a medium-sized university in central Sweden. An advertisement was sent to the departments, and employees that met all criteria for inclusion were invited to participate. An overview of the study sample and criteria for inclusion are presented in Table 4.

4.2.4 Study IV

Four different samples of participants were recruited for study IV. For the brainstorming workshop (B-WS), employees at a medium-sized university in Sweden with different kind of technical experience or knowledge were recruited via a purposeful selection method. People who had participated in study III were asked to participate in the user workshop (U-WS), meaning that recruited participants fulfilled the criteria for study III. The pre-testers were recruited among the employees at a medium-sized university in Sweden. For the usability study, students and employees at a medium-sized university in Sweden were recruited by convenience selection. An overview of the study sample and criteria for inclusion are presented in Table 4.
Table 4. Presentation of the study sample based on the selection method, number of participants and criteria for inclusion for all four studies in this thesis.

<table>
<thead>
<tr>
<th>Study</th>
<th>Selection method</th>
<th>Nb of participants</th>
<th>Criteria for inclusion</th>
</tr>
</thead>
</table>
| I     | Convenience and random selection | 20 | - employed at a medium-sized university in Sweden  
- adult men and women  
- different ages (over 18 years)  
- ability to move physically in everyday life  
- consider themselves to be healthy |
| II    | Random selection  | 107 | - adult men and women  
- between 18-84 years old  
- registered in the region of Mälardalen |
| III   | Purposive selection | 11 | - between 18-65 years old  
- employed at a medium-sized university in Sweden  
- physically inactive (defined as not meeting the physical activity recommendation)  
- no previous experience of regular use of physical activity self-monitoring technology |
| IV    | Purposive selection | 6 | - employed at a medium-sized university in Sweden  
- possessed different kinds of technical knowledge or experience |
|       | Purposive selection | 4 | -inclusion criteria for study III |
|       | Convenience selection | 2 | - employed at a medium sized university in Sweden  
- using an Android smartphone (at least Android Version 5.0) |
|       | Convenience selection | 23 | - employed or student at a medium-sized university in Sweden  
- between 18-64 years old  
- does not meet current physical activity recommendations (defined as 150 min moderate intensity physical activity/week)  
- has a sedentary occupation (work, studies or other form of occupation)  
- owns/uses an Android smartphone (maximum 3 years old)  
- understands Swedish in spoken and written terms  
- consider themselves healthy  
- has the ability to move physically in everyday life |
4.3 Data collection and procedure

4.3.1 Study I

The data collection was performed during autumn of 2013. The participants carried two smartphones with the same pedometer application and one traditional pedometer. The smartphones were carried in two different positions: the right chest pocket and the lower left pocket of a measuring vest, and the traditional pedometer was attached to the waistband of the pants on the participant’s right hip. Six different environments (test sequences) were investigated: uphill, downhill, flat asphalt road, flat lawn, up in stairs and down in stairs. The participant was positioned at the start point, was informed to walk his/her normal walking speed, the equipment was calibrated, and all test sequences were investigated in chronological order. The test leader (the author) counted the steps manually with a mechanical hand clicker and measured the time. All test sequences were performed at the same time and location for each participant, and the entire test was performed in approximately one hour.

4.3.2 Study II

The data collection was performed with a questionnaire from February – May of 2015. The physical activity products questionnaire (PHYS-PRO) was developed partly based on available questionnaires and designed to be used by the adult population in Sweden. PHYS-PRO includes a total of 22 questions divided into six areas: background information, level of physical activity, readiness for behavior change, use of different technical devices, physical activity measurements and physical activity encouragement. The response scales consist of both open-ended and closed options. PHYS-PRO was distributed via a letter by traditional post, but respondents also had the possibility to respond via a web link.

4.3.3 Study III

The collection of data for study III was performed by two focus group interviews from May – June of 2016. The focus group interviews were performed at the university by a moderator (the author) and an assistant moderator (a co-author). At first, the respondents filled out a form consisting of background information (regarding age, gender, education and technology use), followed by an introduction and the rules for the interview. A questioning
4.3.4 Study IV

The B-WS was conducted in November 2016, and the data collection consisted of written notes, post-it-notes and Dictaphone recordings. A moderator (the author) led the B-WS, and two observers (two co-authors) took notes. The participants gave written consent to participate and completed a form with background information. The participants were prepared by distributing an information letter that was sent in advance. At B-WS, information was provided about the study and the aim of the B-WS, followed by the use of four steps in the “10 plus 10 method (Greenberg et al 2012). The U-WS consisted of Dictaphone recordings and was performed in March 2017. The same moderator (the author) led the U-WS. The participants provided written consent to participate and stated their background information, followed by general information about the study and the aim of the workshop. A Power Point presentation with a first draft of the interactive health technology solution was presented to the participants, followed by a discussion using a questioning route including eight questions. Both WS in study IV were held at the university and were performed in a maximum of 1 ½ hour.

The pre-testing was performed in August and September in 2017, and the pre-testers were asked to use the developed health technology solution for four weeks. Regular meetings were held once a week, and the test leader documented the meetings in written notes. These notes were sent to the company who developed the health technology solution, which refined and revised the version of the interactive health technology solution.

For the usability evaluation, the data collection was performed in October and November in 2017, and it consisted of the activity data from the developed interactive health technology solution and two questionnaires (Q1 and Q2). The activity data were converted to active minutes per day, and the participants were identified using Android ID. Q1 consisted of 12 questions (demographic information, health status, level of physical activity and behavior change), and Q2 consisted of 24 questions (same as Q1 + usability questions). The participants attended a meeting, where information was given about the study and about how to use the interactive health technology solution. All participants provided written consent to participate, filled in Q1, downloaded an Android ID application and downloaded the interactive health technology solution. Thereafter, they used the interactive health technology solution independently for four weeks. All participants were instructed to perform a baseline measure, to formulate a first personal goal and
to revise the goal three times during the test period. After the test period, the participants attended the next meeting, where they completed Q2.

4.4 Data analysis

Descriptive statistics were used to describe the results (Study I). Repeated measures analysis of variance (ANOVA) (Field, 2013) was used to determine if the mean scores for the equipment in the six environments were significantly different, and pairwise comparisons were performed to locate the source of the differences. The manual step count was regarded as the reference score (Study I).

The data from the questionnaire were presented with descriptive statistics. Pearson’s Chi2-test and independent Mann-Whitney U-test (Field, 2013) were used to investigate differences between users and non-users regarding demographic variables and opinions about physical activity self-monitoring technologies (Study II).

The demographic data were presented by descriptive statistics. The focus group interviews were analyzed using a qualitative content analysis (Graneheim and Lundman, 2004) (Study III).

B-WS was analyzed with qualitative content analysis (Graneheim and Lundman, 2004), and U-WS was presented as a short summary per asked question, without any categorization. In the usability evaluation, the ISO definition and usability aspects were used: effectiveness, efficiency and satisfaction (ISO 9241-11, 1998). The activity data from the developed interactive health technology solution were presented as baseline measure, activity minutes per week 1-3 and personal goals in minutes. Demographic data from the questionnaires (Q1 and Q2) and the kind of Android Smartphone used were presented with descriptive statistics. The Wilcoxon signed-rank test (Field, 2013) was used to investigate possible differences between Q1 and Q2 in different variables. The usability questions (U1-U13) were analyzed using a qualitative content analysis (Graneheim and Lundman, 2004), and were presented in the text as categories and quotations (Study IV).

Statistical analyses were performed using Microsoft Excel (version 2013, Microsoft, Washington, USA) and IBM SPSS Statistics (version 22/24, IBM Corporation, USA).
4.5 Ethical considerations

When conducting research in which people are involved, it is important to make careful ethical considerations. Most medical research studies on humans involve risks, and the research can only be performed if the importance or benefits outweigh the potential risks (World Medical Association, 1964). I am convinced that the benefits of this technical solution are greater than any potential risk to which the user could possibly be exposed when using it and when becoming less sedentary and more physically active. The users have been made fully aware that they were using the technical solution for their own benefit and that by using it they will hopefully increase their level of physical activity and thereby also improve their overall future health.

This research has been approved by the Regional Ethics Committee in Uppsala, Sweden (EPN Dnr: 2013/072). All participants were informed about the studies, both orally and in writing, and all provided written consent to participate. They were informed that they could withdraw their consent to participate at any time without giving any reason. The collected data were protected according to the Secrecy Act (SFS 1980:100) and Privacy Act (SFS 1998:204). The results were presented on a group level in such a way that no participant or statement from a participant could be recognized. All collected data will be treated according to ethical rules and will be stored in a locked space at the university.
5. Results

5.1 The characteristics of the participants

Study I and II had a wider target group compared with study III and IV, in which the target group had been narrowed down to be more specific - to physically inactive adults. The demographic data for all participants in this thesis, described as gender and age, are illustrated in Table 5.

Table 5. Illustration of demographic information for the participants.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Range</th>
<th>n</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Study I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (nb, %)</td>
<td></td>
<td></td>
<td>9</td>
<td>45%</td>
</tr>
<tr>
<td>Women (nb, %)</td>
<td></td>
<td></td>
<td>11</td>
<td>55%</td>
</tr>
<tr>
<td>Age (years)</td>
<td>40</td>
<td>30-61</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Study II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(users+non-users)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (nb, %)</td>
<td></td>
<td></td>
<td>55</td>
<td>51%</td>
</tr>
<tr>
<td>Women (nb, %)</td>
<td></td>
<td></td>
<td>52</td>
<td>49%</td>
</tr>
<tr>
<td>Age (years)</td>
<td>51</td>
<td>19-84</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Study III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(F1+F2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men (nb, %)</td>
<td></td>
<td></td>
<td>6</td>
<td>55%</td>
</tr>
<tr>
<td>Women (nb, %)</td>
<td></td>
<td></td>
<td>5</td>
<td>45%</td>
</tr>
<tr>
<td>Age (years)</td>
<td>42</td>
<td>28-63</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Study IV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(all phases)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-WS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td>21</td>
<td>60%</td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
<td>14</td>
<td>40%</td>
</tr>
<tr>
<td>Age</td>
<td>42</td>
<td>28-69</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>U-WS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>48</td>
<td>40-64</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>36</td>
<td>33-38</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Usability study*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, frequency 18-24</td>
<td>2</td>
<td></td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Age, frequency 25-34</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, frequency 35-44</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, frequency 45-64</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*For study IV (the usability study), the participants indicated their age within an age interval, and therefore means and ranges could not be determined.
5.2 User perspectives before and during the technical development

The results from the different studies in this thesis have generated different user perspectives (UP). The study process can be described as follows: each study in the thesis resulted in one or several UP-related results, and all UPs generated from the study process generated decisions on how to develop the interactive health technology solution. Figure 6 presents a summary of the study process. The boxes in the middle describe the different UPs in the studies. The UPs could be sorted into two categories according to a time perspective: before and during the technical development, as illustrated in the two boxes on the right in Figure 6.

Figure 6. Illustration of the studies, study process, different user perspectives (UPs) in all studies and two different time perspectives of UPs.
5.3 Three dimensions of user perspectives

When all the UPs in the results (yellow boxes in Figure 6) were summarized, two different dimensions of the UPs could be identified with respect to their content and context: technical user dimension (TUD) and user input dimension (UID). The cooperation between the TUD and UID generated the interactive health technology solution, pre-testing and usability evaluation, which can be referred to as the third UP dimension: combined user dimension (CUD). The different dimensions of UP imply different forms of UP that work iteratively together or in parallel. The three dimensions of the UP are illustrated in Figure 7.

Figure 7. Illustration of the three dimensions of the user perspectives (UPs) in the results.
5.3.1 The Technical User Dimension

The TUD describes a UP that has more technical features. An example of this is when technology is used for physiological measurements or when technology is developed.

Study I indicated that neither the established pedometer nor the pedometer application managed to perform valid measurements in all investigated environments and positions. Both devices and all device positions (app chest, app pants, trad, ped) indicated good validity compared with the reference method (manually) on flat asphalt road, flat lawn and down stairs. None of the devices or device positions was valid in all environments. However, this study showed that the technical solution of a smartphone could be useful in some environments for physical activity self-monitoring. (*Study I*)

During study IV, an application supporting behavior change was developed in cooperation with a private company. The application, App&Move, was based on scientific evidence and was specially developed for the Android platform. App&Move was available and could be freely downloaded at Google Play. The focus of App&Move is to encourage and support the user in becoming less sedentary and more physically active. It has built-in functions for encouragement with integrated behavior change technics (BCTs). With the built-in accelerometer in the Android smartphone, App&Move also measures physical activity (everyday activity and exercise) in minutes per day.

The first model of App&Move is equipped with levels from 0 up to 4. The user starts from level 0 and has the ability to advance up to level 4 (but with the same functions as for level 0). Every user creates a user ID, and the first seven days consist of a blind baseline measure. The user can see the results from the blind baseline phase after seven days as mean minutes per day. The application presents activity data in text and illustrations on the main page. Feedback is given as notifications, text and icons, and feedback on the performed activity is given in the form of bar graphs over a maximum of 21 days of activity. The application further consists of written information, tips and recommendations, and it is also equipped with integrated and selectable reminders. The user is expected to set and revise a personal goal to be reached, in minutes during a selectable number of weeks. A link is also available to the App&Moves closed Facebook group. The application stores and uploads accelerometer data to a server. Seven days of raw data is saved on the smartphone, and the data are delivered to the server when an internet connection is available.
App&Move is compatible with Android smartphones equipped with a minimum of Android version 5.0. Requirements for using the application are to carry the smartphone and to have access to WIFI or mobile data.

For the development of the interactive health technology solution, parts from the previously mentioned recommendations (see section 1.3.4 Recommendations regarding physical behavior) have been adopted. This decision mainly includes the following sections from these recommendations:

I. Minimum of 150 minutes of moderate-intensity physical activity, or minimum of 75 minutes of vigorous-intensity aerobic physical activity per week, or a combination of these intensities (WHO, 2010, section 1; similar to YFA/Svenska Läkaresällskapet, 2011, section 1)

II. The moderate and vigorous physical activity are in addition to the light intensity physical activity that is performed in everyday life (for example, washing dishes, walking to the parking lot, taking out the trash) (Haskell, 2007, section 4, American Heart Association).

III. Long periods of time sitting should be avoided. It is recommended to take regular short muscle activity breaks for people with sedentary jobs or who sit a lot during leisure time (YFA/Svenska Läkaresällskapet, 2011, section 4).

IV. In addition to engaging in regular physical activity, it is recommended to attempt to decrease the total amount of daily sedentary time (Colberg, 2016, American Diabetes Association).

(Study IV)

When studying the technical features of the TUD, it can be divided in two different technical focuses: evaluate available technology, and build or develop technology. In this sense, the TUD from study I and IV (mentioned above) can be regarded as having two dimensions of TUD.

5.3.2 The User Input Dimension

The UID presents a type of UP in which different kinds of user groups have contributed with different user inputs. Examples of UID could be needs, opinions and relevant user information, described from the users’ perspective.

Study II was an investigation about the use of physical activity self-monitoring technology, the motives for using it, and a mapping of the respondents’ opinions about how the physical activity self-monitoring technology could work. The study indicated that a substantial portion of the respondents were non-users of physical activity self-monitoring technology (66 %). Half of the non-users were also physically inactive.
The most frequently used technology among the users in the study was a cell phone/smartphone and counting steps, as illustrated in Figure 8.

![Figure 8. Presentation of the physical activity self-monitoring technics that the user group (n=36) had used or not used, described in absolute frequencies.](image)

The participants’ opinions about the technology were mainly positive, and the most common reason for using the technology was to obtain a measurement value and to be motivated (Table 6).
Table 6. The users’ opinions about the used physical activity self-monitoring technics, described in absolute and relative frequencies for each variable.

<table>
<thead>
<tr>
<th>Q15 – Description of the technics</th>
<th>Reason for using the technics</th>
<th>How often</th>
<th>Opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Get a measure value</td>
<td>To motivate</td>
<td>Other reason</td>
</tr>
<tr>
<td>Simple pedometer</td>
<td>7/ 64%</td>
<td>3/ 27%</td>
<td>1/ 9%</td>
</tr>
<tr>
<td>Advanced pedometer</td>
<td>1/ 100%</td>
<td>0/ 0%</td>
<td>0/ 0%</td>
</tr>
<tr>
<td>Monitored steps with cell/smart phone</td>
<td>4/ 50%</td>
<td>3/ 38%</td>
<td>1/ 12%</td>
</tr>
<tr>
<td>Other application (cell/smart phone)</td>
<td>8/ 67%</td>
<td>4/ 33%</td>
<td>0/ 0%</td>
</tr>
<tr>
<td>Monitored steps with activity/wrist band</td>
<td>2/ 67%</td>
<td>1/ 33%</td>
<td>0/ 0%</td>
</tr>
<tr>
<td>Heart rate watch</td>
<td>6/ 60%</td>
<td>2/ 20%</td>
<td>2/ 20%</td>
</tr>
<tr>
<td>Biking computer</td>
<td>3/ 75%</td>
<td>1/ 25%</td>
<td>0/ 0%</td>
</tr>
<tr>
<td>Swimming computer/watch</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Web based training program</td>
<td>1/ 25%</td>
<td>2/ 50%</td>
<td>1/ 25%</td>
</tr>
<tr>
<td>Other kind of device/monitor</td>
<td>3/ 75%</td>
<td>1/ 25%</td>
<td>0/ 0%</td>
</tr>
</tbody>
</table>

Study II also showed that with a few exceptions, the users and non-users had similar opinions about the future functions of the physical activity self-monitoring technology. Significant differences were found for two of the investigated demographic parameters: education level and exercise level. A higher degree of users had a significantly higher education level compared with the non-users. The number of participants who exercised more than the recommended level were twice as high among the users compared with the non-user group. It was therefore concluded that demographic characteristics seemed more relevant to study than opinions about the technology. (Study II)
To gain more detailed knowledge about physical activity self-monitoring technology, the target group for study III was narrowed down to only consist of physically inactive adults with no experience of physical activity self-monitoring technology. This study indicated that the respondents in the two focus groups had positive, innovative and mainly similar opinions about how the physical activity self-monitoring technology could possibly work.

Because the concept of encouragement permeates more or less the entire results, it can be concluded that to encourage physical activity was essential for this particular target group of physically inactive individuals. Physical activity technology for this target group should primarily be based on encouraging features and functions and not focus so much on measurements, which is important information for the development process. It was also preferable to integrate the physical activity self-monitoring technology into available technology that the potential user already owned. (Study III)

The B-WS in study IV generated 57 meaning units and 11 categories, among which four themes were generated; Focus, Platform, Characteristics and Content. The themes generated from B-WS were used as basic decisions when developing a first draft of the interactive health technology solution. (Study IV)

The first draft of the interactive health technology solution (a Power Point presentation) was presented at the U-WS in study IV. The first draft included the creation of a user name, a suggestion for the main page and possible menu tabs. A short summary of discussions in the U-WS; there were positive reactions to the draft and to use it, one could see its benefits. The draft seemed to be simple and clear. There were positive reactions such that the functions could be encouraging, and the participants also liked the colors of the data feedback being clearly red and green. Suggestions for personal, individual and innovative settings and feedback were provided. Reminders were perceived as important, for example, when being inactive for too long. Additionally, reminders with suggestions concerning a choice of action were considered important. Suggestions to integrate games and competitions were given: possibilities to connect with other users, compete or challenge each other, possibility to see when the other person is active. User demand (to carry or wear the smartphone during awake times of the day) can be a problem; therefore, it is very important to provide clear instructions about user demand. According to the participants, the challenge is to develop a technical solution that encompasses differences among people, and the user demand could possibly be a challenge. (Study IV)

When studying the content of the UID, it could be divided into three groups depending on the different users that participated and provided their input: a broad user group (including both users and non-users of physical activity self-
monitoring technologies), a narrowed down and more specific user group (potential end-users), and experts. Therefore, the UID in this thesis (mentioned in the sections above) can be regarded as having three dimensions of UID.

5.3.3 The Combined User Dimension

The behavior change application App&Move is a result generated from the two UPs TUD and UID working together in an iterative process, generating the third UP – the combined user dimension (CUD). The CUD was initiated when the behavior change application was developed and continued during the pre-testing and usability evaluation.

An application, App&Move, aiming at behavior change was developed based on the user perspective. App&Move is mainly focused on encouraging the user to become more physically active and less sedentary, has 19 integrated BCTs, and measures physical activity in minutes per day (everyday activity and exercise). The application is compatible with Android smartphones with at least Android version 5.0, and the specific requirements for use are to carry/wear the smartphone during time awake and to have access to WIFI or mobile data. App&Move is based on available physical activity recommendations and scientific evidence. A short description of the main functions of App&Move is as follows: all users has an unique user ID; presents activity data in text and illustrations; provides feedback; performs a baseline phase over 7 days (partly blinded for the user); includes several pages with information, tips and recommendations; has functions for formulating and revising personal goals in minutes; has integrated and voluntary reminders; provides a link to the App&Moves Facebook group; allows storage of accelerometer data to a server. The pre-testing generated minor changes and elimination of some bugs in the testing version of App&Move. (Study IV)

Among 23 test persons in the usability evaluation, activity data were generated from 22 persons. The response rate for Q1 was 100% and 96% for Q2. (Study IV)

Assessment of effectiveness as a usability aspect
The activity data from App&Move showed that the participants slightly increased their activity minutes from week 1 until week 3. The data for activity goals in minutes showed that the mean increase in minutes was highest for the first goal (m=45 min, range 12-199) compared with baseline. The total increase in activity minutes from baseline to the 4th goal was 59 minutes (range 21-124), generating a mean of 15 minutes per week (5-31 minutes). The participants estimated their health status in Q1 and Q2, and the Wilcoxon signed-rank test showed no significant differences in self-estimated health status (p =
No significant differences were shown either for the self-estimated level of exercise (p = 0.23), everyday activity (p = 0.43), sedentary time at work (p = 0.70), sedentary time at leisure time (p = 0.52) or SOC stages (p = 0.06). For the usability questions, a medium mean score (5.1-6.1) was generated for the three usability questions (U1-U3) concerning encouragement and measuring outcomes. (Study IV)

**Assessment of efficiency as a usability aspect**

Six usability questions (U4-U9) were assessed for the efficiency aspect. The questions about the users’ own ability to use the app, if the app was simple to use, if the information in the app was understandable and experiences of using the app during awake time (U4-U8) generated high mean scores (7.0-8.4). The question about user demand to carry/wear the smartphone (U9) generated a low mean score (3.6). (Study IV)

**Assessment of satisfaction as a usability aspect**

Four usability questions (U10-U13) were assessed as belonging to the satisfaction aspect. The participants scored a mean slightly higher than neutral (6.7) regarding their attitudes toward using App&Move (U10). A high mean was generated (7.5) for the question of whether the participants perceived the app as generally useful (U11). Among the participants, 55% had a positive response to using the app for a limited time (U12), and 36% wanted to continue using the app after the test period ended (U13). (Study IV)
6. Discussion

6.1 Main findings
The results of this thesis indicated that the developed behavior change application, App&Move, has the potential to encourage the target group of physically inactive adults to participate in physical activity. The application is focusing on encouraging physically inactive adults to become more physically active and thus less sedentary.

When developing App&Move, a wider approach to conduct the studies was applied, involving the intended users in the whole process, a so-called user-centered design. App&Move was iteratively developed based on the user perspective. Different user perspectives (UPs) were generated from the studies, contributing to the development of App&Move.

Available and commonly used pedometers for physical activity monitoring were investigated. A traditional pedometer and a smartphone pedometer application were found to have limitations and did not measure the steps accurately. Furthermore, the measurement of steps might not be the best measure if a holistic and complete solution to assess physical activity is the goal.

Before the technical development was performed, user perspectives from different user groups were investigated to determine user’s opinions and needs about the future physical activity self-monitoring technology. This work indicated that users and non-users had similar opinions about physical activity self-monitoring technologies. However, there were significant differences regarding the level of exercise and education between users and non-users.

The target group was reduced to physically inactive adults. When investigating the physically inactive non-users of physical activity self-monitoring technologies, the results indicated that encouraging physical activity was of higher importance than measuring physical activity in this target group. This important finding, the encouragement focus, was used in the development of and in the functions of the interactive health technology solution.
Two workshops were performed, both of which generated important input from different user groups that contributed to decisions during the development of the theoretical idea of the interactive health technology solution. A theoretical prototype was presented to a group of non-users, and it was received positively. A behavior change application, App&Move, was developed for the Android platform and was available for free download. The focus of the application is to encourage the physically inactive user to become more physically active and thus less sedentary. App&Move is based on available physical activity recommendations, has 19 integrated behavior change techniques (BCTs) aimed at encouraging physical activity behavior change, and measures everyday activity and exercise in minutes per day with the built-in accelerometer.

The motive for choosing specific parts of the various available physical activity recommendations (WHO, 2010, section 1; Haskell, 2007, section 4; YFA/Svenska Läkaresällskapet, 2011, section 4; Colberg, 2016) was to cover the complete concept of physical behavior in the same recommendation, including sedentary behavior and light, moderate and vigorous physical activity. This kind of complete recommendation is not currently available. These recommendations were chosen as the starting point and basis for the development of the interactive health technology solution, which encourages physical activity at any intensity. To encourage physical activity, regardless of its intensity, was regarded as a logical first step for the target group of physically inactive adults. There is accumulating scientific evidence that even light physical activity can generate health profits, and a study by Füzéki (2017) concluded that physically inactive people should be encouraged to engage in physical activity of any intensity. The chosen parts of the physical activity recommendations do mention light intensity; however, no recommendation concerning the total amount of time in minutes or hours per day of light intensity physical activity are provided in any recommendation. Lewis et al. (2017) suggests that further investigations are needed regarding which behavior should replace sedentary behaviors. Füzéki and colleagues (2017) suggests to add advice regarding light intensity physical activity in future physical activity recommendations, at least for physically inactive individuals. A greater focus on light activity has been observed in several studies; for example, in a study of B-MOBILE, a smartphone tool aimed at reducing sedentary time among overweight and obese persons. The results showed that B-MOBILE reduced sedentary time, which was replaced by an increase in light and moderate-to-vigorous activity (Bond et al. 2014). The basis for the development of App&Move, to include all physical activity intensities, is in agreement with the latest research and advice regarding future physical activity recommendations.
Several studies have shown that smartphone applications have the ability to facilitate increases in physical activity levels in different populations, for instance, the Accuro-Pro Pedometer (Glynn et al. 2014), Starfish (Paul et al. 2017) and Pokemon Go (Althoff et al. 2016). Additionally, App&Move seems to affect physical activity levels. A usability evaluation of App&Move showed that usability was promising and also indicated that users seemed to be encouraged to engage in physical activity to some extent. Thus, App&Move changed their behavior to some extent. The data from App&Move indicated a slight increase in activity minutes, but the Wilcoxon signed-rank test found no significant differences between the two time points in terms of self-estimated health, physical activity levels, sedentary levels or SOC levels. It is possible that a behavior change was initiated, but the increase in activity minutes was too small, as in the study sample, which might have increased the type 2 error of the results.

In the usability study of App&Move, a medium mean score were generated for questions about encouragement and measurement outcomes (U1-U3). Because encouragement was the main focus and the aim for App&Move, it would have been desirable to achieve a higher score for the encouragement question. Gamification can be defined as the use of game design elements in a non-game context (Deterding et al. 2011), and studies have shown that gamification is effective in promoting healthy behaviors (Cugelman, 2013). Despite this finding, there are still few smartphone applications that utilize gamification to promote health (Edwards, 2016). An investigation of another smartphone application, Pokémon Go, showed that the app increased the level of physical activity by more than 25% over a 30-day period (Althoff et al. 2016). Pokémon Go has incorporated gamification to encourage users to walk (Clark and Clark, 2016) and is a good example of an innovative smartphone application that applies both encouragement and gamification theories, as does App&Move but not to the same extent as Pokémon Go. For future development of App&Move, gamification can be further extended to increase encouragement and motivation.

All participants were informed about the user demand of carrying the smartphone during awake time. Nevertheless, a low mean score was generated for this user demand (U9), indicating that it could be a problem to carry the smartphone during all awake times. For this first model of App&Move, accessibility was considered important, meaning that most people today own a smartphone. The possibility for all people to download and use the application was also important. This study did not investigate wear time, which could affect the reliability of the results. For future development of App&Move, consideration must be given to the user demand and wear time.
The usability study of App&Move showed that the design, layout and content of the application was successful, as observed in the high mean scores for U4-U8 (if the application was simple to use; if it was understandable; own ability to use the application and experiences of using it). Another promising result was that more than half of the participants in the study were willing to use App&Move for a limited time, and 36% were interested in continuing to use the app after the test period. These results were promising. Hypothetically, assuming that a similar result could be generated from a more extended study of App&Move, these results could be discussed in relation to the world population. In 2010, between 23-55% of the adult world population was not sufficiently physically active (WHO, 2017), which corresponds to between 1-3 billion people. Assuming that 36% of these, which corresponds to between 375-898 million people, starts to use and continue to use App&Move, enormous benefits could be realized for society if these insufficiently active people become more physically active.

6.2 The user perspective

This thesis used technology as a means for promoting physical activity. The technology was also strongly based on the users’ perspective. Thus, it was essential to collect different user input before the technical development was performed. To achieve an interactive health technology solution that could be well accepted and usable, it was necessary to involve the users throughout the process. This was done to avoid the risk that lack of user input would generate a technical product or service that the user did not want or need. Other studies have highlighted the importance and benefits of involving the user in health care device development (Sarwar Shah and Robinson, 2007; Bridgelal et al. 2008; Van der Weegen et al. 2013). Therefore, the application of a user perspective in this thesis was relevant and in line with research within the field, and it is considered to contribute to a higher acceptability, usability and quality of the interactive health technology solution.

Study I, II and III generated important user input data, which led to significant decisions regarding the development of the interactive health technology solution during study IV. For example, the smartphone was seen as an important component of the technical solution; however, it needed to be more useful. Significant input was generated that the technical solution should mainly focus on encouraging physical activity, and it should be simple and easy to use. The first three studies clearly showed the significance of user input in both the content and the technological development of the application.

Two time perspectives of the user perspectives (UPs) could be observed: *User perspectives before technical development* and *user perspectives during technical development*. The first set of data was collected before the technical development was performed, and the second set of data was collected during the development process. This was done to ensure that the user perspective was included throughout the development process, and to ensure that the final product was well accepted and usable by the users. 

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the technical development. Important results of this thesis are the three dimensions of the user perspectives (UPs): the technical user dimension (TUD), the user input dimension (UID) and the combined user dimension (CUD). In this process, investigations were first made of the available technology. It was necessary to gain knowledge on the available technology (TUD) before adding user input (UID). The development of App&Move was a result of TUD and UID working together in an iterative process, generating the combined user dimension (CUD). This strategy was regarded as useful when developing App&Move.

6.3 Focus on encouragement

In the research area of physical activity, encouragement is highlighted as one of the most important strategies to increase physical activity (Tuso, 2015). Due to findings during the thesis, the focus has been slightly altered. From the beginning, the focus and intention was mainly to measure physical activity. Due to the progress of the work, the findings showed that encouragement was more important than measurements of physical activity for the target group of physically inactive adults. Especially in study III, in which non-users were investigated, encouragement was important for this target group, which in turn led to the significant reduction of the measurement focus and instead highlighted the encouraging component. This result is in accordance with research within the field of behavior change, where encouragement and motivation are essential for enabling successful behavior change (Michie et al. 2009). Active2Gether is a system that aims to encourage young adults to be more physically active. The system, which has integrated behavior change techniques (BCTs), includes a mobile phone application that monitors the context of a person (Klein, Manzoor and Mollee, 2017). Moreover, as already mentioned, Pokémon Go uses gamification to encourage the user to walk (Clark and Clark, 2016).

Figure 9 presents how the concept of encouragement was applied in this thesis.
Figure 9 illustrates how the concept of encouragement is applied in this thesis. The large circle at the top illustrates the concept of encouragement as follows: the challenging situation in the figure was defined as “make effort to be more physically active”. The communications that took place consist of A: App&Move that communicated encouragement in some form to B: the physically inactive user of App&Move. The time perspective is always present or in future time. App&Move has been equipped with integrated functions that are able to encourage the user, but another possibility is also functions by which, by using App&Move, the users can encourage each other. The communicated encouragement between App&Move (A) and the physically inactive user of App&Move (B) leads to motivation. The stages of change, SOC, (Prochasha and DiClemente, 1982; 1983; and 1986) are illustrated at the bottom of the picture. It is important to note that the physically inactive user (B) can be in different SOC stages, but possibly in any of the first steps (precontemplation, contemplation or preparation). When the physically inactive user (B) used App&Move (A), he or she was encouraged and motivated in each
step he or she was in at that moment. Eventually, the physically inactive user (B) progressed in the SOC steps, both up and down.

During progress in the SOC model, specific change processes can be applied at each step to advance upwards in the ladder (Prochaska et al. 1992). When the physically inactive person is in the precontemplation stage, he or she seeks information about physical activity, can observe others or can confront oneself about the problem (the process of consciousness raising). (The person can gain information in App&Move by clicking on the menu Encouragement, where the person can read about the health impact of being sedentary and physically inactive and about the positive effects of physical activity. The person can also obtain advice on when, where and how to be physically active.) It is also possible that the physically inactive person has strong feelings towards events associated with physical activity (the process of dramatic relief).

When progressing to the contemplation stage, the physically inactive person needs to re-experience how he/she thinks and feels about physical activity (the process of self-re-evaluation). (In App&Move, when the baseline measure is completed, it is possible that the person re-experiences and has strong feelings toward the problem, being physically inactive, because of the outcome of the baseline measure.)

In the preparation stage, the person starts to believe in the ability to change and makes commitments to increase levels of physical activity (the process of self-liberation). (Now, the person has decided to start to use App&Move, formulates a first personal goal and agrees to make a behavior change.) In the preparation and action stage, the person accepts support from others to become more physically active (the process of helping relationships) (the person seeks support from others and can also request to participate in the App&Moves Facebook group to gain support from other users) and starts to replace physical inactivity with being physically active (the process of counter conditioning) (the person creates strategies to become more physically active, for instance, by using the functions for regular reminders and by thinking about how to adjust the nearest environment to enable successful behavior change regarding physical activity).

During the action stage, the person gives rewards to oneself for successfully becoming more physically active (the process of reinforcement management) (the person can acquire feedback at the menu gaming and can see top-ranking scores for total activity, mean activity and activity for the best day, as well as different achievements. Reward feedback is also shown on the main page when goals and level advancements are achieved).
After progressing upwards in the ladder, a behavior change results in the form of an increased level of physical activity and, thus, a reduced sedentary time. The expected outcome of using the concept of encouragement in this thesis was that the developed interactive health technology solution should communicate encouragement to the user, leading to increased motivation progress in the SOC stages. The concept of encouragement in this thesis could enable users to progress through the SOC stages and thereby become more motivated, leading to a successful behavior change.

6.4 Methodological strengths and limitations
The user-centered design is often recommended to increase the usability of a product or a system (Nielsen, 1993; Abras et al. 2004). To apply UCD in this user-based thesis can be seen as relevant and as a strength for improving the usability of the application. The users have been involved in the whole process in different ways, contributing to an iteratively developed behavior change application that is expected to be more useful. Because of the user focus and design, it was most appropriate to test the usability of the behavior change application, contributing important results for its further development, refinement and investigation.

In this thesis, the concept of physical behavior (Granath, 2014) is used; however, only physical activity is measured in the studies. The concept of physical behavior was used to enable a more appropriate image of all movements that humans perform in their everyday life. Sedentary behavior is a large part of people’s everyday lives. Using the concept of physical behavior when developing App&Move is considered a strength in this project and is recommended for any future refinement of the application when aiming to reflect a more holistic picture of people’s physical behavior.

During the development of this thesis, the target group was redefined, mainly as a result of the findings of the first two studies. In study I and II, the target group consisted of the general adult population, and after study II, the target group was narrowed down and specified to consist of physically inactive adults. This target group is in line with earlier studies, indicating that less physically active or physically inactive people gain the most benefits by increasing their physical activity level (Warburton, 2006; Hagströmer and Franzèn, 2017). Thus, the results of this thesis contribute to a current knowledge gap regarding sedentary lifestyle, which can be seen as a strength.

Mode, frequency and duration, were essential physical activity dimensions in the thesis. The physical activity dimension intensity was not regarded important, especially in the first step when the target group aimed at becoming
more physically active and thus less sedentary, regardless of physical activity intensity. Intensity can be seen as an important component later in the behavior change process, when the target group has made successful progress in the beginning and requires encouragement and motivation for further steps and maintenance of the new behavior. The occupational domain and leisure time were also important components. It was assumed, and also an inclusion criteria for the usability evaluation, that the target group was working and therefore spent around eight hours at work every day. The decision to focus on these physical activity dimensions and domains was therefore regarded as relevant and useful when developing and usability testing the first model of App&Move.

Regarding the recruitment of participants in the studies, some important decisions were made. Study II showed that the users of physical activity self-monitoring technology had a significantly higher education compared with the non-users. Study III and IV still recruited participants from a university for the following reasons: it was a small first usability evaluation of the first model of App&Move, the employees possessed an understanding of research and reasons for participating, the students were considered to be users of Androids to a high degree, and for reasons of convenience. This type of recruitment could potentially have biased the results. In future studies of App&Move, considerations need to be made regarding how and where to recruit physically inactive adults to reflect this population in the most accurate manner.

The developed behavior change application is considered to have some strengths based on scientific evidence generated from the users’ perspectives, available physical activity recommendations, and integrated relevant BCTs. Special effort was made to integrate recommended BCTs or effective BCTs that are often missing in applications.

Important considerations were made by which parameters of physical activity should be measured with the interactive health technology solution. Most fitness trackers monitor steps; however, it is unclear whether steps are the best parameter to use (Alley et al. 2016). To measure steps is a common method to measure physical activity, but it has some limitations. For example, it measures only physical activity generated by steps or acceleration of the legs or lower parts of the body. Sullivan and Lachman (2017) claim that the amount of time in different intensities, including both light, moderate and MVPA, might be a more useful parameter. Both physical activity and sedentary time is frequently measured with modern wearable accelerometer technology (Ferguson et al. 2015; Rosenberger et al. 2016; Kozey-Keadle et al. 2011; Aguilar-Farias et al. 2014). Important input from the studies in this thesis indicated that users desired a simple solution that was easy to use. It was
important to find a suitable measurement parameter that could measure all physical activity (everyday activity and exercise) and to which all people had equal access or the potential to use. For this first model of a behavior change application, to measure time spent in physical activity was considered a simple and practical parameter.

The current physical activity recommendations (WHO, 2010; Haskell, 2007; YFA/Svenska läkaresällskapet, 2011) are based on minutes per week; however, they reflect only moderate and vigorous physical activity, which is also a motive for choosing the use of minutes as a measurement parameter. For instance, advanced pedometers based on accelerometers and activity trackers present moderate and vigorous physical activity in minutes (Cadmus-Bertram et al. 2015; Ferguson et al. 2015). However, App&Move shows a more holistic physical activity behavior measure that includes all physical activity intensities, as well as light intensity. For example, the Actigraph device measures both light and moderate to vigorous activity; however, this device is developed for and used by researchers around the world.

The Android platform was chosen when developing the first model of the application because it is open source based, which means that anyone can acquire access to the codes, and because Android is the leading mobile platform internationally. For future development of App&Move, it would be beneficial if the application is accessible to both Android and IOS platforms.

Physical activity as a behavior is complex and difficult to assess accurately, and according to Michie and colleagues (2009), self-monitoring is the most effective behavior change technique (BCT) in physical activity interventions. It is therefore important to reflect on what behavior the App&Move reflects. The results from this study indicate a slight increase in activity minutes, but it could be difficult to identify the reason underlying this change because the participants were self-monitoring their behavior or because the App&Move encouraged their physical activity. Thus, it is not possible to answer this question in the present study, but it is important to be aware of these possible explanations in future studies.

For the usability evaluation of App&Move, an established and well used definition and usability aspects were chosen according to ISO 9241-11 (1998). However, specifically developed usability models for evaluation for mobile applications, for instance, the PACMAD model (Harrison et al. 2013; Saleh et al. 2015), are available. The PACMAD model was not selected for use in this study because it was not as well established or validated as the one developed by ISO.
The overall participation and response rates in the usability study were high, which possibly could have generated more accurate results. In the usability study, the integrity of the participants and the collected data were high. The main author delivered the Android IDs to the developer of App&Move, and the developer delivered the registered data, identified by the participant Android IDs. Only the main author could identify the participants in the usability study. A limitation of the usability study could be the short test period and the small number of participants; however, this was a first evaluation of the developed behavior change application. Another potential limitation is that the application can only be used by Swedish speaking individuals, limiting its accessibility to other ethnic groups in society.

6.5 Ethical considerations

When conducting research where individuals are involved, it is essential to make careful ethical considerations and to be aware that there might be some ethical problems.

The target group for this thesis consisted of physically inactive adults. It was possible that these individuals (the target group) were healthy, but it was also possible that they might have been suffering from several health conditions that were not known by the researchers. However, we must assume that the user was fully aware of his or her own health status and the possible limitations that he or she might have and therefore adjust the physical activity according to possible limitations. Additionally, the user was capable of formulating realistic personal goals.

This thesis aimed to develop an interactive health technology solution that communicates encouragement and motivates individuals to become more physically active and thus less sedentary. The functions of this technical solution cannot be developed in such a way that they might be offensive to the user. In addition, the expression of encouragement must be developed in such a way that all individuals, regardless of age, gender or level of education, can perceive the message in the same way.

Technology is used as a means to promote physical activity in this thesis, and the arena for this is mainly in people’s homes, workplaces and during leisure activities. Therefore, considerations can be made regarding if possible ethical dilemmas can occur for the people who are intended to use this technology. Today’s society is high-tech, meaning that people use technology in their everyday lives and that modern society needs technology to function. Therefore, people are highly accustomed to using technology. It is, however, possible that technology may affect people in different ways, both positive
and negative. The positive way corresponds to normal use of the technical device, which satisfies the user and encourages the user to be more physically active, which is the aim of the application. The negative way corresponds to use of the device in a way that is not intended from the beginning and that create negative feelings, thoughts or consequences that may be harmful to users. However, the risk of negative consequences for users are assumed to be minimal.
7. Conclusion

To conclude, this thesis has investigated user perspectives of physical activity self-monitoring technology for the target group of physically inactive adults. The findings have contributed to the iterative development of a first model of a behavior change application, App&Move, which is strongly based on the users’ perspective, a so-called user-centered design. App&Move in mainly focused on encouragement, measures everyday activity and exercise in minutes per day, and is based on available physical activity recommendations and relevant behavior change techniques. The first model of App&Move was evaluated for usability aspects of effectiveness, efficiency and satisfaction, and it showed promising results. Furthermore, App&Move seemed to encourage users to engage in physical activity to some extent.
8. Future research

The work presented in this thesis could be the basis for the further development, refinement and evaluation of the behavior change application App&Move. This work requires continued cooperation between the involved disciplines and the developer, with sustained user perspectives and user involvement during the entire iterative process. Continued investigations of App&Move include a relevant amount of test participants and sufficiently long test periods to permit reliable conclusions.

Suggestions for future research are as follows:

- To improve the encouragement focus and to further investigate to what extent App&Move encourages users to physical activity
- To further improve the usability aspects (effectiveness, efficiency and satisfaction) according to the results from the present study
- Further investigations about the user demand of the application and clarifications and/or investigations regarding the wear time
- Continued work with the functions, BCTs, and progress in the SOC stages, and subsequently also to focus on the maintenance of the new behavior
- To validate App&Move in comparison to a reference method.
9. References


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