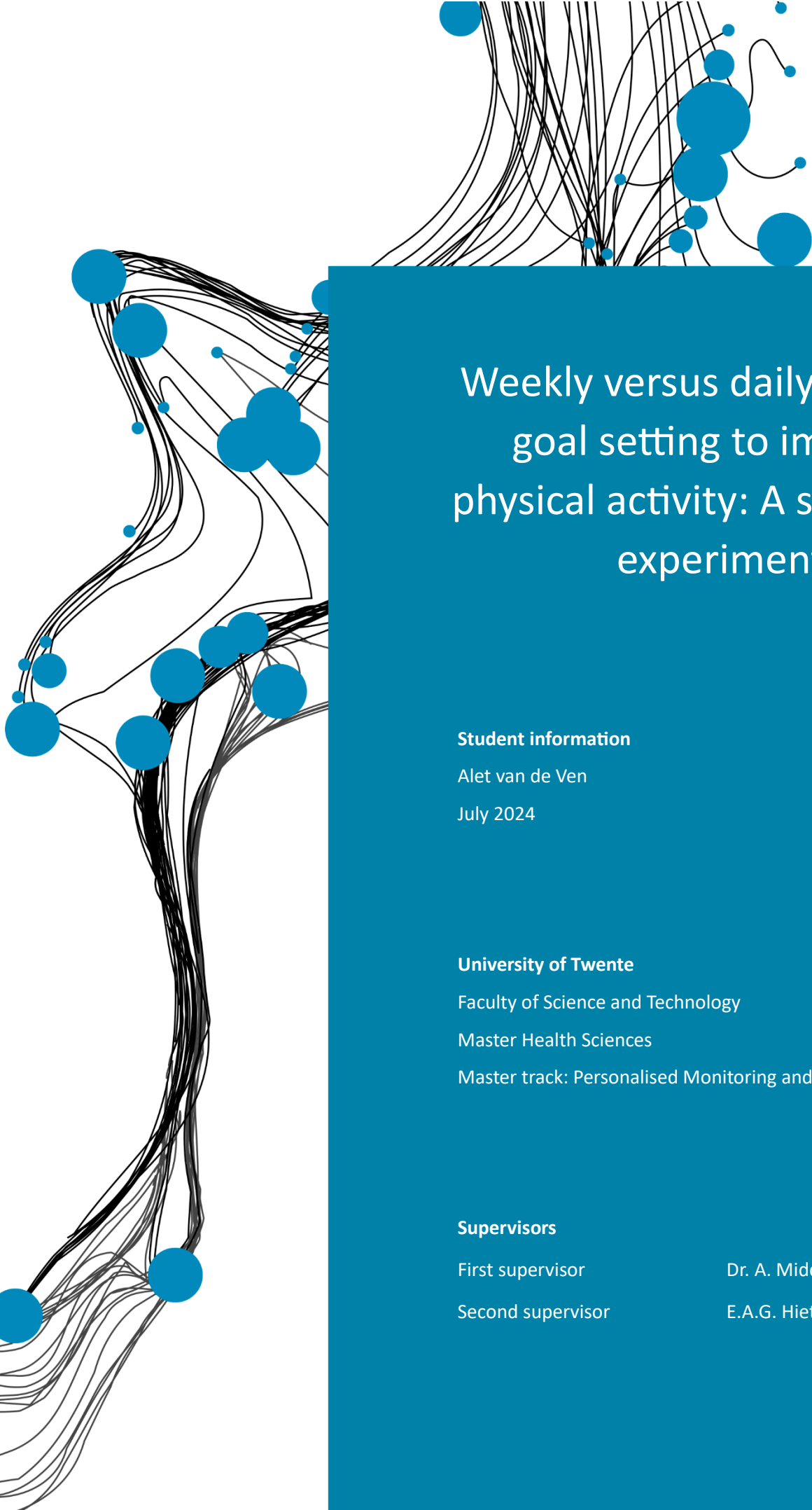




Weekly versus daily adaptive goal setting to improve physical activity: A single case experiment

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Preface

This thesis was written as the final work for the completion of the Master Health Sciences at the University of Twente, within the specialization track of Persuasive Monitoring and Coaching. Over a period of 6 months, I worked on this final report of my master thesis. I would like to express my gratitude to my supervisors who helped me write this theses. Firstly, Dr. A. Middelweerd and E.A.G Hietbrink, I would like to thank you for the feedback and involvement in my thesis. Secondly, I would like to thank Dr. T. Dekkers for the expert advice on how to best perform a Single-Case Experiment. I would like to acknowledge the use of ChatGPT, which played a role in aiding my research. ChatGPT provided assistance in refining my writing and helped with writing my R-code. Finally I would like to thank all the participants that were involved in the experiment. Without these people, this thesis would not have succeeded.

I hope you will enjoy reading this thesis.

Alet van de Ven

Abstract

Background: Increasing physical activity (PA) is a major public health priority. Less people of the Dutch population are meeting the PA guidelines. Changing lifestyle behaviour is necessary, but behaviour change costs time and energy. According to the goal setting theory, goals that are clear, specific, and challenging are more motivating than vague or easy goals. eHealth interventions are increasingly becoming a popular method for delivering health programs. At the moment, many eHealth interventions include goal setting, but only use static goals, fixed goals that are set without adjustment based on activity levels. This does not consider whether a person is achieving their goal or not. Adaptive goal setting could be a solution in personalising goals, which could benefit eHealth applications. Adaptive interventions provide a personalized approach, wherein treatment is continuously adjusted over time in response to the individual's evolving needs.

Aim: The aim of this study was to evaluate different adaptive goal setting approaches with the use of a Fitbit, with adaptive step goals. In which weekly adaptive goals are compared to daily adaptive goals.

Methods: The goal setting approaches were evaluated in a six-week period with a single case experiment design. To calculate the weekly- and daily step goals, the 60th percentile schedule was used. The study compared the effectiveness of weekly- and daily step goals, with a hierarchical piecewise linear regression. As well as the mean, median, and standard deviation for each participant was calculated, and regression coefficients were calculated for each phase of the experiment. Also the step trend lines of the baseline, weekly, and daily goals were created. At the end of the experiment, the participants filled in a questionnaire, in which the Likert scale was used to rate different statements about the weekly- and daily goals.

Results: The regression coefficients showed, that the baseline had a decline in steps per day, while in the weekly- and daily goals an increase was seen. The hierarchical piecewise linear regression in which the goal setting approaches were compared to the baseline measurement. Proved that the slope effect of the daily goals, compared to the baseline was significant ($p=0.037$). While both the level effects and the slope effect of the weekly goal setting were non-significant ($p>0.05$). In comparing the weekly goals too the daily goals using the hierarchical piecewise linear regression, both the level and slope effect were non-significant ($p>0.05$). The questionnaire was in line with the results of the analysis. Participants found the frequency of the daily goals to be more motivating and offered more flexibility in the variety of steps, than with the weekly goals. Both the adaptive goal setting approaches were found to be more appealing, than other methods. Of all the participants 80% had a preference for the daily goals.

Conclusion: In comparing the effectiveness of daily versus weekly step goals, the study analysed PA trends and participant feedback across different phases. Key conclusions include: daily step goals provided consistent motivation and immediate feedback. Weekly step goals offered greater flexibility with the variety in daily schedules. Both daily and weekly goals were sometimes perceived as unachievable. However, the regular frequency of daily goals was preferred by participants for maintaining motivation. The regression coefficients support this finding, seeing a higher step increase in the daily goals.

Table of Contents

Preface.....	1
Abstract	2
1. Introduction.....	5
2. Theoretical framework	9
3. Methodology	12
3.1 Study design.....	12
3.2 The intervention of the goal setting approaches	12
3.3 Participants	13
3.4 Sample Size	13
3.5 Procedure.....	13
3.6 Data Collection	14
3.7 Analysis	16
3.8 Ethical considerations	17
4. Results	19
4.1 Steps per day.....	19
4.1.1 Group results	19
4.1.2 Individual results	21
4.2 Questionnaire.....	25
5. Discussion.....	28
5.1 Principal findings and explanations	28
5.2 Strengths and limitations	30
5.3 Future work.....	32
6. Conclusion	33
7. References	34
8. Appendix.....	40
Appendix A – R code calculating 60 th percentile	40
Appendix B – information forum.....	41
Appendix C – Evaluation questionnaire.....	45
Appendix D – R code piecewise linear regression	51
Appendix E – Figures steps/day and step goals.....	54
Appendix F – Figures trend lines	57

1. Introduction

Increasing physical activity (PA) is a major public health priority [1, 2]. In 2022 only 44% of the Dutch population meets the PA guidelines, this is less than in 2017, when 47% of the Dutch population met de PA guidelines [3, 4]. PA has a positive effect on an individual's health, it lowers the risk of getting different chronic diseases and improves fitness and muscle power [5, 6]. PA is also associated with a lower risk of premature death, breast- and colon cancer [5, 6]. While physical inactivity can be associated with a higher risk of developing chronic diseases [7]. For adults, moving 75 minutes per week at a moderate intensity, already has health gains [8]. Doubling the weekly moderate exercise has even more health gains. The Dutch activity guidelines emphasize, that health gains can be achieved when adults who only exercise at light intensity, increase their intensity level to moderate and heavy [5, 9]. When the recommendations are not feasible, some exercise is better than not moving [5].

Changing lifestyle behaviour is necessary to achieve the PA guidelines, but behaviour change is a complex process that often requires time, motivation and perseverance [10]. Even small behaviour changes, have health gains [11]. Self-efficacy involves an individual's ability to control and adjust his or her thoughts, emotions, and behaviour to achieve certain goals [12]. Self-efficacy is strongly associated with health behaviours, including PA [13]. Individuals with higher levels of self-efficacy are more likely to engage in higher levels of PA [14]. Three essential components of self-efficacy that have proven to be effective in supporting behaviour change in eHealth are goal setting, self-monitoring, and feedback [15, 16]. One of the behaviour change techniques that is often used in lifestyle change is goal setting [17, 18].

A notable behaviour change technique that has been the focus of a lot of research is goal setting. Goal setting is the process of defining specific, measurable, achievable, relevant, and time-bound goals to guide and motivate peoples actions towards achieving their desired outcomes [19]. While many theories in health and behaviour change incorporate goals, goal setting theory has a central focus on the nature and process of setting goals [20]. Several researches have been published on the effects of goal setting on health behaviours, including PA [21, 22]. Positive relationships with PA have been shown in goal setting interventions [23, 24]. PA guidelines serve as assigned behavioural goals that can lead to appropriate action, as proposed by the goal setting theory [11]. Goal setting theory is defined as, "what an individual is trying to accomplish; it is the object or aim of an action" [25]. Goal theory specifies moderators that are used to determine whether a goal should be set [26]. According to this theory, goals that are clear, specific, and challenging are more motivating than vague or easy goals. People who are more motivated, are more successful in hitting their goal [27]. While unachieved goals may diminish

self-efficacy [28]. Self-determined or goals set with an expert are more effective for evoking behaviour change, than given goals [22, 29]. Patient-selected goals represent a patient-centred approach to increasing PA, that is consistent with the intrinsic motivation and autonomy required by self-determination theory [30]. Studies have shown that goal setting activity is associated with more successful weight management [31-33]. Goals specifically related to PA, are more strongly associated with corresponding strategies than vague goal setting related to weight [33]. A number of studies within the behavioural medicine field have pointed to the benefits of goal setting in encouraging PA behaviour [21, 34]. Goal setting had been beneficial in relation to PA in a variety of populations and in various settings [35, 36]. Goal setting can promote PA in obese adults, supporting its use as a behaviour change technique and as a strategy in counselling obese adults [35]. Whitehead et al. concludes that goal setting in PA may be an effective strategy to support people to achieve glycaemic targets [36].

Goal setting also is an effective behaviour change technique to increase PA [35]. Goal setting techniques are often used in larger multicomponent applications, but can also be used as a primary strategy [37]. A behaviour change technique involves implementing strategies to modify or alter an individual's habits or actions towards a desired goal or outcome [38, 39]. The effectiveness of behavioural change is directly related to how far the goal is set in the future [22]. Outcome goals represent measurable health outcomes or targets that individuals aim to achieve by altering their behaviours. While the goal reflects the expected result of behaviour, it does not involve planning how the individual's behaviour will change to attain the goal [40]. While short-term, also called behavioural goals, entail the specific steps an individual plans to take to achieve their outcome goal. For instance, if someone has set an outcome goal to lose weight, a corresponding process goal might involve committing to running three times a week [41].

Outcome goals are frequently too distant and do not provide an accurate indication of progress [40]. While behavioural goals provide a fast insight into progress. Achievement of a behavioural goal can increase motivation, making small improvements provides people with successes on which they can build [42]. A study had shown that people who set specific, short term are more likely to succeed, than those who set outcome goals [42, 43].

Goal setting is one of the most used behaviour change technique in eHealth [44], this is the use of digital technologies to enhance healthcare services, including health apps [45]. eHealth interventions are increasingly becoming a popular method for delivering health programs. Using smartphone apps have the potential to improve health, because of the widespread use [46]. eHealth interventions can be used to promote PA behaviour, particularly if these tools use behaviour change strategies, such as goal setting [47]. When looking for behaviour change techniques that contribute to behaviour change

in eHealth interventions, behavioural goals was found to have an association [47]. Applications are well accepted by people and may provide beneficial effects on multiple things, such as increasing PA, thus encouraging a healthier lifestyle [48]. eHealth supports people's self-management for improving T2DM, such as promotion of PA and improving glycaemic control [49].

At the moment, many eHealth interventions include goal setting, but only static goals are used [50, 51]. Static goals are fixed and will not change the step goals, that are set to be achieved in a specific timeframe [19]. However, this does not consider whether a person is achieving their goal or not [52]. Many applications are not yet exposed to the latest research regarding personalization of goals, through adaptive goal setting. Dynamic goals are flexible and adaptable, allowing them to change based on new information [53]. Using static goals is conceptually limited in supporting behaviour change, because it overlooks past goal achievement, or day-to-day changes [53]. Static goals also do not take interindividual differences into account. Lack of adaptation may result in lack of attainment. Traditionally, goal-setting approaches for PA are fixed over time and the same across all participants in the study, everybody receives the same goal recommendation [54]. The second common approach involves using an individual's baseline level of steps as a starting point and then implementing a linear stepped increase, increasing the steps each week [52, 55]. Adaptive interventions represent a new class of behaviour change research in which it is designed to adjust for the baseline information, as well as information that is gathered throughout the intervention progress [53, 56, 57]. Providing a personalized approach, wherein treatment is continuously adjusted over time in response to the individual's evolving needs [58]. Previous studies show that an adaptive intervention can be more effective than fixed goals for increasing PA [55]. Results showed a higher rate of goal achievement in the adaptive intervention, than what would be expected on average [59].

Adaptive goal-setting techniques often employ a percentile schedule method [55, 60]. Algorithms can give personalized goals and look at previous days as of how the individual performed. One of the more widely used algorithms involves setting daily PA goals to the 60th percentile of an individual's nine most recent PA observations [55, 61, 62]. The 60th percentile schedule is used in different eHealth interventions [55, 59, 61, 62]. Adaptive goal setting aims to incrementally enhance PA performance by tailoring goal difficulty according to individual performance variations over time, the adjustment of goals can be done weekly or daily. Studies have found that adaptive goal setting improves steps per day [53, 55, 61]. In a previous study, adaptive goals contributed to a more sustainable behaviour change, than static goals [61]. A factorial randomized study, found that adaptive goals outperformed static goals in promoting moderate-to-vigorous PA [59]. Linear stepped increases are implemented weekly, while adaptive interventions are adjusted daily, complicating the comparisons due to the difference in

timeframes of the intervention adjustments and step goal settings [63]. This discrepancy makes it challenging to directly compare the effectiveness of weekly step goals versus daily step goals.

Currently adaptive interventions are relatively new and not used often in eHealth. While previous research shows that adaptive goals are more effective than static goals [64]. With adaptive step goals, the intended use is for people to get step goals in gradual increments to foster mastery experience through the achievement of goals.

The objective of this study is to make and evaluate adaptive weekly- and daily step goals. In this study a weekly adaptive goal setting intervention will be compared with a daily adaptive goal setting intervention, with the aim to find the intervention which gives the highest increase in the step count of participants. One way to increase PA is to encourage participants to walk more [65]. To evaluate the adaptive goal setting interventions the weekly- and daily adaptive step goals are compared, and the participants experience are asked.

The first research question is; Which of the adaptive goal settings, weekly- or daily step goals, is most effective in increasing physical activity?

The second research question is; What are the participants experiences with using the daily-, and weekly adaptive goals?

2. Theoretical framework

Goal setting theory

Goal setting is the theory that is applied to this research. Locke and Latham's goal setting theory emerges as the result of nearly forty years of empirical research on the relationship between conscious performance goals and task performance level [19]. A lot of experimental research had been done by Locke and Latham, in 1990 goal setting theory was formalized [19, 66]. Although the research focuses mainly on the work setting, this theory is still amongst the most used in interventions aiming at the promotion of a healthy lifestyle in general. The theory is now seen as one of the most influential frameworks in motivational psychology [67].

Goal setting theory is defined as, "what an individual is trying to accomplish; it is the object or aim of an action" [25]. Goal setting theory defends that individuals are more likely to change behaviour when a goal is higher in specificity and difficulty [19, 66]. The authors suggest that urging an individual to "do his best" is not the most effective approach. Instead, individuals should be given specific goals that reduce the ambiguity of what is aimed for [19]. Patient directed goal setting is an increasingly popular method of behavioural counselling [68]. Programs have incorporated goal setting to help patients improve their self-efficacy in for example diabetes management, to change their behaviour, and improve their health outcomes. The higher the goal, the greater the effort and self-efficacy needed to attain it. Setting proximal goals in which a difficult goal is divided into more manageable subgoals enhances the self-efficacy, as people realize progress can be made [19].

The model in figure 2.1, seen below, consists of three parts: concepts, constructs, and proposition. The concepts include key factors that affect performance, with moderators and mediators that affect the set goals [69]. The constructs indicate that the concepts have an impact on the motivation and performance of people. The proposition shows that a specific and challenging goal, combined with feedback, can increase motivation and performance, which can lead to a better performance [69]. The model aspects are described below.

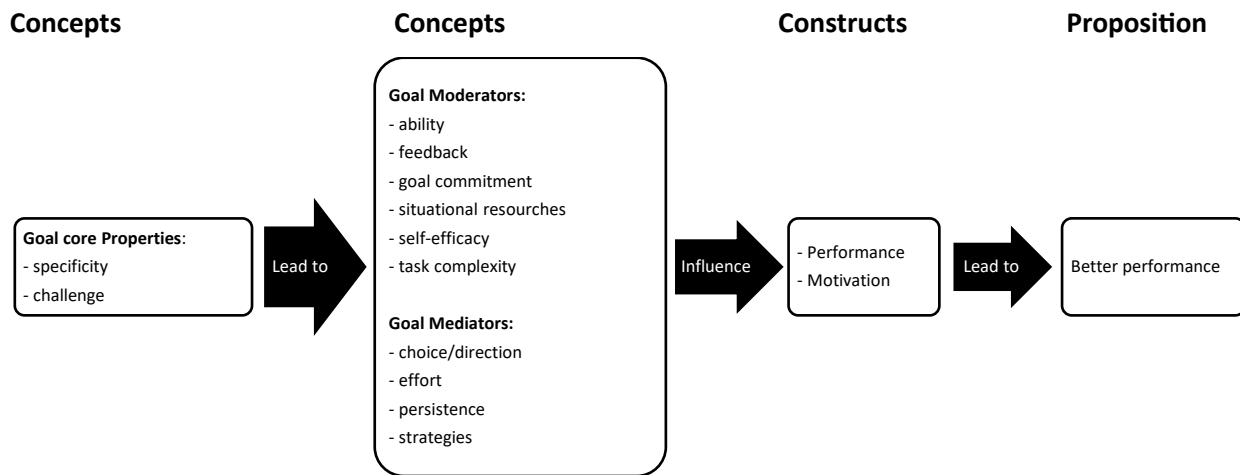


Figure 2.1 Model of goal setting theory [69]

There are some significant factors that can have an impact on a individuals' performance: Goal core properties, moderators, and mediators. Individuals that have specific, challenging, but attainable goals have better performance, than people who set vague goals [40].

For the part of the moderators, ability is whether people possess the skill or knowledge to finish a task/goal [37, 66]. Feedback is needed for people to decide whether more effort should put in or the goal needs adjustment. For example, when a goal is too hard and cannot be achieved, individuals should receive this in the feedback and make a change in effort or goal. Feedback also reveals progress to a goal, the combination of goals and feedback promotes a greater success than goals by themselves [70]. Commitment refers to the extent that an individual is attached to the goal. To achieve a high goal, a high level of commitment is needed [66]. In addition, task complexity affects goal attainment. Goals may not always prompt the selection of optimal strategies, especially for new, complex behaviours without prior training [20]. If achieving the goal doesn't rely on subconscious skills, individuals draw from past experiences and apply relevant skills. Training improves the use of effective strategies for novel, complex behaviours [37]. Situational resources, are related sources/materials needed for people to achieve their goal, this is essential. Finally, self-efficacy refers to whether people are confident in doing something, that will affect their goals and performance [66].

For the goal mediators part, choice is that people make an effort to become active when they choose to set goals. Persistence refers to how long people are willing or will stick to the goal and the time they are willing to spend on achieving their goal. Lastly, a goal needs a strategy to attain it, so it can help with decisions, resources, and operations to achieve a goal [69].

With the important factors of the concepts, people tend to have a better performance and the willingness to face new challenges is higher [20]. Lastly, the proposition of goal setting theory is that when the concepts are optimal, better performance can be a result [20].

Locke and Latham's goal setting theory plays a major role in the research to PA promotion and maintenance. Individuals setting goals for PA are often encouraged to set goals in accordance with the goal setting theory [20].

3. Methodology

To answer the research questions, an experiment was conducted and evaluated. This chapter explains how the experiment was done, who the study population was, and how they were recruited to take part in the study.

3.1 Study design

The single-case experiments design (SCED) used, is the ABC-design, figure 3.1. With a SCED individual behaviour is repeatedly measured, both in presence and absence of the intervention [71]. The repeated measures allow a participant to serve as their own control. This by starting with a baseline measurement, and later do measurements with the different goal setting approaches [71].

We began with a baseline measurement. After the baseline was measured, the weekly goals were implemented, after this approach the daily goals were implemented. With the help of this study design a comparison can be made between the baseline and intervention phase, also the interventions can be compared to each other. The total length of the experiment was 6 weeks.



Figure 3.1 ABC-design

3.2 The intervention of the goal setting approaches

For both the weekly and the daily goals the same algorithm was used. For the weekly goals, the algorithm was used once per week, while for the daily goals it was used every day.

The 60th percentile approach offers a standardized, scalable, and generalizable approach to personalized goal setting across individuals [61]. A percentile algorithm is required; 1. Continuous and repeated measurement of steps per day, 2. Ranking steps per day from low to high, and 3. Calculating a new step goal based on the 60th percentile criterion [72]. To achieve customized targets, percentile

shaping capitalizes on the normal behavioural variability. Percentile shaping also generates specific, measurable goals inherently that can be explicitly rewarded [73].

Adaptive goals could increase, decrease, or stay the same, based on a 9-valid-observation moving window capturing each participant's recent performance. Goals were calculated using the 60th percentile-rank algorithm, which was already tested in different studies [55, 59, 61]. If we score in the 60th percentile, then 60% of the values are below this score. To get the 60th percentile out of steps, a code was created in RStudio (Appendix A). This code takes the previous nine measurements of steps and calculates the new step goal.

When necessary, the value will be rounded up to the nearest multiple of 25 steps to simplify the goals and ensure that the step goals are easy to remember and achieve. The moving window incorporated each new day's steps. The new day, replaces the oldest day step count, so the most recent nine days were used.

The 60th percentile approach offers a standardized, scalable, and generalizable approach to personalized adaptive goal setting. With steps per day values unique to each individuals' performances [61].

3.3 Participants

The participants had to be healthy individuals to be included in this study. They had to study at the University of Twente between April and June 2024, to be included.

3.4 Sample Size

For a SCED ABC-design, between 3 and 6 participants needed to be included [74]. Included in this study were 5 participants, expected was that this would be enough for the data analysis. Because of the use of the SCED, patients were their own control group, this made it possible to include fewer participants, than for example with a randomized controlled trial.

3.5 Procedure

The experiment was carried out from April to June 2024. Participants were recruited through the researcher. The researcher recruited, through sending messages to contacts.

When the information form was read and informed consent (Appendix B) was filled in and accepted, the researcher planned a meeting to give the participant the Fitbit charge 4 or Fitbit inspire 2 and give the login details. Participants incurred no cost to use the activity tracker and/or application.

Participants were instructed to track their steps during waking hours, when they started the program. Participants started with the baseline measurement of 9 to 14 days, followed by the weekly goals of 14

days, followed by the daily goals of 14 days. Participants were excluded from the study, when they did not go through all the stages of the experiment. To collect all the data, participants had to open the Fitbit app once per day, so the step data could be uploaded. Figure 3.1 shows the procedure in short. In this study all data was manually put into an excel sheet and after this was done the r-code was run by the researcher. This was done every day. When the data was put in, the step goals were send weekly or daily by the researcher. These were send via WhatsApp to the participants. The messages were send early in the day, so the participants could still work on their goals.

Baseline measurement (A)

The baseline phase, during which no intervention was applied, lasted between 9 and 14 days. The participants began data collection in week 17, at a day that was convenient for them, ensuring they could commit to the study protocol. On this day, the researcher set up the Fitbit and participants were instructed to wear it during active hours. This period served as the a priori baseline, providing a stable measure of the participant's typical activity level before any intervention was introduced.

Weekly goals (B)

Following the baseline measurement participants began to use the first goal setting approach. Participants got weekly goals for two weeks. Before starting, the participants received a message, explaining the intervention. The goals were assigned, and could not be adjusted, on Mondays the weekly goals were send to the participants before 9:30 AM. So they could start working on their goal that Monday. They could see their daily progress in the Fitbit app. In the weekly goals the participants received the same daily goal for a week, based on their performance the previous nine days. The 60th percentile schedule is used to create these step goals.

Daily goals (C)

After using approach 1 for two weeks, the participants had to use goal setting approach 2. Participants' got the daily goals for two weeks. Before starting, the participants received a message, explaining the second goal setting approach. The goals were assigned and could not be adjusted, each day the goals were send to the participants before 9:30 AM. So they could work on their goal throughout the day. They could see their daily progress in the Fitbit app. In the daily goals 2 the participants received a new step goal every day, based on their performance in the previous nine days. The 60th percentile schedule is used to create these step goals.

3.6 Data Collection

Physical activity

To measure the PA of the participants, the Fitbit Charge 4 was used to measure steps. The primary outcome were steps recorded by the activity tracker. This was also compatible with the Fitbit

application. Participants could always see visual feedback in the Fitbit app. The activity tracker provided by the researcher, was the Fitbit charge 4. The Fitbit uses a 3D accelerometer capable of accurately measuring steps [75]. At first all the participants wore the Fitbit charge 4, in week 3 of the experiment the Fitbit of two participants broke. So they received another Fitbit a week later. The data collection of these participants, stopped when the watch broke and continued a week later, when they received the new Fitbits. The Fitbits they received were the inspire 2 or inspire 3. These Fitbits mainly work the same as the Fitbit charge 4. All three the watches used an 3D accelerometer, to measure steps [75-77].

The Fitbit Charge 4 is reliable when measuring steps, while walking [78]. However, the Fitbit overestimated the step count consistently compared to other watches and counting steps. A study has shown, that error increases when more steps are recorded. This aligns with a literature review, which discovered that various Fitbits tend to underestimate in controlled laboratory settings and overestimate in real-world free-living conditions [79]. Because the overestimation is consistent, the researcher does not foresee a problem in using the Fitbit. In this experiment, PA was measured through steps per day.

Goal

In the goal setting approaches, the step goals will not be marked as achieved or not achieved. The 60th percentile approach, uses a moving window of nine days. When a goal is not achieved, this approach takes this into account, and the next step goal will be adjusted accordingly. Step goals are a continuous outcome.

Self-efficacy

To measure self-efficacy, the SCI Exercise Self-Efficacy Scale (ESES) was used [80]. This questionnaire assesses self-efficacy in PA and is known for its high internal consistency and validity. The ESES is available in Dutch [81] and consists of ten items that evaluate self-confidence in PA. The assessment employs a four-point Likert scale with the anchors: “1. not at all true,” “2. rarely true,” “3. sometimes true,” and “4. always true” [80]. The outcome is a total score obtained by summing the individual item scores, yielding a possible range from ten to forty, where a higher score indicates greater self-efficacy.

Demographics

In the questionnaire, multiple demographics were asked, to identify choices that are made. The demographics that were asked are, gender (male, female, different, or I rather not say) , and age (17-, 18-20, 21-29, or 30+).

Questionnaire

The questionnaire was created to assess the weekly- and daily goal setting. The descriptive part of the study consisted of an evaluation of participants' preferences towards an intervention. In the questionnaire, participants rated the intervention on experience and effectiveness (Appendix C). This was done to evaluate the intervention. The Likert scale was used to rate different statements for the goal setting approaches. When responding, the participants specify their level of agreement or disagreement on a symmetric agree-disagree scale [82], in this survey a five-level format was used.

The participants filled in an questionnaire made by the researcher. The questionnaire was done after the participant completed the experiment. For the weekly goals, three questions were created, that could be rated with the Likert scale and two open ended questions were created. The questions were about the achievability, motivation, and frequency of the weekly steps. For the open ended questions, it was asked what the most and least appealing was about getting weekly goals. For the daily goals the same questions were used and an extra question was added, which was about the varying difficulty of the daily goals. At the end of the questionnaire the preference of the participant was asked. The first question was about liking this personalised goals more, than other methods. Then the choice had to be made between weekly- and daily goals. At the end an open ended question was asked, why they liked this particular frequency more.

3.7 Analysis

Physical activity

The primary outcome was the difference between groups in the change in steps per day from baseline to the weekly- and daily goal setting approaches. Mean, median, and standard deviation were calculated as the total number of steps taken for every goal setting approach.

The weekly and daily step goals were analysed by creating a figure for each participant, in which the steps per day and the received goals could be seen.

Using a piecewise linear regression, the data was analysed for each participant. The code can be seen in Appendix D. With the piecewise linear regression, the trend lines for each participant was calculated, with this the regression coefficients of each participant was calculated. These trend lines were put into a table and also made visually with a figure for each participant. This was done separately for all participants.

Afterwards, a hierarchical piecewise linear regression was used to compare all the participants with each other and the baseline measurement. This calculated the intercept, trend, level and slope for the weekly step goals, and the level and the slope for the daily step goals. In this analysis, a p-value was given. When it was below 0.05, it was proven to be statistically significant. The model includes random

intercepts for each participant to account for individual variability. The variance of random intercepts, reflects the variation in baseline step counts across participants. The residual variance represents the unexplained variability in step counts within participants after accounting for the fixed effects.

Then another hierarchical piecewise linear regression was done, for comparing the weekly and daily goals with each other. In this comparison the same regression code was used, only the baseline measurement was removed from the dataset.

The data was analysed using RStudio, and the code was written with the help of the book; “Analyzing Single-Case Data with R and Scan” [83].

Goals

To observe the goals and steps per day, figures were made for each participant. In which the researcher could see the difference between goals given and steps per day.

Self-efficacy

For all the participants, the self-efficacy number was calculated. By adding the points of each question, then the mean and standard deviation was calculated. The maximum score possible was 40 points and the minimum score was 10 points.

Demographics

In the demographics section, participants' responses to questions about gender and age were collected and organised into a table, displaying the frequency (N) and percentage distribution of their answers.

Questionnaire

After the questionnaires were completed, it was analysed to create a group score. With a score of 1 given to “strongly disagree” and 5 was given to “strongly agree”, this score was given per statement. It was observed which answer was most frequently given, and the mean and standard deviation was calculated. Afterwards a bar chart was made, for the weekly goal questions, daily goal questions and the comparison questions.

3.8 Ethical considerations

During this study in which participants participated, some ethical considerations had to be made. In particular, the anonymity and burden on the participants were important considerations. Individuals interested in participating in the study, were instructed to contact the researcher. The individuals were

provided with more information, through an information forum (Appendix B), about the study and the questions regarding the study were answered by the researcher. If the individuals wanted to participate, they could fill in the informed consent form, which was attached in with the information forum. Enrolment was on a voluntary basis, and the participant had to right to stop the experiment at any time. Thus, the law on privacy was observed. The participants got a premade Fitbit account, by the researcher.

Furthermore, the study was approved by the Ethics Committee of the University of Twente. Sensitive information was saved on the p-drive of the University of Twente.

4. Results

In total, six participants participated in the single-case experiment and five completed the baseline measurement, the goal setting approaches and the evaluation. One participant stopped in the weekly goals. Participant 2, had problems with the Fitbit in week 19, because of this, the experiment was a week longer, than for the other participants. So, all the data could be collected.

Two out of five participants were male and four out of five participants were in the age category 21-29 years. Of the five participants, three had a baseline of 10 days, the other two had a baseline of 12 days. The self-efficacy mean is 36.2.

In total there were six days of missing data, because the Fitbit was not worn or not charged. Phase B, the weekly goals, had the most missing data. Three days of data were missing, because three different participants each had one day of no data.

Table 1 Characteristics of participants and missing data

CHARACTERISTICS	N = 5
MALE; N (%)	2 (40)
AGE CATEGORY 21-29; N (%)	4 (80)
AGE CATEGORY 18-20; N (%)	1 (20)
SELF-EFFICACY; MEAN (SD)	36.2 (1.48)
MISSING DATA	
PHASE A; (%)	1 (1.85)
PHASE B; (%)	3 (4.29)
PHASE C; (%)	2 (2.86)

4.1 Steps per day

4.1.1 Group results

Hierarchical Piecewise Regression Analysis

The intraclass Correlation Coefficient (ICC), was found to be 0.142, indicating that approximately 14.2% of the variance in total steps per day is attributable to differences between participants steps/day. This suggests moderate within participant consistency over time. The likelihood ratio test yielded a value of 18.6, with a highly significant p-value of 0.000. This indicates that the model fits the data well.

The fixed effects in the model include the overall intercept, the trend during the baseline phase (mt), the level changes in the weekly and daily goals, and the slope changes in weekly and daily goals. The intercept represents the average number of steps per day at the beginning of the baseline phase, with a standard error (SE) of 1857.813. The trend (mt) during the baseline phase indicates a non-significant decrease in steps per day over time, because the confidence interval (CI) includes zero.

The level change from the baseline to the weekly goals ($B=2088.931$) shows an increase in steps, but this change is not statistically significant, because the CI includes zero. The level change from the baseline to daily goals (5295.089) indicates an increase in steps, though this change is not significant, because the CI includes zero, it can also be seen in the p-value (0.308) which is above 0.05 , indicating non-significance. The slope change in the weekly goals ($B=482.027$) suggest an increase in the rate of steps per day, which is non-significant, because the CI includes zero. The slope change in the daily goals ($B = 638.414$) is significant (CI lower; 43.144 , CI upper; 1233.684), because it does not include zero at the 95% confidence level, suggesting a meaningful increase in the rate of steps per day.

Table 2 Results Hierarchical Piecewise Linear Regression with comparison to the baseline

Effect	Estimate	Standard Error	p-value	95% CI lower	95% CI upper
Intercept	12045.764	1857.813	0.000	8352.231	15739.297
Trend baseline	-317.497	248.854	0.204	-806.145	171.151
Level weekly goals	2088.931	2146.458	0.332	-2127.096	6305.958
Level daily goals	5295.089	5181.621	0.308	-4861.108	15451.268
Slope weekly goals	482.027	305.220	0.116	-116.183	1080.237
Slope daily goals	638.414	303.607	0.037	43.144	1233.684

The significant intercept indicates a high baseline number of steps taken per day, by the participants. There was no significant trend over time (CI lower; -176.668 , CI upper; 498.804), indicating that the number of steps taken did not change significantly during the observation period. A decrease in steps taken in the daily goals (-3499.750) can be observed in table 3. There is no significance in the level or slope of the daily goals, as the CI includes zero, and the p-value is above 0.05 .

Table 3 Results Hierarchical Piecewise Linear Regression comparing weekly with daily goals

Effect	Estimate	Standard Error	p-value	95% CI lower	95% CI upper
Intercept	10715.748	1861.313	0.000	7070.996	14360.500
Trend weekly goals	161.0668	171.932	0.351	-176.668	498.804
Level daily goals	-3499.750	1951.144	0.075	-7326.947	327.447
Slope daily goals	161.637	241.482	0.504	-314.652	637.926

4.1.2 Individual results

Regression Coefficients

Table 4 regression coefficients

	Trend baseline	Trend weekly goals	Trend daily goals
Participant 1	-1136.836	61.947	224.099
Participant 2	-217.77	400.499	174.262
Participant 3	-524.473	260.525	587.91
Participant 4	-172.913	489.642	72.426
Participant 5	-271.638	-432.372	559.968

In table 4 the trend of the different slopes per participant can be seen. In the baseline trend, every participant had a decrease in steps/day. Giving a difference between the baseline and the daily and weekly goals. All participants showed an increase in steps in the daily step goals, while in the weekly step goals participant 5 had a decrease of 432.372 steps/day. Only participant 2 had a smaller increase in steps in the daily goals (174.262), then in the weekly step goals (400.499). For a visual representation of table 4, Appendix F shows figures with the Trend lines per participant.

Descriptive statistics

Table 5 shows the mean, median, and standard deviation of the baseline (A), weekly goals (B), and daily goals (C). Participant 1 has a mean of 8801.8 steps per day and participant 3 has a mean of 12407.6 steps per day in the baseline (m.A.), comparing this to the weekly- and daily goals, it is seen that mean the steps per day in the weekly and daily goals are below the mean of the baseline. While participant 4 had a mean of 8003.917 steps per day and participant 5 had a baseline of 12234.27 steps per day. The weekly and daily goals had a mean of 10756.6 (m.B), and 10407.71 (m.C) for participant 4, and 14307.46 (m.B.) and 17249.85 (m.C) for participant 5.

In the median, table 5 shows that the baseline (md.A) was with none of the participants the highest median. Participants 1, 2 and 4, median was 8993, 13803 and 9848 steps per day in the weekly goals (md.B), in comparison with 6008, 13379, and 9644.5 steps per day in the daily goals (md.C). For participants 3 and 5 the median in the weekly goals was 10126 and 14568 steps per day (md.B), in comparison to the daily goals with 10373 and 14740 steps per day (md.C).

The standard deviation is varying a lot per participant and phase. Participants 1 and 3 had the largest standard deviation in the baseline, with a deviation of 8827.738 and 8929.431 (sd.A). While weekly goals and daily goals for participant 1 had a standard deviation of 3703.349 (sd.B), and 3602.44 (sd.C), and participant 3 had a standard deviation of 4584.617 in the weekly goals, and 4439.116 in

the daily goals. Participants 2,4, and 5 had the lowest standard deviation in the baseline, 3977.702, 2907.585, 3964.313 (sd.A). For participant 2 the standard deviation was higher in the weekly goals (5965.761), than in the daily goals (5953.671). While for participants 4 and 5 this was the other way around, with the standard deviation of the weekly goals being 5230.082 and 7451.661, and the daily goals being 6430.679 and 8338.425.

Table 5 descriptive statistics of the mean, median and standard deviation for each participant

	m.A¹	m.B²	m.C³	md.A⁴	md.B⁵	md.C⁶	sd.A⁷	sd.B⁸	sd.C⁹
Participant 1	8801.8	8041.231	6047.5	5531	8993	6008	8827.738	3703.349	3602.44
Participant 2	11309.6	15292.64	13179.85	12277.5	13803	13379	3977.702	5965.761	5953.671
Participant 3	12407.6	10335	10964.79	10216	10126	10373	8929.431	4584.617	4439.116
Participant 4	8003.917	10756.64	10407.71	8580	9848	9644.5	2907.585	5230.082	6430.679
Participant 5	12234.27	14307.46	17249.85	12545	14568	14740	3964.313	7451.661	8338.425

Weekly step goals

With three out of the five participants the weekly step goals became significantly higher with the second step goal they were given, which can be seen in table 6. Specifically, in the second week of the weekly goals, the step goals for participants 1, 3, and 5 increased with 2000 or more steps. Indicating that they achieved their previous step goals. Participant 2 and 4, showed a slight decline in their second step goal. Indicating that they did not achieve their previous step goal. In Appendix E, the figures for every participant can be seen, below in figure 4.1 participant 5 can be seen.

¹ Mean of the baseline

² Mean of the weekly goals

³ Mean of the daily goals

⁴ Median of the baseline

⁵ Median of the weekly goals

⁶ Median of the daily goals

⁷ Standard deviation of the baseline

⁸ Standard deviation of the weekly goals

⁹ Standard deviation of the daily goals

Table 6 weekly step goals per participant

Weeks in the weekly step goal approach	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
1	4925	13425	11000	9900	12450
2	8100	13300	13000	9450	14750

In figure 4.1, when giving the first step goal (start of phase B), participant 5 achieved the goal most days. When increasing the goal after a week, it can be seen that it became harder for the participant to achieve the step goal.



Figure 4.1 Participant 5 steps/day and step goals

Daily step goals

The participants progressed to the daily goals. The step goals are varying day-to-day. The standard deviation in participants 4, and 5, is higher in the daily goals (6430.679, 8338.425), than in the weekly (5230.082, 7451.661). The figures of the daily step goals, show that 4 out of the 5 participants got a higher goal after the weekly goals, which can be seen in appendix E. Only participant 3, received a lower goal after the weekly goals. Table 7 shows that participants 1 through 4 step goals, declined after the first day, for example participant 2 started with a daily step goal of 16175, the second step goal was 15025. In the table it can be seen that the participants could get the same daily step goal for multiple days, for example participant 1 had a step goal of 7800 steps from day 7 to 12. A visual representation of the daily step goals can be seen in appendix E.

Table 7 daily step goals per participant

Days in the daily step goal approach	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
1	9375	16175	10575	10850	15400
2	9075	15025	10150	10125	15400
3	6400	14400	10575	10125	17200
4	4925	14400	10025	9775	15750
5	5575	13900	8950	9650	15500
6	8100	13875	10750	10075	13400
7	7800	13925	11125	11875	13300
8	7800	13925	10600	13375	13300
9	7800	13900	10700	11875	15500
10	7800	15800	11125	11875	13075
11	7800	15800	10900	10925	13800
12	7800	15800	10900	8700	14575
13	6425	15800	10900	12425	12600
14	6425	15175	11550	12675	18075

Figure 4.2 shows the results of participant 1. The arrow points at the first day in the daily goals approach, after that the step goals become lower. All participants first received decreased step goals, before they increased later on. In Appendix E the figures of all participants can be seen.



Figure 4.2 Participant 1 steps/day and step goals

4.2 Questionnaire

Weekly step goals

In figure 4.3 the three statements can be seen. The first statement has a mean of 3.2 and the standard deviation is 0.84. The mean shows that it is a little higher than the “neither agree nor disagree” statement. For the second statement the mean is 3 with a standard deviation of 0.71. Suggesting that “neither agree nor disagree” was the most frequently answered by the participants. The third and last statement of the weekly goals, has a mean of 3 with the standard deviation of 1. Also suggesting that “neither agree nor disagree” was most frequently answered by the participants.

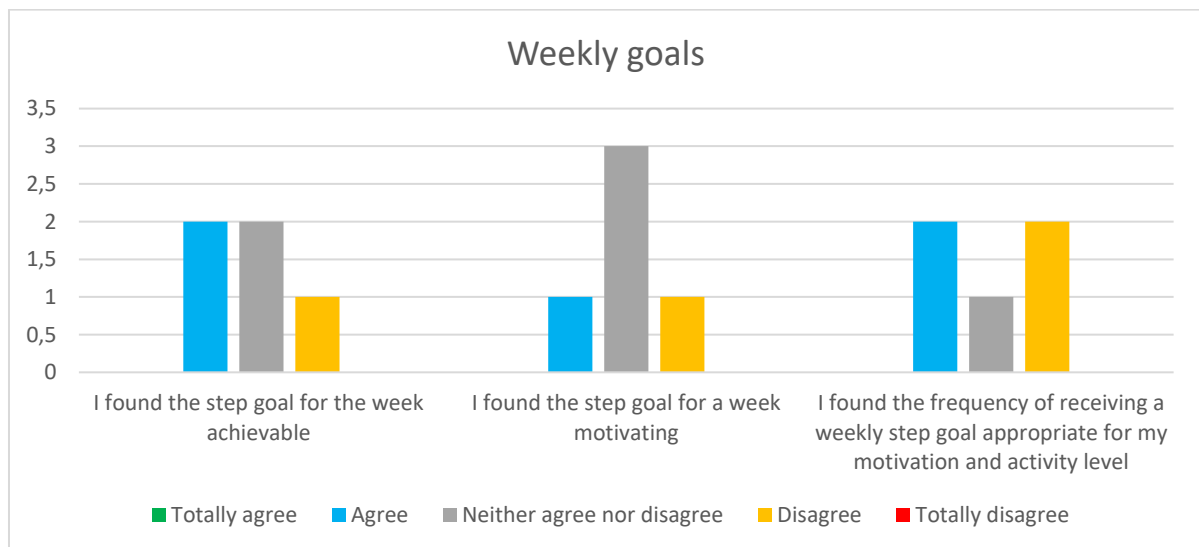


Figure 4.3 Questionnaire answers weekly goals

At the end the participants gave their opinion on what the most and least appealing in getting weekly step goals was. Starting with most appealing, participants 2 and 3 answered that they found the goal motivating, participant 3 stated, “I didn’t want to miss my goal too often, so this motivated me to walk extra.” Participants 1 and 4 found the stability of knowing their goal positive, with participant 1 stating, “I knew where I stood every day, I liked this stability.” Participant 5 found the weekly goals achievable. Participants found the frequency less appealing, three of the participants found this gave less variation in their goals, with participant 1 stating, “I found it less chill that there was no variation between the different days. I take more steps on days when I exercise and this is not taken into account, for example.” Participants 2 and 3 found their goal not achievable, because their goals were found to be too high, with participant 3 stating, “I had a very high goal one week because of an exceptionally active day, which makes it difficult to achieve goals on days when you don't have much time to walk.”

Daily step goals

In figure 4.4 the four daily statements can be seen. The first statement has a mean of 3.2, with a standard deviation of 0.84. The mean shows that it is a little higher than the “neither agree nor

disagree” statement. The second statement has a mean of 4.2, with a standard deviation of 0.45. Suggesting that most participants agree with this statement. All participants agreed with the third statement resulting in a mean of 4 and standard deviation of 0. The fourth and last statement of the daily goals has a mean of 4 and standard deviation of 1.22. The standard deviation shows that the opinions of the participants differed from each other.

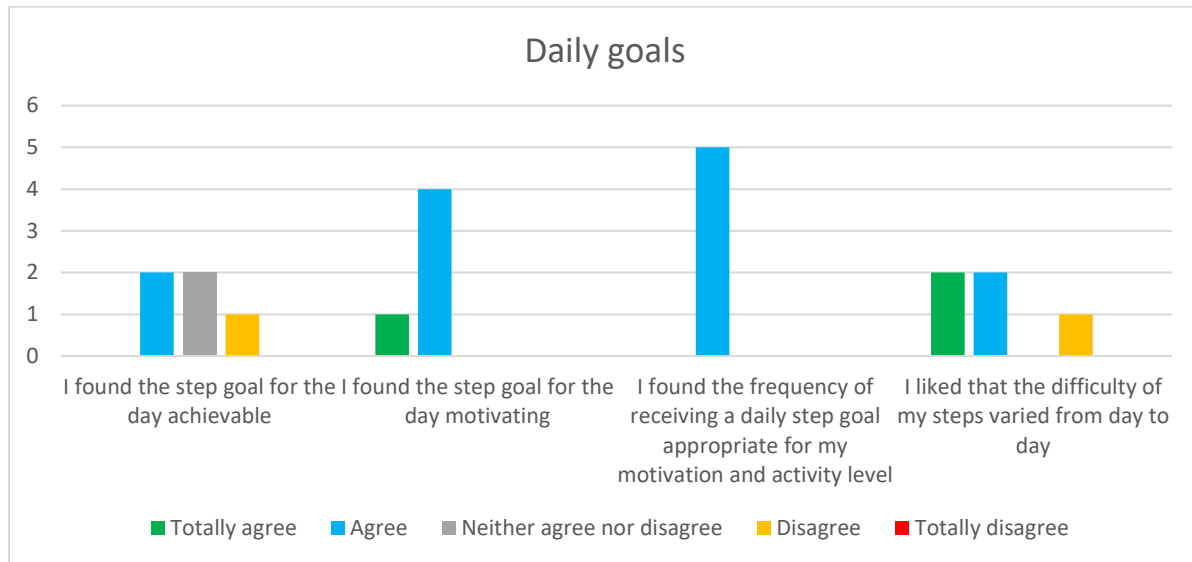


Figure 4.4 Questionnaire answers daily goals

At the end the participants gave their opinion on what the participants found the most and least appealing in getting daily step goals. The most appealing for three out of the five participants, was the variation of the goal every day, with participant 1 stating, “I liked that my step goal was adjusted (often downwards) if, for example, I was sick for a day.” Participants 2 and 5 found the frequency of the messages of the step goals most appealing with participant 5 stating, “That I thought about it every day! And even in the morning I thought about how I was going to take so many steps that day, so I included it in my daily planning.”

Four out of the five participants found the least appealing aspect to be that the goals were not always achievable. Participant 2 expressed this by saying, “The goal was very high, which made it difficult to achieve on some days.” Participant 3, however, found that the step goals were more easily forgotten.

Comparison

The first statement, “I find getting step goals personalized for me more appealing than other methods I know of.” All participants agree, that the goal setting approaches are more appealing than other methods. Four out of the five participants, “agree” with the statement, participant 5 totally agrees, giving a mean of 4.2 and a standard deviation of 0.44. Four out of the five participants had a preference to the daily step goals. With the reasoning that the goals variate more on a day-to-day basis, participant 3 stated “It adapts a little more to my previous days and I felt just a little more challenged to move.”

Another reasoning is the frequency of the messages for the step goals, which was daily in the daily step goals, for example participant 5 stated, “It makes it more topical every day and it also feels more like a challenge from myself to do better than the day before. I was much less concerned with the weekly goals.” Participant 4 liked the weekly step goals more stating; “I like the stability more.”

5. Discussion

This study aimed to evaluate adaptive interventions using weekly and daily step goals. To find which adaptive step feature the participants' enhanced PA, and was found to be encouraging in increasing the PA levels.

5.1 Principal findings and explanations

The hierarchical piecewise linear regression model reveals several important findings about the impact of the goal setting approaches on PA. The high intercept, suggests that participants were already very active from the start. The non-significant trend during the baseline, suggests little change in PA before the goal setting approaches. The level and slope change to the weekly goals, show a positive, but non-significant increase in step counts. In the daily goals, the level change shows a more pronounced but non-significant increase in step count, compared to the baseline. The slope change in comparison with the baseline during the daily goals is significant, indicating that participants continued to increase their step count, suggesting sustained behaviour change. The results suggest that the daily goals particularly had a positive impact on PA. This finding is important as it indicates that the intervention influenced immediate behaviour change, this is in line with literature of daily adaptive goals [61]. The non-significant trends and level changes during the goal setting approaches suggest that immediate changes in PA might require more intensive or longer usage to become statistically significant. Another reasoning could be, that because of the high baseline measurements, the participants started higher, which could make it harder to see an effect. Literature supports that a high baseline measurement can make it harder to see an effect, participants starting with higher initial levels of PA, may experience smaller gains [84, 85]. This observation aligns with findings from previous research, indicating that long-term or more intensive PA interventions are often necessary to produce significant and sustained changes in PA levels [86]. Because there was no follow-up in between and after the goal setting approaches, the long-term effects per goal setting approach cannot be seen. The lack of follow-up measurements limits the ability to assess the sustained impact over time, literature indicates that follow-up assessments are crucial for understanding the maintenance of behaviour change and the long-term efficacy of interventions [87].

The moderate ICC and significant random intercept variance, highlight that participants responded differently to the intervention. This variability suggests that personalized or tailored interventions might be more effective, than one-size-fits-all approaches. Personalised interventions, which take into account individual differences and provide tailored feedback, have been shown to be more effective in increasing PA, compared to standardized programs [88]. The 60th percentile is already personalized per participant, but exploring giving people a choice in step goals, could influence individuals responses.

This could be done, by including self-efficacy in the goal setting approach. While previous research showed that giving participants an option of choosing their own goal, is more useful than giving a goal [89, 90]. This was not included in this study, because firstly the 60th percentile schedule and the frequency was tested. Now for future use of this goal setting feature, the inclusion of giving people an option, should be included. Previous research showed that people reacted more positively, when being included in the decision [91]. Including this, could be done in a simple way, so could participants get a choice between the normal 60th percentile outcome, or multiplying the 60th percentile outcome with 1.2, to give a more challenging goal, or multiply with 0.8 to give an easier goal.

The participants generally show different patterns of change in mean and median steps across the phases. While some participants exhibit an increase in PA during both interventions (e.g., participant 5), while others show more complex patterns with initial increases followed by declines (e.g., participant 1). The standard deviation data indicates varying degrees of consistency in participants' step counts. The mixed results highlight that while the goal setting appears to be effective for some participants, it may not have the same effect for others [19], or the effect may diminish over time. Research indicates that the effectiveness of goal setting interventions for increasing PA may diminish due to various factors, one reason being the initial enthusiasm and motivation, which could wane as participants face challenges [92]. The increases in steps during the daily goal setting approach, could suggest that the approach has positive effects on PA. The variability in responses underscores the importance of considering individual differences when designing and implementing the daily- and weekly goals, these results are consistent with literature found [93, 94].

In the baseline measurement the participants wore the Fitbit for around 1.5 weeks, a decline in PA can be seen, while they had a chance of self-monitoring with the Fitbit app. Literature suggests that giving participants Fitbits could initially motivate users to be active during the first week of wearing [95-97]. An Fitbit makes people more aware of their steps, whereas people subconsciously give themselves goals to achieve, thus becoming more active [97, 98]. In this case, it is most likely not due to the longer duration of wearing the Fitbit, but rather because the measurements included public holidays. The public holidays included in the baseline were king's day and liberation day. The steps were much higher than you would expect on a normal day. This was at the beginning of the experiment, making the beginning of the slope very high. This could be an explanation why the slope is decreasing. The trend during the weekly goals are predominantly positive, indicating that the weekly adaptive goals had a positive effect on PA levels. The positive trends in the daily goals for all participants suggest that the daily adaptive goals had a positive effect on PA levels. Participants were longer in the experiment, which could explain the enhanced trend lines.

Making a comparison with previous studies done on adaptive interventions, the results of this study are in line [61, 64]. In these studies it is indicated that participants receiving individualised goals, saw an increase in the number of steps walked [59], which was also the case in this experiment. Initially this was smaller than with static goals, but the participants with the adaptive goals were able to maintain their walking behaviour. What could be seen is that the daily goals increased PA more, than in the baseline measurement, which is in line with previous studies, that saw an increase in PA that was greater in the adaptive intervention than with static goal setting [60]. Another study saw a significant increase in the daily steps ($p < 0.01$) [53], from the baseline, in this experiment the slope of the daily steps was significant ($p = 0.037$) compared to the baseline. In the comparison of the weekly step goals to the daily step goals, both the trend as the level effect were non-significant ($p > 0.05$), which could indicate a variability in response to the intervention.

The evaluation results indicated that daily goals were more motivating for participants than weekly goals. The higher frequency of daily goals provided a constant reminder and helped participants stay focused on achieving their targets. A key issue was highlighted with the weekly goals, participants noted that it did not integrate seamlessly into participants' daily routines, because of the frequency of the messages. This discrepancy is understandable since participants received a new goal and reminder message every day with daily goals, whereas weekly goals only came with a message at the start of the week. Literature discusses the importance of frequency in goal-setting and habit formation, highlighting that daily goals are more likely to be integrated into day-to-day life [99, 100].

However, the feasibility of both daily and weekly step goals posed challenges. In both cases, goals could become too high, which some participants found demotivating, literature also states that high goals are found to be demotivating [19, 101]. Despite this, participants unanimously agreed that the method of setting goals used in the study was more attractive than other methods they had encountered. The most preferred the daily goal frequency, citing that receiving daily messages was more motivating. Unlike the weekly messages, daily updates provided continuous adaptation and a sense of daily challenge, which helped participants feel more engaged and encouraged to stay active. This is also supported by literature, studies found that frequent, smaller goals were more effective and motivating for participants [102].

5.2 Strengths and limitations

Strengths

One of the strengths of using a SCED, is that it allowed for a detailed and nuanced analysis of individual participant responses. This level of granularity provides rich data on how each participant reacted to

the intervention, highlighting individual differences that might be obscured in group-level analysis [71]. The SCED offered flexibility in the implementation of the goal setting approaches. It gave the ability to tailor the approaches to the needs of each participant and to adjust the study design based on the ongoing data collection. This enhanced the relevance and applicability of the findings to real-world settings. By employing a phased approach, the study can clearly illustrate relationships between the approaches and changes in step count. The focus of the study on practical, daily step count makes the findings highly relevant and easily translatable to everyday life. This practical focus enhances the potential impact of the study on public health practices and interventions aimed at increasing PA. Another strength is that in addition to the quantitative data, qualitative feedback from the participants was included. Providing a deeper understanding of their experiences, preferences, and challenges. This could be compared with the quantitative results, thus creating an insight for refining and improving the goal setting approaches.

Limitations

The measurements of the steps were not always valid, because other activities were sometimes measured as steps. Therefore, step goals became higher, even if the participant was not walking a lot the previous day. This made some goals unattainable to reach, making participants feel unmotivated [19]. An option to improve this in the future is to set a limit on how high the goal can get. So when the baseline measurements are taken, the mean could be calculated, and the maximum goal could be set as the mean steps plus an additional 2000 steps. This aligns with the recommendations from literature, which emphasize the importance of setting realistic and attainable goals [103]. Another option could be to give people the option to choose between several step goals, thus not giving people unattainable goals.

Another limitation of this study is that the participants, are all healthy people studying at the University of Twente. This limits the generalizability of the findings. The results observed in this study may not be representative of the broader population. In this study healthy individuals were included, thus the demographics of this study are not representative of the population who would end up using this approach. The population which would benefit the most from this goal setting approach, would be people in need of improving PA. This particular research also had a short duration. Which made it insufficient to observe long-term effect of these approaches. Looking at previous studies, long-term behaviour change is indicated [53, 61], but because there is no follow-up after the goal setting approaches in this study. It cannot be proven, with only this study.

While step count is a clear and measurable outcome, it might not capture the full scope of PA and the benefits. Step goals might not be applicable to all individuals or types of PA. People with different health

conditions or preferences might not find step goals motivating or relevant [104]. This could limit the goal setting approach's applicability.

5.3 Future work

This study included only a small sample size of healthy individuals and was of exploratory nature. To enhance generalizability of the goal setting approach, further research with a larger sample size and people with low PA is necessary. This study had healthy people who already walked a lot, this made improving PA not a priority for this group. Implementing this in an eHealth application, in which increasing PA is the aim. So it can benefit people who are in need of lifestyle change.

In future research there should be looked into automating the analysing of the step goals. For this small experiment, it was doable to manually do this, but when including a larger sample size, automating this process will be necessary to make larger experiments possible.

In this study it was chosen to only include step goals. For future research it would be interesting to look at other goals, such as activity minutes. When different sports can be included, the goals would be achievable for a larger variety of people. This way sports like, biking, swimming, etc. will also be taken into account, through active minutes.

6. Conclusion

This study aimed to evaluate adaptive interventions using weekly- and daily step goals to enhance physical activity (PA) and find the approach which was found to be encouraging in increasing PA levels. In comparing the effectiveness of weekly versus daily step goals, the hierarchical piecewise linear regression analysis only revealed a significance in the slope change of the daily goals. Implying that daily goals are more effective in increasing the rate of steps per day compared to weekly goals. Thus, setting daily goals appears to be an more effective strategy for increasing PA.

Key conclusions of the evaluation include that daily step goals provided consistent motivation and immediate feedback, which helped participants stay focused on their daily PA. Weekly step goals offered greater flexibility with the variety in daily schedules. Both daily and weekly goals were sometimes perceived as unachievable. However, the regular frequency of daily goals was preferred by participants for maintaining motivation. The regression coefficients support this finding, seeing a higher step increase in the daily goals, in comparison to the baseline and weekly goals.

7. References

1. Polgreen LA, Anthony C, Carr L, Simmering JE, Evans NJ, Foster ED, et al. The effect of automated text messaging and goal setting on pedometer adherence and physical activity in patients with diabetes: A randomized controlled trial. *PLoS One*. 2018;13(5):e0195797. doi: 10.1371/journal.pone.0195797.
2. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, Lancet Physical Activity Series Working G. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*. 2012;380(9838):219-29. doi: 10.1016/S0140-6736(12)61031-9.
3. Centraal Bureau voor de Statistiek, 2023. <https://www.cbs.nl/nl-nl/nieuws/2023/37/ruim-4-op-de-10-volwassenen-bewegen-voldoende>.
4. Loketgezondleven: Cijfers en feiten sport en bewegen. <https://www.loketgezondleven.nl/gezondheidsthema/sport-en-bewegen/cijfers-en-feiten-sport-en-bewegen> Accessed.
5. Gezondheidsraad. Beweegrichtlijnen 2017. Den Haag: Gezondheidsraad; 2017.
6. Weggemans RM, Backx FJG, Borghouts L, Chinapaw M, Hopman MTE, Koster A, et al. The 2017 Dutch Physical Activity Guidelines. *Int J Behav Nutr Phys Act*. 2018;15(1):58. doi: 10.1186/s12966-018-0661-9.
7. Netherlands HCot. Sedentary behaviour and risk of chronic diseases. In: Netherlands HCot, editor. *Gezondheidsraad2017*. p. 26.
8. Bajpeyi S, Tanner CJ, Slentz CA, Duscha BD, McCartney JS, Hickner RC, et al. Effect of exercise intensity and volume on persistence of insulin sensitivity during training cessation. *J Appl Physiol* (1985). 2009;106(4):1079-85. doi: 10.1152/jappphysiol.91262.2008.
9. Gezondheidsraad. Richtlijnen goede voeding voor mensen met diabetes type 2. In: *Gezondheidsraad, editor.2021*.
10. Kenniscentrum Sport & Bewegen, 2016.
11. Szymczak H, Keller L, Debbeler LJ, Kollmann J, Lages NC, Gollwitzer PM, et al. An Increase in Vigorous but Not Moderate Physical Activity Makes People Feel They Have Changed Their Behavior. *Front Psychol*. 2020;11:1530. doi: 10.3389/fpsyg.2020.01530.
12. Blom V, Drake E, Kallings LV, Ekblom MM, Nooijen CFJ. The effects on self-efficacy, motivation and perceived barriers of an intervention targeting physical activity and sedentary behaviours in office workers: a cluster randomized control trial. *BMC Public Health*. 2021;21(1):1048. doi: 10.1186/s12889-021-11083-2.
13. Zhang S, Gamaldo AA, Neupert SD, Allaire JC. Predicting Control Beliefs in Older Adults: A Micro-Longitudinal Study. *The Journals of Gerontology: Series B*. 2019;75(5):e1-e12. doi: 10.1093/geronb/gbz001.
14. Gu D, Dupre ME. *Encyclopedia of Gerontology and Population Aging*. 2021.
15. Schunk DH, Ertmer PA. Chapter 19 - Self-Regulation and Academic Learning: Self-Efficacy Enhancing Interventions. In: Boekaerts M, Pintrich PR, Zeidner M, editors. *Handbook of Self-Regulation*. San Diego: Academic Press; 2000. p. 631-49.
16. Zimmerman BJ. Chapter 2 - Attaining Self-Regulation: A Social Cognitive Perspective. In: Boekaerts M, Pintrich PR, Zeidner M, editors. *Handbook of Self-Regulation*. San Diego: Academic Press; 2000. p. 13-39.
17. Chevance G, Baretta D, Golaszewski N, Takemoto M, Shrestha S, Jain S, et al. Goal setting and achievement for walking: A series of N-of-1 digital interventions. *Health Psychol*. 2021;40(1):30-9. doi: 10.1037/hea0001044.
18. Strecher VJ, Seijts GH, Kok GJ, Latham GP, Glasgow R, DeVellis B, et al. Goal setting as a strategy for health behavior change. *Health Educ Q*. 1995;22(2):190-200. doi: 10.1177/109019819502200207.
19. Locke EA, Latham GP. Building a practically useful theory of goal setting and task motivation. A 35-year odyssey. *Am Psychol*. 2002;57(9):705-17. doi: 10.1037//0003-066x.57.9.705.

20. Swann C, Rosenbaum S, Lawrence A, Vella SA, McEwan D, Ekkekakis P. Updating goal-setting theory in physical activity promotion: a critical conceptual review. *Health Psychol Rev.* 2021;15(1):34-50. doi: 10.1080/17437199.2019.1706616.
21. McEwan D, Harden SM, Zumbo BD, Sylvester BD, Kaulius M, Ruissen GR, et al. The effectiveness of multi-component goal setting interventions for changing physical activity behaviour: a systematic review and meta-analysis. *Health Psychol Rev.* 2016;10(1):67-88. doi: 10.1080/17437199.2015.1104258.
22. Pearson ES. Goal setting as a health behavior change strategy in overweight and obese adults: a systematic literature review examining intervention components. *Patient Educ Couns.* 2012;87(1):32-42. doi: 10.1016/j.pec.2011.07.018.
23. Gardiner PA, Eakin EG, Healy GN, Owen N. Feasibility of reducing older adults' sedentary time. *Am J Prev Med.* 2011;41(2):174-7. doi: 10.1016/j.amepre.2011.03.020.
24. Narayan A, Mazzola J. Encouraging Employees to Be More Active: Taking "Steps" Toward Personal Goals. *Journal of Psychological Issues in Organizational Culture.* 2014;4(4):5-17. doi: 10.1002/jpoc.21121.
25. Locke EA, Shaw KN, Saari LM, Latham GP. Goal setting and task performance: 1969–1980. *Psychological Bulletin.* 1981;90(1):125-52. doi: 10.1037/0033-2909.90.1.125.
26. Latham GP. Goal-setting theory: Causal relationships, mediators, and moderators. *Oxford Research Encyclopedia of Psychology.* 2016. doi: <https://doi.org/10.1093/acrefore/9780190236557.013.12>.
27. Lunenburg FC. Goal-setting theory of motivation. *International journal of management, business, and administration.* 2011;15(1):1-6.
28. Ritchie ND, Sauder KA, Kaufmann PG, Perreault L. Patient-Centered Goal-Setting in the National Diabetes Prevention Program: A Pilot Study. *Diabetes Care.* 2021;44(11):2464-9. doi: 10.2337/dc21-0677.
29. Klinkner GE, Yaeger KM, Brenny-Fitzpatrick MT, Vorderstrasse AA. Improving Diabetes Self-Management Support: Goal-Setting Across the Continuum of Care. *Clin Diabetes.* 2017;35(5):305-12. doi: 10.2337/cd17-0029.
30. Nguyen-Vaselaar H, Lappe JM. Goal-Setting Behavior for Physical Activity in Adults With Diabetes: A Pilot Project. *Jnp- the Journal for Nurse Practitioners.* 2021;17(10):1281-4. doi: 10.1016/j.nurpra.2021.08.015.
31. Knauper B, Cheema S, Rabiau M, Borten O. Self-set dieting rules: adherence and prediction of weight loss success. *Appetite.* 2005;44(3):283-8. doi: 10.1016/j.appet.2005.01.008.
32. Estabrooks PA, Nelson CC, Xu S, King D, Bayliss EA, Gaglio B, et al. The frequency and behavioral outcomes of goal choices in the self-management of diabetes. *Diabetes Educ.* 2005;31(3):391-400. doi: 10.1177/0145721705276578.
33. Nothwehr F, Yang J. Goal setting frequency and the use of behavioral strategies related to diet and physical activity. *Health Educ Res.* 2007;22(4):532-8. doi: 10.1093/her/cyl117.
34. Michie S, Johnston M, Francis J, Hardeman W, Eccles M. From theory to intervention: Mapping theoretically derived behavioural determinants to behaviour change techniques. *Applied Psychology- an International Review-Psychologie Appliquee-Revue Internationale.* 2008;57(4):660-80. doi: 10.1111/j.1464-0597.2008.00341.x.
35. Samdal GB, Eide GE, Barth T, Williams G, Meland E. Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *Int J Behav Nutr Phys Act.* 2017;14(1):42. doi: 10.1186/s12966-017-0494-y.
36. Whitehead L, Glass C, Coppel K. The effectiveness of goal setting on glycaemic control for people with type 2 diabetes and prediabetes: A systematic review and meta-analysis. *J Adv Nurs.* 2022;78(5):1212-27. doi: 10.1111/jan.15084.
37. Miller CK, Bauman J. Goal setting: an integral component of effective diabetes care. *Curr Diab Rep.* 2014;14(8):509. doi: 10.1007/s11892-014-0509-x.
38. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international

consensus for the reporting of behavior change interventions. *Ann Behav Med*. 2013;46(1):81-95. doi: 10.1007/s12160-013-9486-6.

39. Fredrix M, McSharry J, Flannery C, Dinneen S, Byrne M. Goal-setting in diabetes self-management: A systematic review and meta-analysis examining content and effectiveness of goal-setting interventions. *Psychology & Health*. 2018;33(8):955-77. doi: 10.1080/08870446.2018.1432760.

40. Locke EA, Latham GP. New Directions in Goal-Setting Theory. *Current Directions in Psychological Science*. 2016;15(5):265-8. doi: 10.1111/j.1467-8721.2006.00449.x.

41. Brown TC, Latham GP. The effects of behavioural outcome goals, learning goals, and urging people to do their best on an individual's teamwork behaviour in a group problem-solving task. *Canadian Journal of Behavioural Science / Revue canadienne des sciences du comportement*. 2002;34(4):276-85. doi: 10.1037/h0087180.

42. Bodenheimer T, Handley MA. Goal-setting for behavior change in primary care: an exploration and status report. *Patient Educ Couns*. 2009;76(2):174-80. doi: 10.1016/j.pec.2009.06.001.

43. Noel TWL, G.P. The Importance of Learning Goals versus Outcome Goals for Entrepreneurs. *SageJournals*. 2006;7(4). doi: <https://doi.org/10.5367/000000006779111594>.

44. Duff OM, Walsh DM, Furlong BA, O'Connor NE, Moran KA, Woods CB. Behavior Change Techniques in Physical Activity eHealth Interventions for People With Cardiovascular Disease: Systematic Review. *J Med Internet Res*. 2017;19(8):e281. doi: 10.2196/jmir.7782.

45. Della Mea V. What is e-health (2): the death of telemedicine? *J Med Internet Res*. 2001;3(2):E22. doi: 10.2196/jmir.3.2.e22.

46. Paramastri R, Pratama SA, Ho DKN, Purnamasari SD, Mohammed AZ, Galvin CJ, et al. Use of mobile applications to improve nutrition behaviour: A systematic review. *Comput Methods Programs Biomed*. 2020;192:105459. doi: 10.1016/j.cmpb.2020.105459.

47. Eckerstorfer LV, Tanzer NK, Vogrincic-Haselbacher C, Kedia G, Brohmer H, Dinslaken I, Corcoran K. Key Elements of mHealth Interventions to Successfully Increase Physical Activity: Meta-Regression. *JMIR Mhealth Uhealth*. 2018;6(11):e10076. doi: 10.2196/10076.

48. Stephens J, Allen J. Mobile phone interventions to increase physical activity and reduce weight: a systematic review. *J Cardiovasc Nurs*. 2013;28(4):320-9. doi: 10.1097/JCN.0b013e318250a3e7.

49. Eberle C, Lohnert M, Stichling S. Effectiveness of Disease-Specific mHealth Apps in Patients With Diabetes Mellitus: Scoping Review. *JMIR Mhealth Uhealth*. 2021;9(2):e23477. doi: 10.2196/23477.

50. Hietbrink EAG, Oude Nijeweme-d'Hollosy W, Middelweerd A, Konijnendijk AAJ, Schrijver LK, Ten Voorde AS, et al. A Digital Coach (E-Supporter 1.0) to Support Physical Activity and a Healthy Diet in People With Type 2 Diabetes: Acceptability and Limited Efficacy Testing. *JMIR Form Res*. 2023;7:e45294. doi: 10.2196/45294.

51. Hietbrink EAG, Middelweerd A, van Empelen P, Preuhs K, Konijnendijk AAJ, Oude Nijeweme-d'Hollosy W, et al. A Digital Lifestyle Coach (E-Supporter 1.0) to Support People With Type 2 Diabetes: Participatory Development Study. *JMIR Hum Factors*. 2023;10:e40017. doi: 10.2196/40017.

52. Lin JJ, Mamykina, L., Lindtner, S., Delajoux, G., Strub, H.B. Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game. *International Conference on Ubiquitous Computing*. 2006:261-78. doi: https://doi.org/10.1007/11853565_16.

53. Korinek EV, Phatak SS, Martin CA, Freigoun MT, Rivera DE, Adams MA, et al. Adaptive step goals and rewards: a longitudinal growth model of daily steps for a smartphone-based walking intervention. *J Behav Med*. 2018;41(1):74-86. doi: 10.1007/s10865-017-9878-3.

54. Schneider PL, Bassett DR, Jr., Thompson DL, Pronk NP, Bielak KM. Effects of a 10,000 steps per day goal in overweight adults. *Am J Health Promot*. 2006;21(2):85-9. doi: 10.4278/0890-1171-21.2.85.

55. Adams MA, Sallis JF, Norman GJ, Hovell MF, Hekler EB, Perata E. An adaptive physical activity intervention for overweight adults: a randomized controlled trial. *PLoS One*. 2013;8(12):e82901. doi: 10.1371/journal.pone.0082901.

56. Collins LM, Murphy SA, Bierman KL. A conceptual framework for adaptive preventive interventions. *Prev Sci*. 2004;5(3):185-96. doi: 10.1023/b:prev.0000037641.26017.00.

57. Poirier J, Bennett WL, Jerome GJ, Shah NG, Lazo M, Yeh HC, et al. Effectiveness of an Activity Tracker- and Internet-Based Adaptive Walking Program for Adults: A Randomized Controlled Trial. *J Med Internet Res*. 2016;18(2):e34. doi: 10.2196/jmir.5295.
58. Almirall D, Nahum-Shani I, Sherwood NE, Murphy SA. Introduction to SMART designs for the development of adaptive interventions: with application to weight loss research. *Translational Behavioral Medicine*. 2014;4(3):260-74. doi: 10.1007/s13142-014-0265-0.
59. Adams MA, Todd M, Angadi SS, Hurley JC, Stecher C, Berardi V, et al. Adaptive Goals and Reinforcement Timing to Increase Physical Activity in Adults: A Factorial Randomized Trial. *Am J Prev Med*. 2022;62(2):e57-e68. doi: 10.1016/j.amepre.2021.09.014.
60. Berry MP, Adams MA, Butryn ML, Kerrigan S, Forman EM. Efficacy and mechanisms of a brief adaptive goal-setting intervention for physical activity: A randomised pilot trial. *International Journal of Sport and Exercise Psychology*. 2022;21(5):894-916. doi: 10.1080/1612197x.2022.2090988.
61. Adams MA, Hurley JC, Todd M, Bhuiyan N, Jarrett CL, Tucker WJ, et al. Erratum to: Adaptive goal setting and financial incentives: a 2 x 2 factorial randomized controlled trial to increase adults' physical activity. *BMC Public Health*. 2017;17(1):303. doi: 10.1186/s12889-017-4231-x.
62. Klasnja P, Rosenberg DE, Zhou J, Anau J, Gupta A, Arterburn DE. A quality-improvement optimization pilot of BariFit, a mobile health intervention to promote physical activity after bariatric surgery. *Transl Behav Med*. 2021;11(2):530-9. doi: 10.1093/tbm/ibaa040.
63. Klasnja P, Hekler EB, Shiffman S, Boruvka A, Almirall D, Tewari A, Murphy SA. Microrandomized trials: An experimental design for developing just-in-time adaptive interventions. *Health Psychol*. 2015;34S(0):1220-8. doi: 10.1037/hea0000305.
64. Hurley JC, Hollingshead KE, Todd M, Jarrett CL, Tucker WJ, Angadi SS, Adams MA. The Walking Interventions Through Texting (WalkIT) Trial: Rationale, Design, and Protocol for a Factorial Randomized Controlled Trial of Adaptive Interventions for Overweight and Obese, Inactive Adults. *JMIR Res Protoc*. 2015;4(3):e108. doi: 10.2196/resprot.4856.
65. Bellicha A, van Baak MA, Battista F, Beaulieu K, Blundell JE, Busetto L, et al. Effect of exercise training on weight loss, body composition changes, and weight maintenance in adults with overweight or obesity: An overview of 12 systematic reviews and 149 studies. *Obes Rev*. 2021;22 Suppl 4(Suppl 4):e13256. doi: 10.1111/obr.13256.
66. Latham GP, Locke EA. Self-regulation through goal setting. *Organizational Behavior and Human Decision Processes*. 1991;50(2):212-47. doi: 10.1016/0749-5978(91)90021-k.
67. Nebel S, Schneider S, Schledjewski J, Rey GD. Goal-Setting in Educational Video Games. *Simulation & Gaming*. 2016;48(1):98-130. doi: 10.1177/1046878116680869.
68. DeWalt DA, Davis TC, Wallace AS, Seligman HK, Bryant-Shilliday B, Arnold CL, et al. Goal setting in diabetes self-management: taking the baby steps to success. *Patient Educ Couns*. 2009;77(2):218-23. doi: 10.1016/j.pec.2009.03.012.
69. Cui Y. Goal-Setting Theory. Theoretical Models for Teaching and Research. *WSU Open Text*; 2020.
70. Neubert MJ. The Value of Feedback and Goal Setting Over Goal Setting Alone and Potential Moderators of this Effect: a Meta-Analysis. *Human Performance*. 1998;11(4):321-35. doi: 10.1207/s15327043hup1104_2.
71. Krasny-Pacini A, Evans J. Single-case experimental designs to assess intervention effectiveness in rehabilitation: A practical guide. *Ann Phys Rehabil Med*. 2018;61(3):164-79. doi: 10.1016/j.rehab.2017.12.002.
72. Joseph RP, Keller C, Adams MA, Ainsworth BE. Print versus a culturally-relevant Facebook and text message delivered intervention to promote physical activity in African American women: a randomized pilot trial. *BMC Womens Health*. 2015;15:30. doi: 10.1186/s12905-015-0186-1.
73. Taj F, Klein MC, Van Halteren A. Towards a Generic Framework for a Health Behaviour Change Support Agent. *ICAART (1)2020*. p. 311-8.
74. Byiers B. Single-Case Designs. In: Liamputtong P, editor. *Handbook of Research Methods in Health Social Sciences*. Singapore: Springer Singapore; 2019. p. 581-602.
75. Fitbit. Fitbit charge 4 User Manual. Fitbit Help Center: Google; 2023.
76. Fitbit. fitbit inspire 3 User Manual. Fitbit Help Center: Google; 2023.

77. Fitbit. fitbit inspire 2 User Manual. Fitbit Help Center: Google; 2023.
78. Waddell A, Birkett S, Broom D, McGregor G, Harwood AE. Validating the Fitbit Charge 4(c) wearable activity monitor for use in physical activity interventions. *J Sci Med Sport*. 2024. doi: 10.1016/j.jsams.2024.01.007.
79. Feehan LM, Geldman J, Sayre EC, Park C, Ezzat AM, Yoo JY, et al. Accuracy of Fitbit Devices: Systematic Review and Narrative Syntheses of Quantitative Data. *JMIR Mhealth Uhealth*. 2018;6(8):e10527. doi: 10.2196/10527.
80. Kroll T, Kehn M, Ho PS, Groah S. The SCI Exercise Self-Efficacy Scale (ESES): development and psychometric properties. *Int J Behav Nutr Phys Act*. 2007;4:34. doi: 10.1186/1479-5868-4-34.
81. Nooijen CF, Post MW, Spijkerman DC, Bergen MP, Stam HJ, van den Berg-Emons RJ. Exercise self-efficacy in persons with spinal cord injury: psychometric properties of the Dutch translation of the Exercise Self-Efficacy Scale. *J Rehabil Med*. 2013;45(4):347-50. doi: 10.2340/16501977-1112.
82. Sullivan GM, Artino AR, Jr. Analyzing and interpreting data from likert-type scales. *J Grad Med Educ*. 2013;5(4):541-2. doi: 10.4300/JGME-5-4-18.
83. Wilbert J. Analyzing Single-Case Data with R and Scan. 2023.
84. Rueegg CS, Zürcher SJ, Schindera C, Jung R, Deng WH, Banteli I, et al. Effect of a 1-year physical activity intervention on cardiovascular health in long-term childhood cancer survivors—a randomised controlled trial (SURfit). *British Journal of Cancer*. 2023;129(8):1284-97. doi: 10.1038/s41416-023-02410-y.
85. De Cocker KA, De Bourdeaudhuij IM, Cardon GM. The effect of a multi-strategy workplace physical activity intervention promoting pedometer use and step count increase. *Health Education Research*. 2009;25(4):608-19. doi: 10.1093/her/cyp052.
86. Gasana J, O’Keeffe T, Withers TM, Greaves CJ. A systematic review and meta-analysis of the long-term effects of physical activity interventions on objectively measured outcomes. *BMC Public Health*. 2023;23(1):1697. doi: 10.1186/s12889-023-16541-7.
87. Wahlich C, Chaudhry UAR, Fortescue R, Cook DG, Hirani S, Knightly R, Harris T. Effectiveness of adult community-based physical activity interventions with objective physical activity measurements and long-term follow-up: a systematic review and meta-analysis. *BMJ Open*. 2020;10(5):e034541. doi: 10.1136/bmjopen-2019-034541.
88. Schroé H, Carlier S, Van Dyck D, De Backere F, Crombez G. Towards more personalized digital health interventions: a clustering method of action and coping plans to promote physical activity. *BMC Public Health*. 2022;22(1):2325. doi: 10.1186/s12889-022-14455-4.
89. Wolf BM, Herrmann M, Brandstätter V. Self-efficacy vs. action orientation: Comparing and contrasting two determinants of goal setting and goal striving. *Journal of Research in Personality*. 2018;73:35-45. doi: 10.1016/j.jrp.2017.11.001.
90. Fan J, Meng H, Billings RS, Litchfield RC, Kaplan I. On the Role of Goal Orientation Traits and Self-Efficacy in the Goal-Setting Process: Distinctions That Make a Difference. *Human Performance*. 2008;21(4):354-82. doi: 10.1080/08959280802347122.
91. Hopfner J, Keith N. Goal Missed, Self Hit: Goal-Setting, Goal-Failure, and Their Affective, Motivational, and Behavioral Consequences. *Front Psychol*. 2021;12:704790. doi: 10.3389/fpsyg.2021.704790.
92. Carr ME, Moore DW, Anderson A. Goal Setting Interventions: Implications for Participants on the Autism Spectrum. *Review Journal of Autism and Developmental Disorders*. 2014;1(3):225-41. doi: 10.1007/s40489-014-0022-9.
93. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*. 2011;6(1):42. doi: 10.1186/1748-5908-6-42.
94. Fynn JF, Hardeman W, Milton K, Murphy J, Jones A. A systematic review of the use and reporting of evaluation frameworks within evaluations of physical activity interventions. *International Journal of Behavioral Nutrition and Physical Activity*. 2020;17(1):107. doi: 10.1186/s12966-020-01013-7.

95. Hodgson W, Kirk A, Lennon M, Paxton G. Exploring the Use of Fitbit Consumer Activity Trackers to Support Active Lifestyles in Adults with Type 2 Diabetes: A Mixed-Methods Study. *Int J Environ Res Public Health*. 2021;18(21). doi: 10.3390/ijerph182111598.
96. Carels RA, Darby LA, Rydin S, Douglass OM, Cacciapaglia HM, O'Brien WH. The relationship between self-monitoring, outcome expectancies, difficulties with eating and exercise, and physical activity and weight loss treatment outcomes. *Ann Behav Med*. 2005;30(3):182-90. doi: 10.1207/s15324796abm3003_2.
97. Wang JB, Cadmus-Bertram LA, Natarajan L, White MM, Madanat H, Nichols JF, et al. Wearable Sensor/Device (Fitbit One) and SMS Text-Messaging Prompts to Increase Physical Activity in Overweight and Obese Adults: A Randomized Controlled Trial. *Telemed J E Health*. 2015;21(10):782-92. doi: 10.1089/tmj.2014.0176.
98. Gleeson-Kreig JM. Self-monitoring of physical activity: effects on self-efficacy and behavior in people with type 2 diabetes. *Diabetes Educ*. 2006;32(1):69-77. doi: 10.1177/0145721705284285.
99. Lally P, Gardner B. Promoting habit formation. *Health Psychology Review*. 2013;7(sup1):S137-S58. doi: 10.1080/17437199.2011.603640.
100. Harkin B, Webb TL, Chang BP, Prestwich A, Conner M, Kellar I, et al. Does monitoring goal progress promote goal attainment? A meta-analysis of the experimental evidence. *Psychol Bull*. 2016;142(2):198-229. doi: 10.1037/bul0000025.
101. Ekkekakis P, Hargreaves EA, Parfitt G. Invited Guest Editorial: Envisioning the next fifty years of research on the exercise–affect relationship. *Psychology of Sport and Exercise*. 2013;14(5):751-8. doi: 10.1016/j.psychsport.2013.04.007.
102. Phillips-Caesar EG, Winston G, Peterson JC, Wansink B, Devine CM, Kanna B, et al. Small Changes and Lasting Effects (SCALE) Trial: the formation of a weight loss behavioral intervention using EVOLVE. *Contemp Clin Trials*. 2015;41:118-28. doi: 10.1016/j.cct.2015.01.003.
103. Schunk DH. Introduction to the special section on motivation and efficacy. *Journal of Educational Psychology*. 1990;82(1):3-6. doi: 10.1037/h0092681.
104. Bassett DR, Toth LP, LaMunion SR, Crouter SE. Step Counting: A Review of Measurement Considerations and Health-Related Applications. *Sports Medicine*. 2017;47(7):1303-15. doi: 10.1007/s40279-016-0663-1.

8. Appendix

Appendix A – R code calculating 60th percentile

```
Steps_per_day_P4 <- read_excel("Health Sciences master/Master assignment/Steps per day.xlsx",  
                               sheet = "Participant4")  
# Calculate the 60th percentile using rollapply  
Steps_per_day_P4$steps_60th <- rollapply(Steps_per_day_P4$`Total steps per day`,  
    width = 10,  
    FUN = function(x) quantile(x[-1], probs = 0.6, na.rm = TRUE),  
    align = "right",  
    fill = NA)
```

Appendix B – information forum

Informatieformulier

Meedoen aan medisch-wetenschappelijk onderzoek, wat betekent dat voor u?

Geachte heer/mevrouw,

Met deze informatiebrief willen we u vragen of u wilt meedoen aan een wetenschappelijke studie. U leest hierachter om wat voor onderzoek het gaat, wat het voor u betekent, en wat de voordelen en nadelen zijn. Het is veel informatie. Wilt u de informatie doorlezen, en beslissen of u wilt meedoen? Als u wilt meedoen, kunt u het formulier invullen dat u vindt in bijlage A.

Stel uw vragen!

U kunt uw beslissing nemen met de informatie die u in deze informatiebrief vindt. Daarnaast raden we u aan om dit te doen:

- Stel vragen aan de onderzoeker die u deze informatie geeft.
- Praat met uw partner, familie of vrienden over dit onderzoek.

Welke informatie vindt u in deze informatiebrief?

U vindt in deze brief deze informatie:

- Wat houdt het onderzoek in?
- Wat betekent het voor u als u meedoet aan het onderzoek?
- Wat verwachten wij van u als u meedoet?
- Wat zijn de voordelen en nadelen als u meedoet aan het onderzoek?
- Wanneer stopt het onderzoek?
- Hoe gaan we om met uw gegevens?
- Krijgt u betaald?

Bij deze informatiebrief vindt u de volgende bijlagen:

A: contactgegevens van Universitair Medisch Centrum X

B: toestemmingsformulier

Om wat voor onderzoek gaat het?

We willen onderzoeken of het stellen van adaptieve stappen doelen, ervoor zorgt dat meer mensen hun stappendoelen bereiken. Doelen stellen kan helpen om beweging te verbeteren. Adaptieve doelen tellen is een relatief nieuwe aanpak, waarbij beweegdoelen tijdens de interventie toenemen, afnemen of hetzelfde blijven als reactie op dagelijkse ervaringen. We hopen dat het aantal stappen verhoogd wordt in vergelijking met voor de interventie. In het onderzoek worden twee verschillende interventies voor het stellen van stappen doelen vergeleken. Met het uiteindelijke doel dat, de meest effectieve eruit gehaald kan worden. De twee interventies zijn; adaptieve wekelijkse stappendoelen krijgen, en dagelijkse stappendoelen krijgen. Na het experiment, krijgt u een questionnaire opgestuurd, waarin uw mening over de verschillende interventies gevraagd wordt.

Wat betekent het voor u als u meedoet?

Hoelang duurt het onderzoek?

Het onderzoek duurt 6 weken. Daarna vindt er een interview/questionnaire plaats, om te vragen hoe u de interventies vond. Dit doen we binnen 1 week na het eindigen van het onderzoek.

Stap 1: Wilt u meedoen?

Allereerst willen wij weten of u mee wilt doen met het onderzoek. Dit kunt u laten weten aan het einde van de informatiebrief. Elk gezond individu mag meedoen aan dit onderzoek.

Stap 2: Het onderzoek

Het onderzoek bestaat uit drie verschillende onderdelen. Allereerst begint u met een beginmeting. Deze meting duurt tussen de 9 en 14 dagen, tijdens deze dagen, draagt u de Fit bit, maar maakt u geen gebruik van de applicatie. Na deze dagen gaat u van start met het onderzoek. Dit onderzoek

bestaat uit twee interventies, die u allen test. Beide interventies test u voor twee weken lang en gebruiken een andere manier van stappendoelen zetten. U begint met het ontvangen van wekelijkse doelen. Daarna zal u dagelijks een nieuw stappendoel ontvangen.

Stap 3: Evaluatie

Na het onderzoek zal er een questionnaire plaatsvinden. Hier zal besproken worden, wat u van de verschillende interventies vond, en wat uw ervaring was. De questionnaire zal maximaal 30 minuten duren.

Welke afspraken maken we graag met u?

We willen natuurlijk graag dat het onderzoek goed verloopt. Daarom maken we de volgende Afspraken met u:

- U wilt alle stappen van het onderzoek doorlopen.
- U neemt contact op met de onderzoeker in deze situaties:
 - o U wilt niet meer meedoen aan het onderzoek.
 - o Uw telefoonnummer, adres of e-mailadres verandert.

Wat zijn de voordelen en nadelen als u meedoet aan het onderzoek?

Meedoen aan het onderzoek heeft voordelen en nadelen. Hieronder zetten we ze op een rij. Denk hier goed over na, en praat erover met anderen.

Voordelen

Meedoen aan het onderzoek heeft deze voordelen:

- U helpt mee in de zoektocht naar een betere manier van doelen stellen.
- U helpt de onderzoeker om meer inzicht te krijgen in stappendoelen.
- U krijgt zelf meer inzicht in uw stappen

Nadelen

Meedoen aan het onderzoek heeft deze nadelen:

- Het onderzoek kost tijd, doordat u, de stappendoelen dagelijks of wekelijks moet bekijken. Dit duurt niet lang, maar kost wel tijd. De evaluatie kost ongeveer 30 minuten.
- U moet zich houden aan de afspraken die horen bij het onderzoek

Wilt u niet meedoen?

Het meedoen aan het onderzoek is op vrijwillige basis, u beslist zelf of u wel of niet mee wilt doen.

Wanneer stop het onderzoek?

In deze situaties stopt voor u het onderzoek:

- Alle onderzoeken volgens het schema zijn voorbij. Dit is na 6 weken. Daarna is er nog een evaluatie enquête.
- U wilt zelf stoppen met het onderzoek. Dat mag op ieder moment. Meld dit dan meteen bij de onderzoeker. U hoeft er niet bij te vertellen waarom u stopt. De onderzoeker kan wel de informatie gebruiken die ze tot nu toe over u hebben verzameld.
- Een van de volgende instanties besluit dat het onderzoek moet stoppen:
 - o het ziekenhuis,
 - o de overheid, of
 - o de medisch-ethische commissie van de universiteit Twente.

Na het onderzoek

Krijgt u de uitslag van het onderzoek?

Ongeveer een 6 weken na uw deelname laat de onderzoeker u weten wat de belangrijkste

uitkomsten zijn van het onderzoek.

Krijgt u een vergoeding als u meedoet aan het onderzoek?

Nee, u krijgt geen vergoeding als u meedoet aan het onderzoek.

Wat bewaren we?

We bewaren gegevens. Met gegevens bedoelen we dit:

- uw naam,
- uw adres,
- uw geboortedatum,
- gegevens over uw stappen die verzameld zijn met de Fitbit,
- uw antwoorden van de questionnaire

Hoe beschermen we uw privacy?

We geven uw gegevens een cijfercode. Op al uw gegevens zetten we alleen deze code. De sleutel van de code bewaren we op een beveiligde plek in de onderzoeksinstelling. Steeds als we uw gegevens verwerken, gebruiken we alleen die code. Ook in rapporten en publicaties over het onderzoek kan niemand terughalen dat het over u ging.

Hoelang bewaren we uw gegevens?

We bewaren uw gegevens minimaal 15 jaar. Dit doen we digitaal, op een beveiligde server van de universiteit Twente.

Mogen we uw gegevens gebruiken voor ander onderzoek?

Uw gegevens worden niet voor een ander onderzoek gebruikt.

Hoe geeft u toestemming voor het onderzoek?

U kunt eerst rustig nadenken over dit onderzoek. Daarna vertelt u de onderzoeker of u wel of niet wilt meedoen. Wilt u meedoen? Dan vult u het toestemmingsformulier in dat u bij deze informatiebrief vindt. U kunt hierop ook aangeven of u wel geen toestemming geeft voor ander onderzoek met uw gegevens.

Bijlage A

Toestemmingsformulier / informed consent

Informatie over het onderzoek

Het onderzoek gaat over het stellen van stappendoelen. Dit wordt op verschillende manieren getest. Tijdens het onderzoek draagt u een Fitbit die uw stappen meet. Aan het einde van het onderzoek, zal u een interview doen met de onderzoeker, om de verschillende manieren te evalueren en te beoordelen. Voor meer informatie over het onderzoek, kunt u het informatieformulier lezen of de onderzoeker benaderen, dit kan ook voor vragen.

Onderzoeksvraag

Wat is een effectieve manier om stapdoelen in mobiele gezondheid-interventies aan te passen, zodat het een adaptieve interventie wordt?

Adaptieve doelen stellen, Universiteit Twente en ZGT

- Ik heb de informatie(brief) gelezen. Ik kon vragen stellen. Mijn vragen zijn voldoende beantwoord. Ik had genoeg tijd om over deelname te beslissen.
- Ik weet dat meedoen vrijwillig is en dat ik mijn toestemming kan intrekken op ieder moment van het onderzoek. Daarvoor hoef ik geen reden te geven.
- Ik weet dat als ik mij terugtrek, mijn gegevens tot dat moment gebruikt kunnen worden, tenzij ik ook vraag om de reeds verzamelde gegevens te wissen. Dit kan enkel als het onderzoek daardoor niet wordt geschaad.
- Ik geef toestemming voor het verzamelen, bewaren en gebruiken van mijn gegevens voor de beantwoording van de onderzoeksvraag in dit onderzoek.
- Ik weet dat alleen ter controle van de wetenschappelijk integriteit van het onderzoek sommige mensen toegang tot mijn verzamelde gegevens kunnen krijgen.
- Ik wil meedoen aan dit onderzoek.

Naam deelnemer:

Handtekening: Datum : __ / __ / __

Ik, de onderzoeker, verklaar dat ik deze deelnemer volledig heb geïnformeerd over het genoemde onderzoek.

Als er tijdens het onderzoek informatie bekend wordt die de toestemming van de deelnemer zou kunnen beïnvloeden, dan breng ik hem/haar daarvan tijdig op de hoogte.

Naam onderzoeker (of diens vertegenwoordiger): Alet van de Ven

Handtekening: Datum: __ / __ / __

Evaluatie stappendoelen



B *I* U

Met deze vragen verzoek ik u om feedback over het experiment waar u aan heeft deelgenomen. Uw antwoorden zullen helpen de sterke en zwakke punten van het stellen van stappendoelen te begrijpen.

In welke leeftijdscategorie valt u? *

1. 17 of jonger
2. 18-20
3. 21-29
4. 30 +

Wat is uw geslacht? *

- ☐ Man
- ☐ Vrouw
- ☐ Anders
- ☐ Zeg ik liever niet



Wij vragen u om aan te geven hoeveel vertrouwen u hebt in uw mogelijkheden om te bewegen. *
Onder bewegen wordt zowel alledaagse lichamelijke activiteit (bijvoorbeeld lopen, fietsen, rolstoel rijden of handbiken om de hond uit te laten of boodschappen te doen) als sport (bijvoorbeeld fitness of zwemmen) verstaan.

Ik ben er van overtuigd:

	Helemaal niet waar	Zelden waar	Soms waar	Altijd waar
dat ik barrières en ...	☐	☐	☐	☐
dat ik middelen en ...	☐	☐	☐	☐
dat ik mijn doelen ...	☐	☐	☐	☐
dat wanneer ik gec...	☐	☐	☐	☐
dat ik kan bewege...	☐	☐	☐	☐
dat ik kan bewege...	☐	☐	☐	☐
dat ik kan bewege...	☐	☐	☐	☐
dat ik kan bewege...	☐	☐	☐	☐
dat ik mezelf kan ...	☐	☐	☐	☐
dat ik kan bewege...	☐	☐	☐	☐

Sectie 2 van 4

Wekelijks doelen krijgen



Tijdens het experiment, heeft u voor ongeveer 6 weken een Fitbit gedragen. Gedurende dit experiment heeft u twee verschillende soorten van stappendoelen gekregen. Deze vragenlijst begint bij het vragen naar de eerste manier van een stappendoel zetten. Hierbij kreeg u één stappendoel voor de hele week. Dit heeft u gedurende 2 weken getest.



Ik vond het gestelde stappendoel voor de week haalbaar. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens



Ik vond het stappendoel voor een week motiverend. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens

Ik vond de frequentie van het wekelijks ontvangen van een stappendoel passend voor mijn motivatie en activiteitsniveau. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens

Wat spreekt u het MEEST aan met deze manier van stappendoelen krijgen? (bijvoorbeeld; de frequentie, de doelen waren haalbaar) *

Tekst lang antwoord

Wat spreekt u het MINST aan met deze manier van stappendoelen krijgen? (bijvoorbeeld; ik kan zelf de doelen niet kiezen, de doelen waren te hoog) *

Tekst lang antwoord

Dagelijkse stappendoelen krijgen



Dit gedeelte van de vragenlijst gaat over de tweede manier van stappendoelen zetten. Hierbij kreeg u elke dag een nieuw stappendoel gedurende twee weken.



Ik vond het gestelde stappendoel voor de dag haalbaar. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens

Ik vond het stappendoel voor een dag motiverend. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens



Ik vond de frequentie van het dagelijks ontvangen van een stappendoel passend voor mijn motivatie en activiteitsniveau. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens



Ik vond het prettig dat de moeilijkheid van mijn stappen varieerde van dag tot dag. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens

Wat spreekt u het MEEST aan met deze manier van stappendoelen krijgen? (bijvoorbeeld; de doelen zorgde ervoor dat ik meer ging bewegen, de frequentie) *

Tekst lang antwoord

Wat spreekt u het MINST aan met deze manier van stappendoelen krijgen? (bijvoorbeeld; de frequentie, te hoge doelen) *

Tekst lang antwoord

Voorkeur



U heeft feedback gegeven op de wekelijkse stappendoel en de dagelijkse stappendoelen. In het laatste stuk van deze enquête zullen deze twee manieren vergeleken worden, en algemeen gekeken worden wat u van deze manier van stappendoelen krijgen vindt.

Het krijgen van stappendoel die voor mij zijn gepersonaliseerd, vind ik aantrekkelijker dan andere methoden die ik ken. *

- ☐ Volledig mee eens
- ☐ Mee eens
- ☐ Noch mee eens, noch mee oneens
- ☐ Mee oneens
- ☐ Volledig mee oneens

Wat is uw voorkeur in de frequentie van ontvangen van een stappendoel? *

- ☐ Wekelijks een nieuw stappendoel
- ☐ Dagelijks een nieuw stappendoel

Waarom ligt uw voorkeur bij deze frequentie? *

Tekst lang antwoord

Appendix D – R code piecewise linear regression

#make scdf of every excel

```
case1 <- scdf(values = c(Steps_per_day_P1$`Total steps per day`),  
              phase_design = c(A = 10, B = 14, C = 14))
```

```
case2 <- scdf(values = c(Steps_per_day_P2$`Total steps per day`),  
              phase_design = c(A = 10, B = 14, C = 14))
```

```
case3 <- scdf(values = c(Steps_per_day_P3$`Total steps per day`),  
              phase_design = c(A = 10, B = 14, C = 14))
```

```
case4 <- scdf(values = c(Steps_per_day_P4$`Total steps per day`),  
              phase_design = c(A = 12, B = 14, C = 14))
```

```
case5 <- scdf(values = c(Steps_per_day_P5$`Total steps per day`),  
              phase_design = c(A = 12, B = 14, C = 14))
```

#combine all participants

```
study <- c(case1, case2, case3, case4, case5)
```

```
print(study, cases = 6, rows = 30)
```

```
summary(study)
```

```
scplot(study)
```

#making plots with different lines, done for every participant

```
scplot(case1) |>
```

```
  add_statline("max") |>
```

```
  add_statline("mean") |>
```

```
  add_statline("median") |>
```

```
  add_statline("min") |> add_legend()
```

```
scplot(case2) |>
  add_statline("max") |>
  add_statline("mean") |>
  add_statline("median") |>
  add_statline("min") |> add_legend()
```

```
scplot(case3) |>
  add_statline("max") |>
  add_statline("mean") |>
  add_statline("median") |>
  add_statline("min") |> add_legend()
```

```
scplot(case4) |>
  add_statline("max") |>
  add_statline("mean") |>
  add_statline("median") |>
  add_statline("min") |> add_legend()
```

```
scplot(case5) |>
  add_statline("max") |>
  add_statline("mean") |>
  add_statline("median") |>
  add_statline("min") |> add_legend()
```

```
#describe single-case data
describeSC(case2)
```

```
# Plot the modified data
scplot(study) |>
  add_statline("trend") |>
  add_statline("trendA")
```

```

#basic function for applying a regression to a SCED
plm(case1)
plm(case2)
plm(case3)
plm(case4)
plm(case5)
hplm(study)

# Filtering only phases B and C for each case
case1_bc <- subset(case1, phase != "A")
case2_bc <- subset(case2, phase != "A")
case3_bc <- subset(case3, phase != "A")
case4_bc <- subset(case4, phase != "A")
case5_bc <- subset(case5, phase != "A")

# Combine the filtered cases into a new study object
study_bc <- c(case1_bc, case2_bc, case3_bc, case4_bc, case5_bc)

# Print and summarize the new study object for verification
print(study_bc, cases = 6, rows = 30)
summary(study_bc)

# Plotting the filtered study object
scplot(study_bc)

# Applying hierarchical piecewise linear model (hplm) on the filtered study object
hplm(study_bc)

```

Appendix E – Figures steps/day and step goals



Figure 8.1 Participant 1 steps/day and step goals



Figure 8.2 Participant 2 steps/day and step goals



Figure 8.3 Participant 3 steps/day and step goals



Figure 8.4 Participant 4 steps/day and step goals



Figure 8.5 Participant 5 steps/day and step goals

Appendix F – Figures trend lines

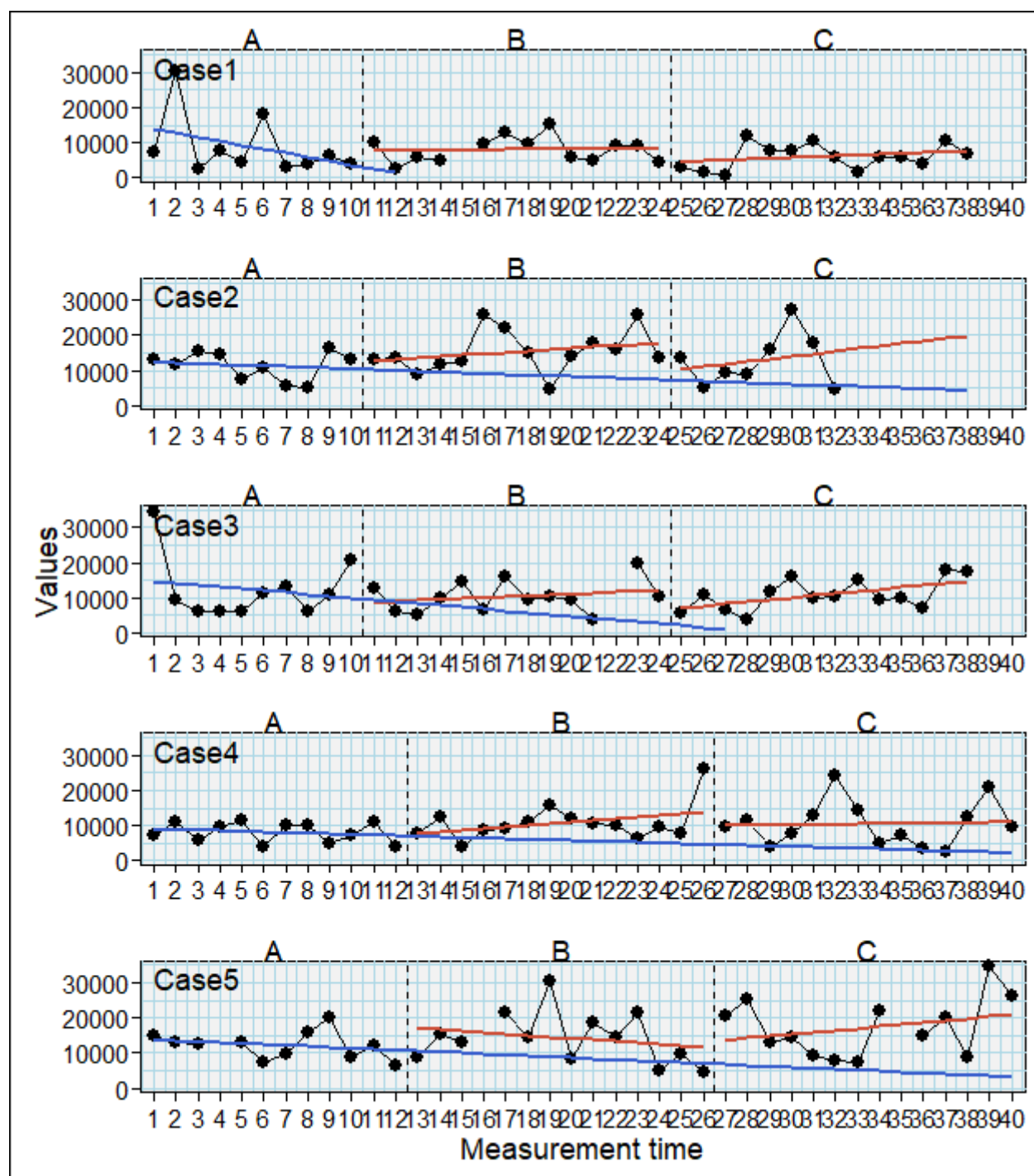


Figure 8.6 Trend lines