Chapter 1

Introduction and discussion of results

“Lack of activity destroys the good condition of every human being, while movement and methodical physical exercise save it and preserve it.”

(Plato)
The relevance of physical activity

As the quote (source: Das & Horton, The Lancet, 2012) above illustrates, the idea that physical activity is essential for people’s health is not new. Physical activity (PA) is, however, a timely topic in today’s world, in which many people have sedentary occupations. Modern societies have created an environment in which non-communicable, lifestyle-related diseases are an important threat to the health of the human population (Hallal et al., 2012). A lack of sufficient physical activity, defined as not meeting the present recommendations for physical activity, has been termed the 21st century pandemic in a series on physical activity in The Lancet (Lee et al., 2012).

Physical activity is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen, Powell & Christenson, 1985, p. 126). There is substantial evidence that physical activity improves or protects people’s health, independent of their age (American College of Sports Medicine [ACSM], 2009). The World Health Organization ([WHO], 2010) published guidelines recommending that adults incorporate at least 150 minutes of moderate-intensity aerobic physical activity weekly, at least 75 minutes of vigorous-intensity aerobic physical activity weekly, or an equivalent combination of the two. Aerobic activity should be performed in bouts at least ten minutes in duration. Due to evidence of the dose-response relationship between physical activity and health, more physical activity is advised for additional health benefits (Nelson et al., 2007; WHO, 2010).

Failure to adhere to the physical activity guidelines was estimated to have caused 9% (5.3 million people) of premature mortality worldwide in 2008 (Lee et al., 2012). This shows that a lack of PA is a global health risk factor whose impact is similar in magnitude to smoking and obesity. Recent evidence from a meta-analysis also shows the possibility to reduce the impact of a lack of PA: sitting time is associated with all-cause mortality, and the risk of too much sitting can be attenuated by high levels of moderate physical activity (i.e., 60-75 minutes a day) (Ekelund et al., 2016).

Older adults and physical activity

Physical activity (PA) decreases with age and is lowest for people aged 65 years and older. The prevalence of physical inactivity varies across European countries, but on average, about one third of people are insufficiently active (Martinez-Gonzalez et al., 2001). Although PA is important for all age groups, it is especially important for older adults because it reduces the health impact of chronic diseases. The ACSM (2009, p. 1523), in their position stand on exercise and physical activity for older adults, conclude as follows: “Although no amount of physical activity can stop the biological aging pro-
Introduction and discussion

There is evidence that regular exercise can minimize the physiological effects of an otherwise sedentary lifestyle and increase active life expectancy by limiting the development and progression of chronic disease and disabling conditions. Table 1 presents part of the summary table of the ACSM's position stand on physical activity and aging. There is strong evidence that physical activity has a strong effect on health by reducing the risk of developing chronic diseases, increasing life expectancy, and holding value as part of treatment for diseases.

**Table 1. Summary of evidence strength for physical activity and aging (ACSM position stand)**

<table>
<thead>
<tr>
<th>Evidence statements</th>
<th>Evidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular physical activity increases average life expectancy through its influence on chronic disease development, through the mitigation of age-related biological changes and their associated effects on health and well-being, and through the preservation of functional capacity.</td>
<td>A'</td>
</tr>
<tr>
<td>Healthy older adults are able to engage in acute aerobic or resistance exercise and experience positive adaptations to exercise training.</td>
<td>A</td>
</tr>
<tr>
<td>Regular physical activity reduces the risk of developing a large number of chronic diseases and conditions and is valuable in the treatment of numerous diseases.</td>
<td>A/B</td>
</tr>
<tr>
<td>Individuals differ widely in how they age and in how they adapt to an exercise program. It is likely that lifestyle and genetic factors contribute to the wide interindividual variability seen in older adults.</td>
<td>B</td>
</tr>
<tr>
<td>Regular physical activity can favorably influence a broad range of physiological systems and may be a major lifestyle factor that discriminates between those individuals who have and have not experienced successful aging.</td>
<td>B/C</td>
</tr>
</tbody>
</table>

Evidence levels: A. Overwhelming evidence from RCTs and/or observational studies that provide a consistent pattern of findings based on substantial data. B. Strong evidence from a combination of RCT and/or observational studies, but some studies show results that are inconsistent with the overall conclusion. C. Generally positive or suggestive evidence from a smaller number of observational studies and/or uncontrolled or nonrandomized trials.

To illustrate the relevance of the effect of physical activity on healthy aging, I will briefly elaborate on the results of a recent longitudinal study of healthy older adults with an average age of 64 years at the start of the study (Hamer, Lavoie, & Bacon, 2014). People who changed over an eight-year period from being inactive to being active were three times more likely to be healthy than participants with prolonged inactivity. People who stayed active had a sevenfold increase in the chance of staying healthy. Healthy aging is defined in this study as surviving without developing major chronic disease, depressive symptoms, or physical or cognitive impairment, and being active is defined as self-reported moderate or vigorous physical activity at least once a week. The study controlled for age, gender, smoking, alcohol use, marital status and wealth. This study illustrates the powerful effect of physical activity on health; becoming more active at an older age has a relevant effect, even if the activity level falls short of recommended. Increasing physical activity also has a profound effect on health care costs for society, as shown by a study in the U.S. (Martinson, Crain, Pronk, O’Conner, & Maciosek, 2003).
Compared to a group that was inactive at two time points, participants who became active reduced their health care cost between 1200 and 2200 U.S. dollars (depending on the definition of activity) over a two-year period.

The process of behavior change

Health promotion professionals worldwide are encouraging the population to reach the recommended amount of physical activity. For people who are not active enough, becoming more active is a goal to work towards. Behavior change to reach this goal consists of a process over time, as described by the Transtheoretical Model, also called the Stages of Change Model (Prochaska & DiClemente, 1983). It distinguishes six stages of a behavior change process: precontemplation (not intending to take action within six months), contemplation (intending to take action within the next six months), preparation (intending to take action within thirty days and taking some behavioral steps in this direction), action (changing overt behavior for less than six months), maintenance (changing overt behavior for more than six months) and termination (no temptation to relapse and 100% confidence) (Prochaska & Velicer, 1997). Not every stage is necessarily followed consecutively, and relapse is possible. An intention to change is a prerequisite for an actual change in behavior.

Theories about intentions and behavior

Intentions are decisions to act in a certain way, and they represent a person's motivation towards a goal in terms of direction and intensity (Sheeran, 2002). The Theory of Planned Behavior (TPB; Ajzen, 1991, 2002) explains how intention is formed. This theory is often applied in the field of health behavior. The TPB has proven to be a good model to predict intentions, and it produces reasonable predictions of behavior (Armitage & Conner, 2001; Hagger, Chatzisarantis, & Biddle, 2002). However, the predictive value of the TPB in a setting of changing behavior is not as well established, and more studies on the TPB in an intervention setting are needed (Hagger, 2010; Noar & Zimmerman, 2005). The TPB describes the concepts of subjective norms, attitude and perceived behavioral control, which together predict intention. In turn, intention and perceived behavioral control predict behavior. Intention is defined in the TPB as an indication of how hard people are willing to try in order to perform a behavior (Ajzen, 1991). Subjective norms refer to the perceived social pressure to perform a certain behavior. Attitude refers to the degree to which a person has a favorable or unfavorable evaluation of a behavior. Perceived behavioral control refers to a person's appraisal of his or her ability to perform a behavior based on past experiences as well as expected future obstacles (Ajzen, 1998). The first study
of this thesis, presented in Chapter 2, assesses the TPB over time before and after a healthy aging program that includes a physical activity component.

Although intention is important in the behavior change process, it does not guarantee successful change. People behave inconsistently over time with regard to their self-determined plans and goals (Sheeran, 2002). The inability to turn intentions into action has been termed the intention-behavior gap and has been a persistent problem in the field of health behavior (Sheeran, 2002). Goal conflict and habits are interesting factors that influence how well people turn intention into action, and these factors can be targeted in interventions. Goal conflict refers to other goals conflicting with the goal of being more physically active (Abraham & Sheeran, 2003). The goal of being more physically active can conflict with other goals, such as working, spending time with family, having fun and relaxing. Overall, the benefits of physical activity are less prominent than its costs at the time when decisions are made. The benefits, such as weight loss, overall fitness, and general health, are mostly long-term outcomes, while the costs, such as effort and time spent, are immediate. This so-called “temporal valuation” of behavior often results in a negative evaluation of the intended physical activity behavior (Hall & Fong, 2007). Therefore, even when there is an intention to exercise, the immediate reward of other behaviors (relaxing) is often more attractive at the time physical activity should be performed. Therefore, unless the activity itself is perceived as very enjoyable or very important, people will have trouble acting on their intentions to become more active. Habits are another reason why people keep choosing other behaviors over physical activity, even when they plan to be more active. Behavior that has been chosen many times before becomes a habit and is performed without much conscious thought (Aarts & Dijksterhuis, 2000). Much of human behavior can be explained from automatic tendencies to perform behaviors (Aarts & Dijksterhuis, 2000; Hall & Fong, 2007). People react to cues in the environment that trigger automatic behavior patterns; thus, people have a strong tendency to stick to habituated behaviors.

A possible solution for bridging the intention-behavior gap is to use a two-phase approach to behavior change that consists of the intentional phase and the volitional or action phase (Sniehotta, Scholz, & Schwarzer, 2005). In the intentional phase, a person decides that he or she wants to change a behavior (i.e., has an intention) based on his or her beliefs. In the action phase, a person makes specific plans to change a behavior (i.e., an active pursuit of a goal, or self-regulation). Self-regulation is defined as “any effort by a human being to alter its own responses” (Baumeister Heatherton, & Tice, 1994, p. 7). Planning how, when and where to perform the preferred behavior is an example of self-regulation, which is needed until a new behavior becomes a
habit (Sniehotta, Scholz, & Schwarzer, 2005). Behavioral components that are most commonly used in physical activity interventions for older adults are goal setting and self-monitoring, i.e., participants recording their physical activity and exercise (Chase, 2015). There is indirect evidence that interventions are more effective in assisting people to change by using intervention strategies that target not only the intentional phase but also the behavioral phase (Chase, 2015; Conn, Hafdahl, & Mehr, 2011). This is why I use the two-phase approach to target both intention and action in the intervention, the design of which is described in Chapter 3.

Physical activity intervention programs
Physical activity interventions can help motivate people throughout the change process and help reduce the intention-behavior gap. Many different types of intervention programs have been implemented, such as media campaigns, community programs, group programs, individual counseling programs and Internet-mediated programs. Interventions designed to increase physical activity among healthy adults have a modest overall effect size ($d = 0.19$, 95% CI [0.15-0.23]), as shown by an extensive meta-analysis of data on a total of 99011 participants (Conn, Hafdahl, & Mehr, 2011). This effect demonstrates that compared with the control participants, the treatment participants took approximately 500 more steps per day or engaged in 15 more minutes of physical activity per week. There was significant heterogeneity in the effect sizes in the meta-analysis, which means that the programs differed in their actual effects between a 95% CI of $d = -0.14$ and $d = 0.53$, or a difference of -11 to 40 minutes of physical activity per week. The association of variables with effect sizes in review studies is an important indicator for possible effective or ineffective intervention methods. Approaches that were based only on behavioral intervention techniques (e.g., goal setting, contracting, self-monitoring, cues, rewards) were more effective ($d = 0.25$) than other interventions ($d = 0.17$), as shown by the significant moderation. Other variables relating to the content of interventions did not matter for effectiveness; examples are recommendations for the form, intensity or duration of the physical activity, the number of intervention strategies or the total minutes of the intervention content. The setting of an intervention was related to effect size; mass media interventions ($d = 0.08$) and interventions targeting entire communities ($d = 0.09$) were less effective than those targeting individuals ($d = 0.19$), as confirmed by moderator analyses. Furthermore, interventions delivered by project staff ($d = 0.21$) had larger effect sizes than those with a train-the-trainer setup ($d = 0.09$). Theory use also revealed different effect sizes; there were smaller effects for interventions based on the Transtheoretical Model ($d = 0.15$) or social cognitive theory ($d = 0.12$) than interventions not based on these theories ($d = 0.23$). Finally, the effect size was not related to the age of the participants or the method of measuring physical activity.
Physical activity programs for older adults
The effects of physical activity programs that are specifically for older adults were described in two meta-analyses (Chase, 2015; Conn, Valentine & Cooper, 2002). Chase (2015) found an overall mean effect size of $d = 0.18$ (95% CI [0.10-0.26]) for two-group posttest comparisons, with significant heterogeneity in effect sizes. This represented a difference of 620 steps per day or 73 minutes of physical activity per week between the treatment and control groups. Although modest, this represents a relevant effect for the health of older adults because small increases in physical activity have been shown to lead to health benefits (Nelson et al., 2007). The older meta-analysis by Conn, Valentine and Cooper (2002) found a larger effect size ($d = 0.26$, 95% CI [0.21-0.31]). Chase suggested that the difference between the effect size of the two meta-analyses was related to the age of the included participants; this meta-analysis included an older age group (mean age above 65, range 69 to 88) than the older study (mean age above 60, range 60 to 77). There were, however, other differences between the studies that might have influenced the results. Chase included more studies ($k = 101$) but fewer total participants ($N = 13,829$) than Conn et al. ($k = 43$, $N = 33,090$), and the inclusion criteria and weighting procedures of the effects were different. In addition to the difference in the overall effect size, the moderators of the effect differed between the two meta-analyses. Conn et al. found larger mean effect sizes among interventions that targeted only physical activity, employed self-monitoring, or were delivered in groups, while Chase did not find these effects. In a moderator analysis, Chase (2015) found interventions that used audio-visual or mailed materials to be more effective ($d = 0.48$) than those that did not ($d = 0.14$) ($p = .03$), while Conn et al. did not find a difference associated with materials used. In correspondence with an earlier review (Chase, 2013; King, 2001) but contrary to meta-analyses in other samples, Chase (2015) found interventions to be more effective when they used a combination of cognitive and behavioral intervention strategies ($d = 0.23$) than when they used either strategy alone ($d = 0.02$) ($p = .03$). Other factors found by Chase (2015) to be related with larger effects were the inclusion of healthy participants ($d = 0.30$ versus $d = 0.11$ for chronically ill participants, $p = .03$) and a reported theoretical basis for the intervention ($d = 0.28$ compared to no reported theory use, $d = 0.05$; $p < .01$). Aspects of the intervention dose (e.g., number of sessions, duration of sessions) and differences in the measurement of physical activity behavior (objective or subjective) were not significant moderators. The differences in findings regarding effective program properties and components indicate a need for studies that systematically compare different intervention techniques and approaches.
A review by King (2001) looked at program characteristics that appeal to older adults and may therefore be more effective. Physical activity interventions appealing to older adults are moderate in intensity, simple and convenient to engage in, relatively inexpensive, and noncompetitive, and they contain a social component. However, a substantial portion of older women and men prefer physical activities outside of group settings. Internet-mediated interventions can cater to some of these preferences as they can be easy to attend at home, do not require a group setting and can be low in cost.

**Internet-mediated interventions**

The use of Internet-mediated health interventions is a fairly new development; it was in a pioneering phase in 2006 (Griffiths, Lindenmeyer, Powell, Lowe, & Thorogood; 2006) but has become more common since then. The effects of these programs are positive but small. A meta-analysis of 34 Internet interventions targeting physical activity found a positive effect with a small overall effect size \( (d = 0.14, \text{95% CI (0.10, 0.19)}) \) (Davies, Spence, Vandelanotte, Caperchione, & Mummery, 2012). A moderator analysis showed that the effect size was larger for interventions with smaller samples, \( n < 35 \ (d = 0.40) \) than with larger samples, \( n \geq 35 \ (d = 0.12) \); larger for those that screened participants for having a low physical activity level in advance \( (d = 0.37) \) than for those with no screening \( (d = 0.12) \); and larger for those that included educational components \( (d = 0.20) \) than for those that did not \( (d = 0.08) \). Internet interventions can increase their effectiveness by improving participant engagement, and more studies are needed on the effectiveness of intervention elements (Kohl, Crutzen, & de Vries, 2013; Davies et al., 2012).

A review of Internet-mediated lifestyle interventions for people over 50 years old included ten studies, of which three focused on physical activity. These three interventions were found to be feasible, and the effect sizes were small to moderate for the two physical activity studies for which they could be calculated (Aalbers, Baars, & Olde Rikkert, 2011). A subcategory within Internet-mediated interventions is web-based interventions. A web-based intervention is a primarily self-guided intervention program that is executed by means of a prescriptive online program operated through a website and used by consumers seeking physical and mental health-related assistance (Barak, Klein & Proudfoot, 2009).

**Prompting as an intervention component**

The use of prompts is one promising intervention technique that can be used as an additional element in existing behavior change interventions to increase the engagement of participants of online interventions. Prompts are defined as
“messages, reminders, or brief feedback communicated to participants multiple times over the duration of an intervention” (Fry & Neff, 2009, p. 2). Fry and Neff (2009) found support for the effects of prompts on behavioral outcomes in behavior change interventions. The effects seem to be stronger when prompts are used more frequently and include personal contact with a counselor.

Research questions, chapter overview and summary of results

The main question of my thesis is: How can intervention programs help adults aged 50 and over be more physically active? I explore how theoretical concepts can guide the development of these interventions. In this section, I briefly describe which research questions I studied by summarizing the content of Chapters 2 to 6. The research in this thesis revolves around two intervention studies with older adults. The first is a healthy aging, group-based, intervention program whose data I used to test the assumptions of the TPB (Chapter 2), an important theoretical model in the field of health psychology. The second is the development and testing of an online intervention for motivating participants to be more active using an approach that builds on the TPB (Chapters 3 to 6).

Chapter 2 examines the TPB by testing its concepts in the context of a healthy aging intervention. The research question is about the extent to which the TPB predicts intention and physical activity behavior over time in the context of the Aging Well and Healthily intervention. I use data from that intervention and test the concepts of the TPB over time in a structural equation model. The results show that intention was predicted well by the measured concepts of the TPB, and the TPB predicted some of the overall physical activity behavior change over time. However, the positive change in doing specific exercises taught during the intervention was not predicted by TPB concepts. Diversity in participants’ starting point on intention to change their physical activity levels might be an issue when assessing the TPB model over time. Future studies with larger samples may conduct separate analysis for groups with different levels of intention to change. The question remains how TPB concepts can be effectively used to change physical activity levels over time in an intervention setting.

In the remaining part of my thesis, I integrate this knowledge into a two-phase behavior change approach in the design of an online program that aimed to motivate people age 50 and older to be more active. In Chapters 3 to 6, I apply this theoretical approach, design and test an online intervention, and study how prompting
increased adherence to this program. In Chapter 3, I explore the question of which content is useful for a web-based intervention for people over 50. I apply a two-phase approach that assumes that an intentional phase and a volitional phase are both part of behavior change, as explained earlier in this chapter. I use the TPB to decide which intervention techniques would be useful to increase intention while adding volitional constructs, such as action planning, to get participants to move from intention to actual behavior. These techniques are then applied in the form of intervention components of the program, which are as follows: two full-color informational brochures about physical activity targeted at older adults, online physical activity tips in the form of animated videos with corresponding text, an online physical activity plan, an online diary and email prompts. The resulting multicomponent intervention is tested in several studies. Personalized content and personal coaching are potentially valuable components that were not used in this intervention. Automatic tailoring of information would create more opportunity to give participants relevant feedback on their behavior (Amman, Vandelanotte, de Vries, & Mummery; 2013). With the increase in the use of smartphones, future interventions may also benefit from a combination of a web-based intervention with an app, which has recently been used more often in health interventions (Lentferink et al., 2017). This has the advantage that people can use the intervention wherever they want and can be reached close to the time that decisions influencing health are made (Lentferink et al., 2017).

In Chapter 4, I ask whether the designed intervention program was feasible and acceptable. I assessed this question in a pilot study. Acceptability was assessed by using a questionnaire that measured appreciation and by looking at program use and dropout rates. Feasibility was assessed by monitoring implementation issues during the pilot. The general interest in the program among the target group and the appreciation for the program among participants showed that the web-based intervention was acceptable. It was also feasible to implement the program at a larger scale as implementation issues could be addressed with small changes. A concern that could not be fully addressed was the modest appreciation for the physical activity tips in the form of animated videos.

Chapter 5 entails a process evaluation of the online intervention program to answer the questions of whether the target group appreciated the intervention content and whether the targeted group was reached. I asked for participants’ opinion on the program to see how the target group appreciated the components of the intervention, and I looked at the characteristics of the people who were reached to evaluate how they matched with the targeted characteristics. The results show that there is a demand for an online program to promote physical activity in older
adults, but targeting the right group is tricky, as this program did not reach the targeted group. Overall, the program was appreciated, but there was variation in the appreciation between components. Paper-based information and an online PA diary were appreciated by this age group. The PA diary and the program in general were also perceived as activating. The online PA plan and animated videos were not appreciated as much as the other elements. The short-term outcomes of increasing knowledge and registering PA were reached, while the use of goal setting and planning was not optimal. Screening participants seems to be necessary to reach the appropriate target group.

In Chapter 6, I explore the effectiveness of the online PA intervention for changing motivation and behavior in adults over 50 years. The study tested whether the intervention with prompting was more effective than the standard intervention in a randomized control trial. The effectiveness of the intervention was assessed by comparing objective and subjective measures before, during and after the intervention. The program did not increase motivation or PA, and the prompting group did not have a higher adherence to the program or better PA outcomes than the non-prompting group. The approach of using email prompts to increase adherence and motivate people over time was not effective in this study. Intervention techniques that are effective in other age groups may not be effective in older adults (French, Olander, Chisholm, & Sharry, 2014). The conditions under which prompts are useful and effective need to be studied in more detail (Alkhaldi et al., 2016).

**Overall conclusion on the results of this thesis**

This thesis has two major research topics. One is the evaluation of predictions derived from the Theory of Planned Behavior (TPB) within the setting of a healthy aging program. The other is the development and testing of an Internet-based intervention program to enhance PA; this intervention is partly based on the TPB but incorporates a broader theoretical approach.

The findings of the study reported in Chapter 2 show that the TPB is useful as an explanatory model for the intention to change behavior. This is important because intentions to change are a prerequisite for actual change. The TPB, however, seems to fall short when used as a behavior change model in the setting of a healthy aging program. The inability of TPB constructs to predict the change in PA in a behavior change program has been observed earlier, e.g., in a study on adults aged 30 to 50 (Hardeman, Kinmonth, Michie, & Sutton, 2011). The lack of success of the TPB to address the intention-behavior gap recently led to a lively discussion in the research community about retiring the TPB. Hagger (2015) summarized this discussion in an
article with the appropriate title ‘Retired or not, the Theory of Planned Behavior will always be with us’.

In Chapters 3 to 6, I report the construction of and studies on an Internet-based program to motivate people aged 50 years and older to engage in PA. I applied intervention techniques aimed at the intentional phase and the volitional phase. These techniques were combined with email prompts to increase engagement. The program was not successful in changing intention or behavior. The email prompts used in the Internet-based program did not increase the engagement of participants or the effectiveness of the program. Although these results were somewhat disappointing with respect to the desired outcomes, it does not mean that these types of programs cannot be effective. It should be noted that my intervention program was appreciated by the participants and that there is a demand for such a program, as concluded from the evaluation (Chapter 5). The question remains regarding which strategies lead to an effective Internet-based intervention for adults over 50. To provide some direction for the further development of PA interventions, I first discuss what other studies conclude about working components in health interventions.

**Findings from other studies**
A growing body of research in the wider field of health interventions provides clues about what works in these interventions. In a review of automated interventions for a healthy lifestyle, Lentferink et al. (2017) found that health outcomes and the usability of these interventions were enhanced by the following key components: setting short-term goals to eventually reach long-term goals, personalization of goals, praise messages, reminders to input self-tracking data into the technology, use of validity-tested devices, integration of self-tracking and persuasive eCoaching, and provision of face-to-face instructions during implementation. A higher level of effort from participants to register their health behavior data with technology did not negatively affect health outcomes or usability. In addition, personalized content appeared to be a key component for adherence and usability. It might be that the effects of Internet-based interventions are largely dependent on human coaching, which is more expensive than fully automated programs. Ten out of 27 health interventions in the review included human coaching in addition to automated coaching. However, the review did not include sufficient studies to compare the two types of coaching, so it remains unclear how big the effect of human coaching is in the field of Internet-based health interventions. A review by Brouwer et al. (2011) specifically focused on factors that influence exposure to Internet-based healthy lifestyle interventions. This review concluded that out of many intervention characteristics that could potentially enhance exposure, only peer support, counselor support, email/phone contact with
visitors, and updates of the intervention website were related to better exposure. No influence of interactive behavior change strategies (such as tailored feedback, goal setting tools, action planning tools, or self-monitoring tools) or other interactive elements (such as quizzes, searchable databases, or audio/video) was found. This result may be partly due to the lack of variation in the use of strategies, which complicates the comparison of strategies. For action planning (detailed instructions for behavioral enactment), evidence from the field of PA behavior change shows that this strategy might not be effective by itself and might be effective only in combination with coping planning (plans to handle barriers) (Rhodes & Yao, 2015).

When I compare the results from these two reviews with the intervention components in the Internet-based program (Chapter 3), I conclude that the lack of personalized content in the form of personalized advice and counselor support and the lack of persuasive eCoaching might have compromised the effectiveness of my intervention. The lack of face-to-face instruction in my intervention may have also influenced its effectiveness, but this was a deliberate choice in favor of a low-cost intervention. Taking into account the reviews above, another effective feature was setting personal goals that ranged from short- to long-term goals. Although I used this in my program, this apparently was not enough to make the program effective. It is possible that counselor support or eCoaching interacts with goal setting in a way that makes it effective. Combined with the fact that many Internet-based coaching programs have a blended approach that includes human coaching, this does raise the question of how important a human component is for the effectiveness of Internet-based programs. I return to this question later.

**Differentiation by age**

As this thesis is about PA in adults over 50, I now focus specifically on the literature in this area in relation to the lack of effects of my intervention. While various intervention components are effective in the general field of Internet-based health interventions, it is not certain that they are also effective in PA interventions for older adults. A review by French, Olander, Chisholm and Sharry (2014), which was published after my intervention was implemented, studied effective PA intervention techniques for older adults. They found three techniques to be positively associated and ten to be negatively associated with intervention effectiveness. Interventions that applied normative information and self-regulation techniques were less effective. The most strongly negatively associated were providing normative information about others’ behavior, providing information on where and when to perform behavior and planning social support/social change. Examples of self-regulation techniques associated with less effective interventions were goal setting and prompting self-monitoring. In
contrast, a meta-analyses on PA and healthy eating interventions in adults (Michie, Abraham, Whittington, McAteer, & Gupta, 2009) found these interventions were more effective if they included self-monitoring combined with at least one of four other self-regulatory techniques (i.e., prompting intention formation, prompting specific goal setting, providing feedback on performance, and prompting a review of behavioral goals).

French et al. (2014) also found behavior change techniques that were related to higher effect sizes on PA outcomes, just as in other age groups. These techniques were barrier identification/problem solving, providing rewards contingent on successful behavior and modeling/demonstrating the behavior. This study was mostly based on associations rather than experimental comparisons. Moreover, the focus was specifically on studies targeting self-efficacy, and many of the interventions simultaneously applied several intervention techniques. Therefore, based on this study, no definite conclusions on effective intervention techniques for older adults can be made. Nonetheless, the findings are important because they suggest that intervention techniques work differently in older adults than in younger people. Overall, the results from this study suggest that my intervention used intervention techniques that are not optimal for older adults. I barely used the techniques related to higher effectiveness in my intervention. Barrier identification, for instance, was only a small part of the online PA plan and could easily be skipped by participants. In my intervention, I incorporated several intervention techniques related to less effective interventions, such as normative information in the form of the PA norms, encouragement to find social support, goal setting as part of an online PA plan, and self-monitoring in the form of an online diary.

The study by French did not specifically focus on Internet-based programs, so the next question to answer is whether Internet-based programs for older adults need a different design than those for other age groups. To increase our understanding of the differential effects of Internet-based interventions across age categories, they need to be compared in experimental research studies. I describe the results of four comparison studies and briefly compare the intervention approaches to my intervention approach.

Two versions of an Internet-based intervention program to promote walking in Australia and a paper logbook supported with a pedometer were compared in two studies (Alley et al., 2018; Kolt et al., 2017). The two variations of the Internet-based program were a ‘Web 1.0’ program with features such as data entry and text forum submissions, and a ‘Web 2.0’ program, with more interactive features such as
‘status updates’, streams, blogs, internal emails, and forum posts. Kolt et al. (2017) studied a group of participants aged 18 and older with a mean age of 51 years old. They found higher engagement for the Web 2.0 intervention than for the Web 1.0 intervention. The logbook and Web 2.0 interventions improved PA in the short term (after three months), with an average of 5 to 7 minutes of daily moderate to vigorous PA, while the Web 1.0 intervention did not. At 12 months, all three interventions showed increased activity of 4 to 5 minutes of moderate to vigorous PA. After 18 months, no effects were significant, and the increase in PA minutes did not seem very different from the 12-month measurement. As there was a decreased number of participants, this could also be a statistical power problem. Alley et al. (2018) additionally compared two age categories (55 years or younger, M age = 42; 55 years and older, M age = 64) on the three intervention variants. There was a difference between older adults and younger participants in the use, appreciation and effect of the Internet-based PA interventions. More specifically, the Web 2.0 intervention was more effective than the logbook at three months, especially in older compared to younger adults. Furthermore, older adults spent more time on the intervention websites and had more days with step entries across all time points. Older adults were especially more likely to spend more time on the Web 2.0 website than on the Web 1.0 website compared to younger participants. At the same time, compared to younger adults, older adults had lower chances of high satisfaction with the Internet-based interventions. Older adults also had lower Internet self-efficacy scores with a greater variance. These two studies show that a more interactive Internet-based intervention and a paper-based intervention both work well in an older population, while a Web 1.0 intervention is not as successful. In my intervention, I used paper-based information in the form of brochures, and an option to print the Internet-based information was provided. However, the actual registration of behavior occurred online, and participants did not have insight into their accelerometer data during the intervention. As our intervention was comparable to a Web 1.0 intervention, the lack of effects may have been related to the lack of interactive components. However, another study of an Internet-based PA intervention questioned the usefulness of interactive components. In that study, the use of interactive features was low, even though they were added based on suggestions from focus groups (Ferney, Marshall, Eakin, & Owen, 2009). In conclusion, the use of interactive components in an Internet-based PA program for older adults is promising but needs more study.

Amman, Vandelanotte, de Vries and Mummery (2013) evaluated a website that delivered a computer-tailored physical activity intervention that compared three age categories (44 or younger, 45-59, and 60 years or older). This website gave personal PA advice using videos based on a questionnaire. Participants in the oldest age
category increased their physical activity more than younger participants and spent the most time on the website, but they had significantly lower perceived Internet self-confidence scores than the youngest category. No differences were found in terms of website usability, which was high, and tailored advice acceptability, which was modest. The biggest difference between this intervention and my approach seems to be the use of personalized information.

Friederichs, Oenema, Bolman and Lechner (2016) compared two Internet-based programs, *I Move* and *Active Plus*, in adults ages 18-70 (mean age of 45) in the Dutch population. Both programs were systematically developed web-based computer-tailored PA interventions that comprise automated PA advice sessions and aim to strengthen behavior-specific self-esteem. *Active Plus* was originally designed for adults over 50 years, so in order to be comparable to *I Move*, *Active Plus* was adapted to be suitable for adults of all ages. A difference in the theoretical approach resulted in more interactive advice in *I Move* with advice sessions that contain simulated conversation. *Active Plus* delivers advice as one text tailored to participants’ background characteristics. The *Active Plus* advice sessions were more concise (10 minutes) than the *I Move* sessions (session one, 20 minutes; sessions two to four, 10 to 15 minutes). *I Move* resulted in a small but significant effect on minutes of moderate to vigorous PA, while *Active Plus* did not; there was no difference between the two effect sizes (*I Move* ES = .09 vs *Active Plus* ES = .07). *Active Plus* was more effective at increasing the number of days in a week with sufficient PA (*I Move* ES = .21 vs *Active Plus* ES = .35). Moderator analyses showed an effect of age for *I Move*, which was effective at increasing the minutes of moderate to vigorous PA in adults aged 47-70 years (ES = .15) but not those aged 18-46 years (ES = .04). Additionally, *I Move* was more effective at increasing the number of days with sufficient PA in adults aged 47-70 years (ES = .26) than in those aged 18-46 years (ES = .17). Furthermore, more *I Move* participants completed all four sessions (25%) than *Active Plus* participants (13%). The differences between *I Move* and my program are that *I Move* has interactive simulated conversation sessions and tailored feedback, while my intervention has Internet-based registering of PA, which *I Move* does not have. *Active Plus* is discussed in more detail later on.

All three studies comparing different age categories in Internet-based PA interventions showed that they are effective for older adults. They also showed that different types of Internet-based interventions can be effective at increasing PA in older adults. Three interventions actually worked better for older adults than younger groups. The study by Alley et al. (2018) also showed that interactive features can be useful for an older adult population, although these participants were less satisfied with
the interventions. Interesting is that two studies found that older adults spend more time on Internet-based interventions, while they are less confident and satisfied with using an Internet-based program. Paper-based interventions still seem to be an interesting alternative.

**Comparison of components of Internet-based intervention studies for older adults**

The studies mentioned above did not specifically compare intervention components. To get an indication of which intervention components are effective in Internet-based PA programs for older adults, we need to delve further into the literature. Review studies specifically for Internet-based PA interventions in older adults do not yet exist. The studies that resemble this are a review on Internet-mediated lifestyle interventions by Aalbers, Baars, and Olde Rikkert (2011) and a review of non-face-to-face PA interventions for older adults (Müller & Khoo, 2014). These two reviews describe in total five Internet-based PA intervention studies with a participant population of older adults. To answer the question of which intervention components might be beneficial for designing an effective program for participants aged 50 years and older, I compare my program with similar intervention programs. For this purpose, I elaborate on a few studies of interventions similar to mine. These include stand-alone Internet-based programs that are focused on increasing general physical activity (not just walking), discuss effects on the behavioral level, are applied to (but not necessarily specially made for) a group of people over 50 years old and are aimed at a population without a specific disease profile living in the community. A few such studies have already been discussed above with the age comparison studies.

I start with a program called Active over 55, which is similar to my program in that it is a self-tailored Internet-based PA program (Irvine, Gelatt, Seeley, Macfarlane, & Gau, 2013). The program was found to be effective in increasing PA at twelve weeks and 24 weeks after the intervention in a group of 405 sedentary adults in the USA (Mage = 60). Participants received $25 for each submitted survey at pretest, twelve weeks and six months. This twelve-session stand-alone Internet program helped users develop a self-tailored personal activity program. This personal plan was created during a one-hour online start-up session using text and video messages to help participants set specific goals, choose exercises and schedule them during the next week. Participants were encouraged to print out their PA plan and exercise-tracking sheets. The eleven subsequent weekly sessions lasted at least ten minutes and added exercises or advanced challenges of the same exercise. Weekly email prompts were sent to remind participants of the Internet-based sessions. Each session was a video-based with interactive educational content presented by a narrator and personal
coach with bulleted text teaching points. The internet-based program components were personal activity planning, the health value of exercise, dealing with barriers, tracking PA, tips and personal stories to stay motivated, safety tips, disease-specific recommendations, and a library with additional related articles and tip sheets. Although this program is similar to my intervention in terms of content, it contains more specific instructions and guidance in constructing a PA plan with examples of exercises and interactive goal setting. This way of automatically guiding people through an Internet-based program seems very useful. It also answers the question raised earlier about the necessity of blended coaching that involves human actions during the program. These results show that it is not necessary to have human involvement to achieve a successful program.

Active Plus is an effective Internet-based program for older adults to increase their PA (Peels, van Stralen, Bolman, Golsteijn, de Vries, Mudde & Lechner, 2014; www.actief-plus.nl). The program targeted a similar group as my intervention, so I used information on the goals for this program as input for my intervention. The Active Plus intervention was designed using a theory-based approach. Participants receive tailored advice based on personal characteristics at three points in time (at the beginning, after two months and after four months). The advice consisted of a five-to eleven-page text with videos, pictures, figures, hyperlinks and schedules. Tailoring was based on personal characteristics such as age, PA level and the phase of change of the participant. Examples of the tailored information are a comparison of their PA level to others of a similar age, model stories and consequences of inactivity. The program was initially a paper-based intervention and was later supplemented with an Internet-based version. A comparison of the printed and Internet-based versions revealed that participants used the printed intervention components more and had higher appreciation (Peels, de Vries, Bolman, Golsteijn, van Stralen, Mudde, & Lechner, 2013). In another comparison study both were found to be effective at changing physical activity after six months (Peels, van Stralen, Bolman, Golsteijn, de Vries, Mudde, & Lechner, 2014). Minutes of PA per week increased by, on average, 231 minutes in the printed condition and 283 minutes in the Internet-based condition compared to an increase of 49 minutes in the control group. The printed version of the intervention was more effective for participants aged 65 and older. Additional environmental information in the Internet-based intervention resulted in no effect on PA. An effectiveness study at twelve months showed that the printed version was still effective but the Internet-based version was not (Peels, Bolman, Golsteijn, de Vries, Mudde, van Stralen, & Lechner, 2013). In yet another study on the same intervention, health outcomes and cost-effectiveness were modeled for a five-year and a ten-year period based on twelve-month PA increases (Peels, Hoogeveen, et al., 2014). Both
the printed and the Internet-based version were found to be cost effective at a five-year time interval, but the cost-effectiveness for ten years and longer was higher for the printed version. It seems that providing tailored advice based on participants’ characteristics is an effective component, which differs from my intervention. Another difference is the lack of self-registering behavior, which is a frequently used intervention component but is apparently not necessary to achieve intervention effectiveness. Also interesting to mention is that the comparison of participants’ PA levels to those of others of similar age was used, while the review by French et al. (2014) found that providing normative information about others’ behavior was strongly negatively related to effectiveness.

**Prompting to increase engagement in Internet-based interventions**

In my study, email prompting was not effective. A recent systematic review on the effectiveness of prompts for engagement in digital interventions, including Internet-based interventions, found mixed results (Alkhaldi et al., 2016). In this study, prompts were defined as “digital and analog technology methods used to promote the user’s regular interaction with all or part of the digital interventions, including, but not limited to, telephone calls, text messages, multimedia messages, emails, automated voice calls, or faxes” (p. 3). They found some positive effects on dichotomous outcomes, with heterogeneity between studies and no effect in a small number of studies with continuous outcomes (Alkhaldi et al., 2016).

The review by Lentferink et al. (2017) on automated healthy lifestyle interventions found that prompts in the form of reminders are an important component of these interventions, and more knowledge is needed about the design and effectiveness of prompts. They also observed that effective interventions applied reminders for the input of behavioral data, while less effective interventions used reminders on changing health behavior. Participants found reminders useful while also indicating that the frequency and timing of reminders can result in adverse feelings such as annoyance, guilt and feeling checked up on. Suggestions from other research on the timing of prompts are to use daily prompts and event-based rather than time-based prompts.

Both reviews indicate that much is unknown about the characteristics of effective prompts, so future research in this area is warranted. One study compared different characteristics and found that strategies promoting new digital intervention content and those sent to users shortly after they started using the digital intervention were more likely to engage users (Schneider, de Vries, Candel, van de Kar, & van Osch, 2013).
Promising components for an Internet-based PA program
The results from the comparison of my program to several successful Internet-based PA programs for older adults suggest that the approach where participants are their own coach in enhancing PA does not work. Action planning by itself was also not found to be effective in several studies. Successful Internet-based PA program components for an older age group include personalized advice and feedback based on behavioral measures, guided interactive goal setting and planning, barrier identification and problem solving, and rewards for successful behavior. It might be that action planning is effective only when combined with coping planning or when guided through the planning. Thus, the available research suggests that the best approach is an automated coaching program that guides participants through the process of behavior change by using the successful intervention techniques mentioned above to provide personalized information.

More research is needed on the use of interactive features of Internet-based programs and on what type of tailoring and prompting are effective. In an older adult population, it might be counterproductive to compare their behavior to that of other people or to give directive information on how to do which activities. Therefore, the focus needs to be on their own behavior, and there should be a balance between providing enough guidance and independence, as was done in my intervention. Evidence for the effectiveness of paper-based intervention strategies exists and should not be overlooked. More work needs to be done to determine which intervention components participants prefer to have on paper and how they can be optimally combined with Internet-based information.

Theory use for PA behavior change interventions
I chose to use the two-phase approach in my intervention design by using elements of an action-oriented approach together with TPB concepts that are aimed at enhancing intention to change behavior (Sniehotta, Scholz, & Schwarzer, 2005). Although the application of this approach did not result in an effective program, I still believe that this approach is useful. It seems that other PA intervention programs with a similar setup were successful in helping participants put intention into action. The action-oriented approach has been integrated in several models. It might be more effective to use such a model. A review providing an overview of these types of models in the PA domain identified sixteen models, of which eight had been applied in 36 empirical studies (Rhodes & Yao, 2015). These studies provide preliminary evidence for the effectiveness of several concepts to predict post-intention PA. The two most applied approaches were the health-action process approach (HAPA) and the multi-process action control (M-PAC) framework. Theoretical constructs from
these models that were found to predict the translation of intention into behavior are affective judgments (enjoyment), perceived control/opportunity (time/access), habit (automatic responses to cues from a patterned and learned behavior), extraversion (sociability, positive affect, assertiveness, preference for lively activity) (M-PAC), maintenance self-efficacy (the confidence that one can perform a behavior given various barriers), and a combination of action planning (detailed instructions of the behavioral enactment) and coping planning (plans to handle barriers) (HAPA). Action planning by itself was shown to have little effect. Further testing of these models in experimental settings and specifically in the PA domain is necessary. However, these models have also received criticism as there is a need for diverse explanations in different types of settings of behavior change, which one overall model cannot provide (Peters & Crutzen, 2017).

I conclude that there is no consensus on the best theoretical approach. Many theories and approaches coexist and need to be applied in accordance with the specific behavior and setting. To increase consensus regarding an effective theory in the domain of health behavior promotion, it is important to conduct intervention studies. These studies should compare theoretical concepts and their power to predict behavior change. Moreover, to stimulate the progress in the field, these studies need a detailed description of the applied intervention and of the operationalization of theoretical concepts.

**Participant selection**

Targeting the right group of people is a challenge. Some participants enrolled in our program even though they were sufficiently active. Therefore, selecting participants based on screening is advised. Screening involves the assessment of the PA level before the intervention. Intervention studies that include only participants with lower baseline PA levels have larger effect sizes (Davies et al., 2012). Other programs use a variety of guidelines for what is considered inactive or too active. For example, Irvine et al. (2013) used the following cut-offs: (1) no more than 60 minutes per week of moderate exercise, defined as exercise that increases the heart rate, with (2) no bouts of continuous exercise lasting thirty-five minutes or more. Wijsman et al. (2013) used the general practice physical activity questionnaire and defined inactivity as less than three hours of exercise and cycling combined weekly. A study by Ferney et al. (2009) showed that a simple screening question for meeting PA levels is not sufficient to screen out sufficiently active people. They found 27% of their included participants to be sufficiently active at a more thorough screening even though they did not meet the PA guidelines in an initial telephone screening. Future research should determine which screening practices are most effective at including inactive
participants. Perhaps recruitment strategies in which health professionals refer participants to such a program can also help reach the right group of people.

Conclusion

In conclusion, much is still unknown about the best approach for designing an Internet-based PA intervention for older adults. The knowledge base about the best use of theory and the most effective types of intervention techniques can be improved. In my study on the Theory of Planned Behavior (Chapter 2), I found that it had modest value for application in the setting of behavior change. From the studies on my Internet-based program, I found a demand for a motivational program regarding PA. However, the approach of letting participants become their own coach was not successful. Although my intervention was not effective, the use of an Internet-based program for PA in older adults might still be feasible and effective. Other studies show that the potentially effective intervention components are fully automated coaching for personalized goal setting, help with barrier identification and problem solving, and feedback on behavior. The effect study in this thesis shows that prompting in the form of static emails was not effective. Prompting can be useful, but care should be taken to cater to participants’ needs, possibly by using tailored prompting. Prompts that provide new information or help remind users register their behavior are most likely to be effective. Studies on the effective design of prompts are needed. The components of Internet-based PA interventions for older adults should be studied and developed further to optimize the effects. Detailed descriptions of theory use and intervention programs are needed. As the program I designed was not successful at changing intention or behavior, I advise policy makers to either use the best available program in the Netherlands - the Active Plus program has been evaluated as effective - or to design a new program based on the latest findings while closely monitoring its effectiveness.