CHAPTER 1
GENERAL INTRODUCTION
Nowadays it is hard to imagine or to remember a world without smartphones. They now play a crucial part in our lives. Although mobile phones already had features like email, fax, and Web browsing in the mid-nineties, it was only in 2007 when Apple launched the iPhone that changed the use of smartphones completely. This new iPhone combined powerful multimedia functions with the familiar email and Web browsing features. Apple transformed the old fashion phone that was used for communication purposes into a pocket-size computer whose functionality is constantly evolving since then. Following the launch of the first iPhone, several other smartphones were launched also aiming to be more consumer-friendly compared to the 'traditional' phones with Web browsing features, furthering what Apple had started, and in 2008 Google came with their own operating system Android which furthered this development even more.

Apps are software applications that are designed to run on smartphones and were originally designed for informational and productivity purposes, e.g. email, calendar, contacts, calculator. At present, millions of apps are available in app stores for a variety of purposes such as education, travel, communication, games, medical, news and lifestyle. Smartphones and their apps have become an integral part of our lives as well and have contributed to the increasing popularity of smartphones. In 2012 – the year we started the work described in the current dissertation – already about 58 percent of the Dutch population owned a smartphone and 552,422 active apps were available in iTunes and 696,527 active apps were available in Google Play (Figure 1.1). Of these apps, respectively 23,490 and 17,756 were categorized as Health and Fitness, indicating the popularity of health-related apps.
PREFACE

Nowadays it is hard to imagine or to remember a world without smartphones. They now play a crucial part in our lives. Although mobile phones already had features like email, fax, and Web browsing in the mid-nineties, it was only in 2007 when Apple launched the iPhone that changed the use of smartphones completely.¹ This new iPhone combined powerful multimedia functions with the familiar email and Web browsing features. Apple transformed the old fashion phone that was used for communication purposes into a pocket-size computer whose functionality is constantly evolving since then. Following the launch of the first iPhone, several other smartphones were launched also aiming to be more consumer-friendly compared to the ‘traditional’ phones with Web browsing features, furthering what Apple had started, and in 2008 Google came with their own operating system Android which furthered this development even more.

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The popularity of these mobile technologies has also encouraged researchers - including us - to use smartphones and apps in health promotion. The Active2Gether project described in this dissertation aimed to develop and evaluate an app-based physical activity intervention targeting young adults. This general introduction provides the rationale for the research described in this dissertation. In 2012 app-based interventions were relatively new in health promotion and therefore it is particularly important to develop such innovative interventions in a systematic way including the identification of the needs of the target population. Health behavior promotion interventions that are developed in a systematic manner and that are built on a solid theoretical basis are more likely to be effective. Applying a systematic approach allows researchers to target the most relevant determinants, with the most appropriate intervention strategies in order to reach the most relevant behavior change goals.

The model of planned health promotion was used as the foundation for the project described in this dissertation (Figure 1.2).

![Figure 1.1 - Number of active apps in the iTunes and Google Play Store 2008 – 2016](image)
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The model of Planned Health Promotion proposes six important steps to plan a health promotion intervention. Each step should be guided by scientific evidence. The first step of the model is to identify health problems that are serious and/or prevalent enough and thus require an intervention. In the second step it is necessary to identify behavioral risk factors that are associated with the health problems identified in step one. The third step is to analyze the determinants of these risk behaviors. Behavioral theories should be used to identify behavior determinants that are modifiable and thus a basis for behavior change. The fourth step is to develop an intervention that addresses the most relevant and modifiable determinants identified in step three. The fifth step is to implement and disseminate the intervention. Lastly, it is important to evaluate each step.

The central aim of this dissertation was to develop and evaluate a new app-based intervention aimed at promoting physical activity among young adults. The aims of the current dissertation were:

1. To gain insights in the publicly available apps that aim to promote physical activity.
2. To gain insights in the preferences of smartphone features of young adults regarding physical activity promotion.
3. To develop an app-based intervention aimed at promoting physical activity among young adults.
4. To evaluate the intervention in order to inform further development and future mHealth interventions.
Chapter 1

HEALTH PROBLEM ANALYSIS

Non-communicable diseases are the top cause of death worldwide and in the Netherlands it is estimated that non-communicable diseases account for 89 percent of mortality. In 2012, cancer was the leading cause of death (33 percent) followed by cardiovascular diseases (29 percent), chronic respiratory diseases (6 percent) and diabetes (2 percent). Risk factors such as smoking, alcohol use, raised blood pressure and obesity are associated with an increased risk for non-communicable diseases. Despite a decreasing trend in the death rates due to those non-communicable diseases, the total health-care expenditures increased with 1.8 percent in 2014. Much effort has been devoted to the treatment of those non-communicable diseases, but prevention of these diseases may be more sustainable and may have a better potential for improving public health on the long term. Prevention programs should then target the modifiable risk factors by focusing on the associated risk behaviors.

ANALYSIS OF BEHAVIOR

Physical inactivity is one of the risk behaviors for non-communicable disease, and was estimated to be responsible for approximately 5 million deaths globally in 2008. There is strong evidence that physical inactivity increases the risk of many adverse health conditions and it is one of the two major risk factors for non-communicable diseases, i.e. coronary heart disease, some types of cancer and type 2 diabetes. To be specific, people who fail to engage in the equivalent of brisk walking for 15-30 minutes each day, have an increased risk of 20-30 percent for cancer, cardiovascular diseases and diabetes. Furthermore, levels of physical activity during adolescence are associated with a decrease in cardiovascular risk factors in adult age.

Sufficient physical activity is at present defined as meeting one of the following criteria 1) 30 minutes of moderate-to-vigorous physical activity on at least 5 days per week, 2) 20 minutes of vigorous physical activity for at least 3 days per week, 3) a combination of the first two criteria that results in achieving 600 metabolic equivalent (MET) minutes per week, where one MET is a resting metabolic rate obtained during quiet sitting. Activities are classified based on their intensities ranging from 0.9 METs for sleeping to 18 METs for running at 17.5 km per hour.

The Lancet Series on physical activity in 2012 declared physical inactivity as a global pandemic. Worldwide approximately 31 percent of the adult population did not meet a criterion for sufficient physical activity which was about twice the 2009 prevalence. In the Netherlands, approximately 47 percent of the adult aged population aged 18-54 years engages in insufficient physical activity. These percentages remained relatively stable between 2002 – 2014, with some growth towards 2011, and a similar decline after that. The percentages varied between 53-60 percent of the adult population aged 18-54 years meeting the criteria of 30 minutes of moderate-to-vigorous physical activity for at
least 5 days a week or 20 minutes of vigorous physical activity for at least 3 days per week. In 2012, approximately 61 percent of Dutch young adults aged 19-30 years did not meet the criteria of 30 minutes of moderate-to-vigorous physical activity for at least 5 days a week or 20 minutes of vigorous physical activity for at least 3 days per week.17

Longitudinal studies show a decrease in levels of physical activity over time.18-20 Life events that occur in young adulthood, such as leaving school and home, getting married or having children may be a reason why they get less active during this life stage.20 In order to minimize the reductions in physical activity we need to interfere when patterns of physical activity are most likely to change, thus during young adulthood. Especially, because higher levels of physical activity at a younger age contribute to the development of a healthy lifestyle in adulthood and thereby can reduce the prevalence of non-communicable diseases.12

ANALYSIS OF DETERMINANTS OF PHYSICAL ACTIVITY

In order to change behavior, the drivers or determinants of the behavior need to be changed. Thus, for a systematic development of effective interventions, information on behavioral determinants is crucial. More specifically, it is necessary to identify and address changeable - and preferably strongly related - behavioral determinants. Various theories and theoretical models of health behavior have been developed to explain health behaviors and to guide health behavior research and behavior change. Among these theories social cognitive theory is one of the most prominent behavior change theories used to inform interventions targeting health behavior change.21-23 This theory is a reciprocal theory, i.e. the proposed determinants and behavior influence each other reciprocally: when individuals adapt and revise their behavior they may adjust their beliefs in their capability to perform a certain behavior, their beliefs about the consequences of a certain behavior, and their goals based on their experiences and self-evaluative reactions.24 Social cognitive theory specifies personal determinants (e.g. self-efficacy, outcome expectations, goals) and environmental determinants (e.g. facilitators, impediments). A meta-analysis found that social cognitive determinants may explain about 31 percent of variance in physical activity.22 Determinants included most frequently in interventions aimed to change physical activity behavior were self-efficacy and outcome expectations.22

INTERVENTION DEVELOPMENT

The fourth step of the model for planned promotion of population health is to develop an intervention that addresses the most relevant and modifiable determinants identified in the previous step. For interventions to be effective, their active components (i.e. behavior change techniques (BCTs)) should be identified and linked with the selected behavioral determinants. To do so, it is crucial to gain insight in existing interventions aiming to change physical activity behavior, to gain insights in which BCTs
effectively can address specific behavioral determinants. When developing an intervention that makes use of an innovative and new communication channel, it is important to gain insights in the preferences of the target population.

EXISTING TAILORED INTERVENTIONS AND COMMERCIAL APPS

Health education interventions targeting healthy lifestyle behaviors, including those aiming to promote physical activity, have been strongly influenced by ICT development. Where until rather recently most health education interventions used to be face-to-face activities, print-based materials, or used more traditional media such as TV and video, today we rely much more on web-based (eHealth) and mobile (app) based (mHealth) interventions that support and enable the personalized tailoring of face-to-face interventions and the large reach of print-based materials. Several reviews and meta-analyses of eHealth interventions targeting physical activity found small effects on levels of physical activity in favor of the intervention groups. Regarding mHealth interventions the available reviews and meta-analyses mainly focused on text message-delivered interventions and interventions delivered via a personal digital assistant (PDA), showing promising results. Systematic reviews further show that ICT-supported individually-tailored interventions are superior to generic interventions in promoting physical activity, in terms of effects as well as user engagement and appreciation. Moreover, Krebs et al demonstrated that dynamic tailoring by iteratively assessing behaviors and determinants of behaviors and providing feedback was associated with larger effect sizes compared to static tailoring. Modern technology such as smartphones, smartphone applications (apps) and activity trackers offer new possibilities in health promotion, especially amongst young adults of whom the majority already owns a smartphone. Furthermore, the rapid growth of the popularity and variety of health and fitness apps and activity trackers, suggests that young adults are more likely to appreciate and adopt an app-based physical activity intervention.

Despite the popularity of smartphones and Health and Fitness apps, in 2012, little was known about the quality and effectiveness of apps that were available in the apps stores. The limited amount of research available, indicated that the quality of most Health and Fitness apps available in iTunes was poor. West et al reported that apps that aimed to promote physical activity mainly focused on enabling factors, such as teaching skills, tracking progress or recording the behavior. Only few apps included reinforcing factors such as providing encouragement, evaluation and opportunity to interact with others. No information was available for apps offered in Google Play store – even when the Google Play Store was growing faster than iTunes - and the little information that was available also indicated poor quality in terms of conditions needed for behavior change. Thus, information on the quality and number of BCTs of existing apps was crucial for the development of an app-based...
intervention. To do so, we conducted two content analyses, one focusing on the extent to which existing physical activity promoting apps were grounded in established health behavior theory, and the other focusing on the technical features included in physical activity apps. The results of the two content analyses are described in Chapter 2 and provide insights in the publicly available apps that aim to promote physical activity (1st aim).

Since apps were relatively new in health promotion, it was deemed necessary to gain insights in how the target population – young adults – already used physical activity apps and what they would prefer in an app. To do so, we first conducted focus group discussions and subsequently an online survey to assess young adults’ ratings of BCTs applied in apps. The results of the two studies are described in Chapter 3 and provide insights in the preferences of smartphone features of young adults (2nd aim).

ACTIVITY TRACKERS

The health and fitness wearable devices market has been growing fast. In 2014, 14 million health and fitness trackers were sold worldwide. Commercial wearable technologies that continuously monitor physical activity may be helpful tools for (self-) monitoring and for providing feedback on physical activity behaviours. Fitbit is a company that develops wireless wearable technology and their health and fitness trackers are very popular. Over the years, Fitbit released various models to the consumer market and one of those devices is the Fitbit One. This is an accelerometer-based wearable activity tracking device that is regarded as easy to use and with a user-friendly interface. The activity monitor wirelessly uploads the activity data to the user’s account, which can be accessed through a smartphone application or website. It assesses daily activities, allows the user to monitor his/her progress and provides real-time feedback (e.g. current amount of steps taken, stairs taken and a growing or shrinking flower depicts the activity level) to encourage the user to be more physically active. In addition, the Fitbit One and its web interface includes behaviour change techniques typically used in physical activity interventions. For these reasons, the Fitbit One was chosen as the activity tracker linked to the Active2Gether intervention. However, before using such a new device for research purposes it is important to know the validity of the Fitbit One among the target population, i.e. young adults. Chapter 4 described the validation study of the Fitbit One that was conducted.

MULTIDISCIPLINARY APPROACH

Human behaviors have been predominantly examined using static data – data that has been assessed for example once a day or once a week or even much less frequently – rather than using dynamic and ongoing measurements. However, behaviors – and certainly physical activities – as well as their underlying determinants, and the relations between these determinants and the behavior may vary and change throughout the day and may depend on other unknown variables and may vary between
individuals. Nowadays, technology allows researchers to collect rich streams of ongoing data that then can be used to better predict health behaviors for each individual separately. This kind of data in combination with sophisticated modelling techniques provide new opportunities in individually tailored health promotion.\textsuperscript{41, 42} Data-driven models can be used to link health behaviors – such as physical activity in daily life – with the individual’s psychological state of mind and their social and physical context, these models can detect behavioral patterns.\textsuperscript{43} This information than can be used to deliver real-time and context specific feedback in order to prevent unhealthy behaviors and to promote healthy choices.\textsuperscript{43} In order to deliver these kinds of sophisticated health behavior interventions, it is necessary for researchers in the field of health promotion to use expertise from computer sciences or artificial intelligence researchers. This is what we did in the work described in this dissertation. We –rather uniquely- used an innovative approach and combined a computational model with theory-based intervention input to deliver a highly tailored and personalized intervention to promote physical activity among young adults. The development of the Active2Gether intervention is described in \textit{Chapter 4} (\textsuperscript{3rd} aim).

\textbf{EVALUATION OF THE INTERVENTION}

When the intervention has been developed it is necessary to evaluate the efficacy of the intervention. The evaluation study described in this dissertation explored the use and the effects of the Active2Gether intervention in comparison to two other interventions. Additionally, we aimed to evaluate the use (i.e. adherence, interaction rates) and the users’ appreciation of the Active2Gether app/intervention. The results of the intervention effects, usage and appreciation of the Active2Gether intervention are described in \textit{Chapter 5} (\textsuperscript{4th} aim).

\textbf{AIMS AND OUTLINE OF THE DISSERTATION}

The aims of the Active2Gether project described in this dissertation were to develop and to evaluate an app-based intervention targeting physical activity behaviors in young adults. The aims of this dissertation were fourfold:

1. To gain insights in the publicly available apps that aim to promote physical activity (\textit{Chapter 2}).
2. To gain insights in the preferences of smartphone features of young adults (\textit{Chapter 3}).
3. To develop an intervention aimed at promoting physical activity among young adults (\textit{Chapter 4}).
4. To evaluate the intervention in order to inform further development and future mHealth interventions (\textit{Chapter 5}).

The final chapter – \textit{Chapter 6} - summarizes the main findings of this dissertation and discusses the implications for further research.