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Towards a balanced and active lifestyle

TOWARDS A BALANCED AND ACTIVE LIFESTYLE

Reinoud Achterkamp

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Chapter 1

General introduction

In 2015, 43 percent of the Dutch population above four years of age was overweight or even obese (Centraal bureau voor de Statistiek, 2016). This is no exception, most developed countries show comparable prevalence (OECD, 2010) or even as high as 68.8% in the USA (National Institute of Health, 2012). Not only does overweight and obesity form a major risk for (cardiovascular) diseases and chronic illnesses (Freedman, Dietz, Srinivasan, & Berenson, 1999), it also leads to enormous additional costs in healthcare (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011; Finkelstein, Graham, & Malhotra, 2014). More importantly, it has been suggested that the increasing prevalence of childhood obesity may make that, for the first time in modern history, today's youth, on average, live less healthy and shorter lives than their parents (Olshansky et al., 2005; Daniels, 2006).

OVERWEIGHT AND PHYSICAL ACTIVITY

Considering the above, it makes sense that a vast amount of time is spent on investigating means to decrease overweight and obesity prevalence. The current thesis adds to this research base. Earlier research shows that a sufficient level of physical activity has significant positive effects on health through prevention of overweight and obesity, but also through prevention of chronic diseases such as cardiovascular disease and diabetes (Warburton, Nicol, & Bredin, 2006). More specifically, research shows that with a decreasing level of physical activity, BMI increases. In addition, sedentary time is higher in overweight and obese subjects than in normal weight subjects (Scheers et al., 2012). Insufficient physical activity is a known risk factor for both higher body mass index (BMI) (Patrick et al., 2004) and higher relative gains in weight and BMI over childhood and adolescence (Must & Tybor, 2005). Conversely, shifting time spent in sedentary behaviour to time spent in light intensive physical activity leads to reduced waist circumference and BMI (Healy et al., 2015). Next to its positive effects on physical health, a sufficient level of physical activity is known to lead to improved mental health condition through reduced perceived stress and lower levels of burnout, depression and anxiety (Jonsdottir, Rödjer, Hadzibajramovic, Börjesson, & Ahlborg, 2010). Despite the above, an increasing number of people tend to live an insufficiently physically active lifestyle, related to a decrease in health and increased risks for numerous diseases (e.g. Warren et al., 2010; Bankoski et al., 2011). But firstly, what, specifically, is physical activity?

The definition of physical activity varies highly in both general public and the research community (Tuder-Locke, Henderson, Wilcox, Cooper, Durstine & Ainsworth, 2003). We used the definition of physical activity as proposed by Caspersen, Powell and Christenson (1985), who stated that physical activity comprises four elements:

1) Physical activity consists of bodily movements via skeletal muscles;
2) Physical activity results in energy expenditure;
3) Energy expenditure (kilocalories) varies continuously from low to high,
4) Physical activity is positively correlated with physical fitness.

This definition makes it possible to distinguish between physical activity, exercise and physical fitness. Exercise is defined as consisting of elements 1, 2 and 3, and additionally including the following aspects: very positively correlated with physical fitness; it is a planned, structured, and repetitive bodily movement; and an objective is to improve or maintain physical fitness component(s), e.g. cardio-respiratory endurance, muscular endurance, muscular strength, body composition, flexibility.

Physical activity is thought to differ from physical fitness; the latter is defined as "one's ability to execute daily activities with optimal performance, endurance, and strength with the management of disease, fatigue, and stress and reduced sedentary behaviour" (Campbell, De Jesus, Prapavessis, 2013). Thus, whereas physical fitness can be regarded as a subjective set of certain beliefs, physical activity relates to the actual movements that people perform.

With respect to the research discussed above, it shall not come as a surprise that much research has focused on interventions to improve level of physical activity in overweight and obese subjects and thereby decrease its prevalence and associated diseases. For example, an intensive, eighteen month physical activity and weight loss program, including individual and group sessions under supervision of healthcare professionals resulted in lower body fat percentages and increased body lean mass (Beavers et al., 2014). Another three-month intervention comprising face-to-face sessions with healthcare professionals show modest efficacy in reducing BMI, but also in changing physical activity levels of overweight subjects (Siwik et al., 2013). Both interventions show that increasing physical activity has positive influences on health outcomes. However, they are also very labor intensive, including multiple face-to-face sessions with health care professionals and group sessions. Additionally, subjects only receive support when they are in a session with a professional or a group. These downsides, among others, are what recent technological advancements try to overcome by providing interventions not only face-to-face, but also through technology, such as smartphones. With respect to overweight populations, objective measurement of physical activity is mostly used in combination with face-to-face consultations to assess effectiveness of face-to-face interventions, i.e. to assess level of physical activity before versus after the intervention and not to provide feedback based on these measurements (e.g. Bäcklund, Sundelin, & Larsson, 2011; Siwik et al., 2013; Beavers et al., 2014; Heiss, 2015). Although short-term results of these face-to-face interventions are promising (Heiss, 2015), research indicates that long-term effectiveness can be improved (Bäcklund, Sundelin, & Larsson, 2011). In this regard, mobile applications are less intensive for subjects, more accessible, and can be used continuously for extended periods of time, possibly leading to better long-term effects than face-to-face interventions. However, these types of self-management focused interventions that do not comprise face-to-face contact are scarcely investigated in overweight subject samples, despite their possibilities regarding continuous availability and effect throughout the entire day, independent of place; providing a platform for continuous care, coaching and feedback.

This ubiquitous nature of modern-day, mobile technology is promising and sensors nowadays provide very detailed information for precise measurement of physical activity (e.g. Alberts et al., 2015; Sandroff et al., 2014). This development created an enormous increase in research on mobile physical activity interventions and applications that use built-in smartphone technology or external sensors for measurement of physical activity throughout the day (Bort-Roig, Gilson, Puig-Ribera, Contreras, and Trost, 2014). The vast majority of this research has focused on accurate objective monitoring of physical activity and as such, it remains unclear how exactly to provide the most effective feedback based on these accurate measurements (Op Den Akker, Jones, Hermens, Hermens, & Jones, 2014); Op den Akker et al. (2014) categorize the possibilities to provide information to individual users of real-time, technology-supported physical activity applications in seven types of tailoring – feedback, inter-human interaction, adaptation, user targeting, goal setting, context awareness, and self-learning – and show that adaptation, i.e. tailoring of feedback based on individuals' scores on constructs from behavioural sciences, is rarely applied in modern-day, mobile physical activity applications. In this regard, mobile, technology-supported physical activity applications do not optimally exploit possibilities with respect to providing real-time feedback to individual users.

Non-technology-supported physical activity interventions frequently apply theories and models from behavioural sciences that describe the constructs thought to underlie behavioural change to determine the content of feedback and other information (Conner & Norman, 2005). Three well-known theories on this topic, so-called Social Cognition Models (SCM), are the Social Cognitive Theory (SCT) (Bandura, 1986), the Theory of Planned Behaviour (TPB) (Ajzen, 1991), and the Transtheoretical Model (TTM) (Prochaska & DiClemente, 1983).

SCM's leave from the assumption that the behavioural patterns that underlie the leading causes of death in industrialised countries can be changed, and attempt to define the cognitive factors that underlie 'social' patterns of behaviours. The SCT (Bandura, 1982) starts from the assumption that motivation and action are influenced by forethought. It assumes three types of expectancies: situation outcome expectancy, action outcome expectancy, and perceived self-efficacy. Situation outcome expectancies regard to expectancies about what consequences will occur when the subject would not interfere. Action outcome expectancies pertain to beliefs about whether certain behaviour will or will not lead to a particular outcome. Self-efficacy expectancies are defined as the belief that the particular behaviour is, or is not, within an individual's control. For example, this means that if subjects expect 1) clear downsides when they do not change behaviour, 2) a high chance of a positive outcome when the behaviour is performed, and 3) they feel able to perform the behaviour, then actual performance of the behaviour is likely. According to the TPB (Ajzen, 1991), behaviour is preceded by intentions, i.e. motivation or one's plan to exert effort to perform the behaviour. Intentions, in turn, are constituted by attitudes, subjective norms and perceived behavioural control. Attitudes concern the overall evaluation of the behaviour, comprising behavioural beliefs about the perceived consequences of the behaviour. Subjective norms are made up based on normative beliefs, which represent perceptions of significant others' opinion about whether the individual should, or should not engage in the behaviour. Perceived behavioural control is based on control beliefs, concerning whether subjects feel that they have access to the necessary recourses and opportunities to perform the behaviour successfully. It is thought that by influencing the various beliefs, behaviour can be changed or maintained. Next, the TTM (Prochaska & DiClemente, 1983) states that as individuals change behaviour, they move through several stages of change – from precontemplation, to contemplation, preparation, action and maintenance – and that different cognitions may be of importance in different stages of change. It is best described as a circular model, since subjects can enter and exit at any point and relapse to an earlier stage is possible. Next to these stages, the model includes several other constructs: a decisional balance about benefits versus costs of performing the behaviour; self-efficacy, or confidence that one can engage in healthy behaviour and resist temptation to engage in unhealthy behaviour; and processes of change, regarding activities that people engage in to progress through the stages.

Constructs that are frequently encountered in research regarding SCM's, tailoring, and physical activity, include stage of change, process of change, behavioural intentions, social norms, attitudes, perceived susceptibility, social support, and self-efficacy (Noar, Benac & Harris, 2007). Use of these models and constructs in physical activity interventions has repeatedly been associated with higher effect sizes (e.g. Spittaels, De Bourdeaudhuij, Brug, & Vandelanotte, 2007). Also, earlier research on non-mobile or face-to-face physical activity interventions provides evidence that incorporation of tailoring increases the effect of the intervention (Hawkins et al., 2008); it enhances relevance for the individual and thereby increases the impact of communication. Guidelines for designing effective physical activity interventions strongly recommend tailoring feedback (Greaves et al., 2011). Indeed, interventions show significantly larger effect sizes when communication is tailored on e.g. subjects' attitudes, stage of change, social support or processes of change than when tailoring is not applied (Hawkins et al., 2008).

Although the different theories describe different constructs to lead to behavioural change, there is also considerable overlap. An important and recurrent factor is self-efficacy – one's belief in one's ability to succeed in specific situations (Bandura, Adams, & Beyer, 1977). Self-efficacy is incorporated in most models, although occasionally labeled slightly different, e.g. 'perceived behavioural control' in Ajzen's Theory of Planned Behaviour (1991). Higher levels of self-efficacy regarding physical activity are associated with higher levels of physical activity, and the percentage of increase in physical activity in a twelve-week intervention period is higher when self-efficacy is high (e.g. Trost, Kerr, Ward, & Pate, 2001). Also, for becoming more physically active, subjects need higher levels of self-efficacy (Haas, 2011). High self-efficacy has not only been associated to successfully achieving, but also to maintaining a sufficient level of physical activity, up to nine months post-intervention (Whipple, Kinney, and Kattenbraker, 2008; Neupert, Lachman, and Whitbourne, 2009; McAuley, Szabo, Gothe, and Olson, 2011). Bandura (1994) describes four strategies to influence self-efficacy, which are still widely applied (e.g. in Rowbotham & Owen, 2015; Willis, 2015):

- Mastery experience: the subject successfully performs the target behaviour;
- Vicarious experience: the subject observes a similar other perform the target behaviour;
- Verbal (or social) persuasion: verbally expressed faith in the subject's capabilities by others;
- Physiological/affective states: (mis)interpretations of bodily states.

Ashford, Edmunds, and French (2010) showed that using mastery experience is the most powerful source to increase self-efficacy, followed by vicarious experience. Still, little is known about how to apply these techniques in mobile, technology supported physical activity interventions or applications.

GENERAL AIM AND RESEARCH QUESTIONS

Based on the above, the main aim of this thesis is to increase our understanding about whether it is useful to incorporate tailoring in mobile, technology-supported physical activity enhancing applications, if so, how to incorporate this, and to provide first insights in what happens on physical activity and self-efficacy levels, when overweight subjects are provided with such an application. More specific, we aim to answer the following three research questions:

1) What is the relation between self-efficacy, stage of change, and objectively measured level of physical activity in patients and healthy adults, and can typical users be identified?
2) What is the effect of a feedback strategy that is delivered through technology and applies self-efficacy increasing techniques on self-efficacy and task performance?
3) Does two-week use of a mobile, technology-supported physical activity application by overweight adults lead to changes in goal achievement, self-efficacy, or level of physical activity over a two-week period or in an interval of fifteen minutes after a feedback message has been prompted?

To answer these questions four studies are performed: one on data previously retrieved in various observational cohort studies, two experimental laboratory-setting studies, and one small cohort field study.

GENERAL OUTLINE

This thesis starts with an analysis of cross sectional physical activity data to investigate 1) the relation between self-efficacy and objectively measured level of physical activity, 2) the relation between stage of change and objectively measured level of physical activity, and 3) compare level of physical activity between patients and healthy adults. Using these results, personas are suggested. A persona can be regarded as a subject with a certain set of specific characteristics. Based on the cross sectional data, various personas with specific characteristics are identified, for which feedback strategies are constructed. These feedback strategies can then be incorporated in mobile, technology-supported physical activity applications.

As it is unclear how to apply known effective techniques from behavioural sciences in mobile, technology-supported physical activity applications, chapter 3 describes results from a laboratory setting study, investigating whether self-efficacy regarding a specific task can be influenced using feedback strategies that rely on mastery experience and are provided through technology. In chapter 4, we present an explorative lab study that is comparable to the study presented in chapter 3, this time focusing on vicarious experience provided through technology and its effect on level of self-efficacy and task performance.

Chapters 5 and 6 are based on results from an explorative study in a more ecologically valid setting. These chapters provide first insights into goal achievement, changes is self-efficacy and changes in physical activity levels of overweight adults using the Activity Coach for two weeks. Additionally, differences between the effects of feedback as in previous versions of the system versus feedback based on feedback strategies as defined in chapter 2 on level of physical activity are explored.

Lastly, in chapter 7, we present general conclusions and discussion of results of the current thesis, future steps for tailoring, implications for clinical practice, and general directions for future research.

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Chapter 2

Strategies to improve effectiveness of physical activity coaching systems: Development of personas for providing tailored feedback

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ABSTRACT

Mobile physical activity interventions can be improved by incorporating behavioural change theories. Relations between self-efficacy, stage of change, and physical activity are investigated, enabling development of feedback strategies that can be used to improve their effectiveness.

A total of 325 healthy control participants and 82 patients wore an activity monitor. Participants completed a self-efficacy or stage of change questionnaire.

Results show that higher self-efficacy is related to higher activity levels. Patients are less active than healthy controls and show a larger drop in physical activity over the day. Patients in the maintenance stage of change are more active than patients in lower stages of change, but show an equally large drop in level of physical activity.

Findings suggest that coaching should at least be tailored to level of self-efficacy, stage of change, and physical activity pattern. Tailored coaching strategies are developed, which suggest that increasing self-efficacy of users is most important. Guidelines are provided.

INTRODUCTION

A physically active lifestyle has significant positive effects on mental health condition (Jonsdottir, Rödjer, Hadzibajramovic, Börjesson, & Ahlborg, 2010) and prevention of chronic diseases such as cardiovascular disease, diabetes, and cancer (Warburton, Nicol, & Bredin, 2006). A recent development regarding physical activity interventions is using mobile applications to achieve behavioural change. Many applications allow for tracking and scheduling of exercise, while only few applications aim at tracking physical activity over the day. Those that are available typically use an external sensor next to a smartphone, like Fitbit (2018) and Samsung Gear (2018). These types of services seem promising in the short-term (Van Weering, Vollenbroek-Hutten, & Hermens, 2011) However, the effectiveness can be further improved.

Traditional, non-mobile physical activity interventions that aim to improve level of physical activity in the general population (Dishman, & Buckworth, 1996; Marcus et al., 1998) frequently personalize, or tailor feedback based on theories and models from behavioural sciences to increase effectiveness and even optimize adherence to the intervention (Conner, & Norman, 2005). This specific type of tailoring – personalization of information or feedback based on an individual's score on constructs from behavioural sciences – is called *adaptation* (Hawkins, Kreuter, Resnicow, Fishbein, & Dijkstra, 2008). Whereas traditional interventions frequently use adaptation of feedback, this is rarely applied in modern- day, mobile physical activity applications (op den Akker, Jones, & Hermens, 2014).

A source for identifying how to apply adaptation is social cognition models (SCMs). These define the cognitive factors that underlie social patterns of behaviour. Three well-known examples are the Social Cognitive Theory (SCT), Theory of Planned Behaviour (TPB), and Trans Theoretical Model (TTM) (Conner, & Norman, 2005). The SCT assumes that motivation and action are influenced by forethought (Bandura, 1982). It describes three types of expectancies: situation outcome expectancy, action outcome expectancy, and perceived self-efficacy. It states that personal sense of control makes it possible to change behaviour; if people believe they can take action to accomplish a certain goal, they become more inclined to do so and feel more committed to the decision. The TPB states that behaviour is preceded by intentions, that is, motivation or plans to exert effort to perform behaviour (Ajzen, 1991). Intentions are constituted by attitudes, subjective norms, and perceived behavioural control. By influencing the various beliefs properly, behaviour can be changed and maintained. Finally, the TTM assumes changing behaviour requires progress through five stages (Table 1) and different cognitions may be of importance at different stages (Procheska, & Diclemente, 1983). The stages can be entered and exited at any point and it is possible to relapse to an earlier stage. Next to these stages, the model includes several other constructs: a decisional balance (benefits versus costs), self-efficacy (confidence that one can engage in healthy behaviour; temptation to engage in unhealthy behaviour) and processes of change (activities that people engage in to progress through the stages).

Table 1. Stages of change and their corresponding definition

Stage of change	Definition
Precontemplation	No intention to change behaviour within six months
Contemplation	Intention to change behaviour within the next six months
Preparation	Intention to take steps to change behaviour within the next month
Action	Changed behaviour for less than six months
Maintenance	Changed behaviour for more than six months

Indeed, research shows that traditional interventions that use adaptation based on constructs from SCMs, like attitudes, self-efficacy, stage of change, social support or processes of change, showed significantly larger effect sizes than interventions that did not tailor on these constructs (Hawkins, Kreuter, Resnicow, Fishbein, & Dijkstra, 2008; Procheska, & Diclemente, 1983; Noar, Benac, & Harris, 2007) In addition, guidelines for designing effective physical activity interventions strongly recommend tailoring feedback (Dishman, & Buckworth, 1996; Greaves et al., 2011). Furthermore, O'Reilly and Spruijt-Metz (2013) conclude a systematic review by stating that with respect to using technology for assessment and promotion of physical activity, more research is needed on the effectiveness of interventions that combine real-time, tailored, and adaptive feedback.

Primary objective

It is hypothesized that implementing knowledge from behavioural sciences into modern-day, mobile physical activity applications can further improve their effectiveness, just as in traditional interventions. As such, the aim of this study is to investigate (1) the relation between self-efficacy and objectively measured level of physical activity; (2) the relation between stage of change and objectively measured level of physical activity; and (3) compare level of physical activity between patients and healthy adults.

Secondary objective

Based on the results typical users, that is, personas, will be identified. Tailored feedback strategies will be developed for these personas, which can be used to improve the effectiveness of mobile physical activity coaches in the future. The reason for choosing self-efficacy and stage of change is that these are two aspects, which are of central importance in most SCMs and common in traditional interventions.

METHOD

Data were available for secondary analysis from previous studies performed from 2008 to 2011 (Tabak et al., 2012; Dekker-van Weering, Vollenbroek-Hutten, & Hermens, 2012). Data about stage of change, level of self-efficacy, and objectively measured physical activity were collected, but not used in any way during and after completion of these studies.

Participants

Data of 407 participants were analysed of which 82 were patients diagnosed with one of the following conditions: chronic obstructive pulmonary disease (COPD) (n=39), chronic low back pain (CLBP) (n=20), or cancer (n=23). All of these patients were grouped together, as the literature shows comparable physical activity data of the separate groups (Tabak et al., 2012; Dekker-van Weering, 2012). The patient group consisted of 43 women and 39 men, averaging 60 years of age (standard deviation (SD)=12). The healthy group consisted of 149 women and 176 men. All participants signed an informed consent. A local ethics committee reviewed and approved the study.

Equipment

Two types of mobile activity monitoring system were used: the Activity Coach (AC; see Figure 1) (Van Weering, Vollenbroek-Hutten, & Hermens, 2011; Tabak et al., 2012; Dekker-van Weering, 2012) and a Commercial Activity Monitoring Device (CAMD). The AC was worn by 139 participants (82 patients and 57 healthy controls (AC control participants)). The CAMD was worn by 268 healthy controls (CAMD control participants). The AC consists of a sensor (MTx-w) and a smartphone (HTC). The sensor includes a tri-axial accelerometer, which is used to measure physical activity. It is worm on the hip and sends data to the smartphone through a Bluetooth® connection. Op den Akker et al. (2012) provides a complete description of the system.

Figure 1. The Activity Coach: smartphone application and external sensor.

Procedure

Participants wore the AC the entire day, for seven consecutive days. The goal here was to obtain a baseline measurement of the users' level of physical activity. They did not receive any kind of feedback during these 7 days; only physical activity was measured throughout the day. Additionally, patients were asked to complete a questionnaire assessing their stage of change and working status at the beginning of the experiment.

Participants using the CAMD completed a questionnaire assessing level of self-efficacy regarding physical activity at the start of the experiment (Rodgers, Wilson, Hall, Fraser, & Murray, 2008). Low, average, and high levels of self-efficacy corresponded to scores of 5 through 12, 13 through 17 and 18 through 25, respectively. Hereafter, participants wore the device the entire day, for 3 weeks, to obtain a baseline measurement of their level of physical activity. They did not receive any kind of feedback during these 3 weeks; only physical activity was measured throughout the day.

Data analysis

The accelerometer of the AC calculates activity counts per minute (CPM) as output, which was processed in MATLAB to gain insight in the level of physical activity and physical activity pattern. Level of physical activity was defined as the average amount of Integral of the Modulus of the Accelerometer (IMA) counts per minute per day. A day was considered a valid measurement day if data are collected for 50% of an hour for at least 6h per day. Furthermore, every day part should contain at least 2h of valid data. The day parts were defined as morning (08:00a.m. – 13:00p.m.), afternoon (13:00p.m. – 17:00 p.m.), and evening (17:00 p.m. – 22:00 p.m.). The averages of IMA counts per minute per day part were calculated to investigate differences in physical activity patterns over the day.

The CAMD calculates a ratio between calorie expenditure and basic metabolism, based on age, length, weight, and sex, to estimate level of physical activity. It uses PAL as output measure, which has a minimum of 1.1. If participants show a PAL of 1.7 or above, they are considered active. The exact calculation cannot be disclosed, since the CAMD is commercially available.

Statistical analysis

The correlation between age and level of physical activity was calculated and an analysis of variance (ANOVA) was performed to examine differences between sexes regarding level of physical activity and the effect of working status on level of physical activity to identify possible confounding factors. The latter only investigated this effect for the patient group, since data regarding working status were not available for the AC control group. Patients were classified as unemployed (less than 12 hours of work per week), part-time (between 12 and 36 hours of work per week), or full-time (more than 36 hours of work per week).

A univariate ANOVA was performed to test the difference between the level of physical activity of patients and AC control participants. With respect to the patient group, the difference in level of physical activity per stage of change was analysed using an ANOVA. Furthermore, the level of physical activity of patients per stage of change was compared to the level of physical activity of AC control participants.

Repeated measures-MANOVA was executed to analyse level of physical activity per day part (morning, afternoon, evening); testing differences in patterns between patients and AC controls, and between patients per stage of change. An ANOVA was performed to test whether CAMD control participants with different levels of self-efficacy (low, average, high) show different levels of physical activity.

RESULTS

Results regarding the AC

The results show no significant correlation between age and average daily level of physical activity for neither the patient group ($r = -.107$, $p = .356$) nor the AC control group ($r = .170$, $p = .21$). The ANOVA indicates no significant difference in level of physical activity between sexes in the AC control group ($F(1, 55) = 1.99$, $p = .164$) or in the patient group ($F(1, 75) = 3.34$, $p = .072$). Regarding working status, 56 patients were unemployed, 11 had a part-time job, and 10 worked full-time. No significant difference in level of physical activity was found between working status ($F(2, 74)=1.75$, $p=.182$). Based on these results, it can be assumed that level of physical activity was not influenced by age, sex, or working status in the current study.

The univariate ANOVA shows that patients (mean IMA=947.77) are significantly less active than AC controls (mean IMA = 1089.6) ($F(1, 132) = 8.58$, $p = .004$). Within the patient group, there is a significant difference in level of physical activity per stage of change ($F(3, 72) = 4.00$, $p = .011$) (Figure 2). Patients in the contemplation, preparation, and action stage of change are significantly less active than patients in the maintenance stage of change ($\beta=-197.69$ ($t=-1.99$, $p=.051$); $\beta = -215,69$ ($t = -3.03$, $p = .003$); and $\beta = -221.67$ ($t = -2.01$, $p = .048$), respectively).

Results also show a significant difference in level of physical activity between patients per stage of change and control participants ($F(4, 128)=5.15$, $p=.001$). Contrasts show that patients in the contemplation, preparation and action stage of change are less active than AC controls ($\beta = -226.17$ ($t=-2.35$, $p=.020$); $\beta=-244,26$ ($t=-3.69$, $p<.001$); and $\beta=-250.25$ ($t=-2.33$, $p=.021$), respectively). No significant difference was found in level of physical activity between patients in the maintenance stage of change and AC control participants ($\beta = -28.58$ ($t = -.51$, $p = .61$)) (Figure 2).

Regarding physical activity pattern, the repeated-measures-MANOVA shows a significant difference in activity per day part ($W = .77$, $p < .001$) (GG: $F(1.63, 198.77) = 28.57$, $p < .001$); physical activity over the day of all participants combined shows a quadratic trend from morning to evening ($F(1, 122) = 11.93$, $p = .001$). The interaction effect between activity per day part and group (patient/ AC control) is significant (GG: $F(1.63, 198.77) = 9.45$, $p < .001$), indicating the difference per day part is different for patients than for AC controls. Figure 3 shows that the decline in level of physi- cal activity over the day is much steeper for patients than for AC controls; they are as active as AC controls in the morning ($\beta = 13.042$ ($t = .17$, $p = .865$)), but whereas AC controls show an increase of physical activity in the afternoon, patients show a decrease ($\beta=-191,489$ ($t=-3.27$, $p=.001$), and an even steeper decrease than AC controls in the evening ($\beta = -287.064$ ($t = -4.95$, $p < .001$)).

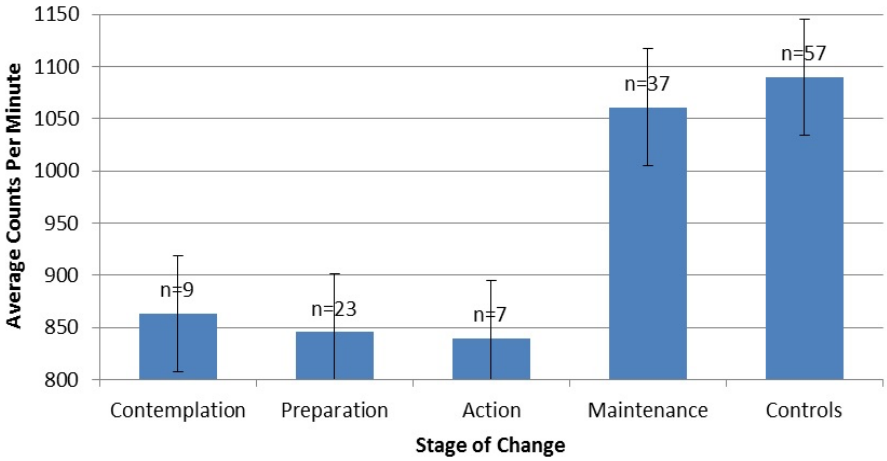

Figure 2. Average CPM per stage of change for patients compared to average CPM of AC control subjects.

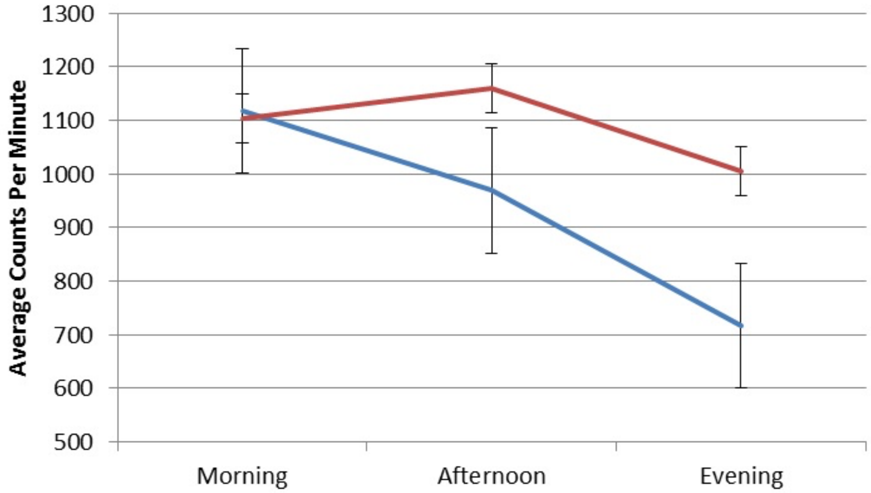

Figure 3. Average CPM per day part for patients (blue) and AC control subjects (red).

With respect to the group of patients, the difference in activity per day part is not different per stage of change (W=.700, p<.001) (GG: F(4.61, 95.35)=1.15, p=.34). To provide an overview, Figure 4 shows the level of physical activity per day part for patients per stage of change as com- pared to the level of physical activity per day part of AC control participants. Whereas AC control participants show a small drop in level of physical activity over the day, all patients show the same pattern of high decline in level of physical activity from morning till evening, regardless of the participant's stage of change.

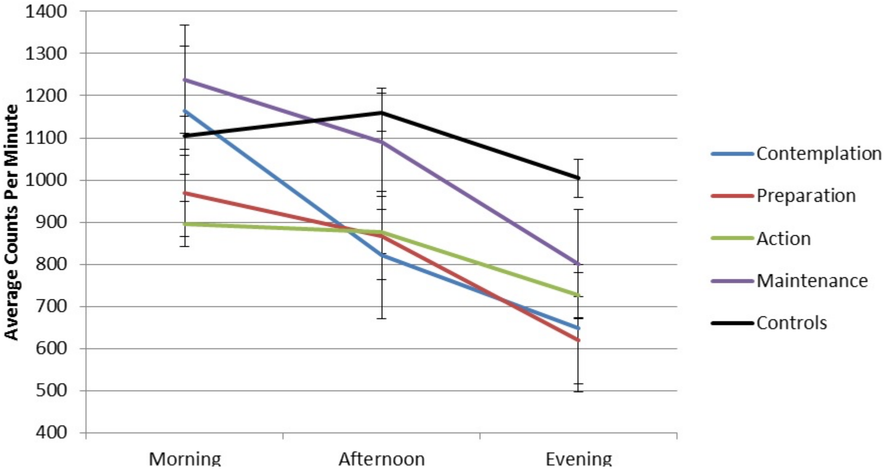

Figure 4. Average CPM per day part for patients per stage of change as compared to AC control subjects.

Results regarding the CAMD

With respect to the CAMD and the relationship between self-efficacy and physical activity, sex was added to the model as a fixed factor, as the ANOVA showed a significant difference in level of physical activity between sexes ($F(1, 266) = 6.55$, $p = .011$); men (mean PAL = 1.657; SD = .133) are more active than women (mean PAL = 1.616; SD = .124).

Most CAMD participants were classified as having an average level of self-efficacy regarding physical activity (n=144), 60 participants reported a high level of self-efficacy and 55 participants indicated a low level of self-efficacy. The test shows a significant difference in level of physical activity per category of self-efficacy ($F(2, 253)=8.69$, $p<.001$). The interaction effect with sex is not significant. Contrasts indicate that participants with a low or average level of self- efficacy are significantly less active than participants with a high level of self-efficacy ($\beta = -.080$ ($t = -2.07$, $p = .039$) and $\beta = -0.090$ ($t = -2.70$, $p = .007$), respectively) (Figure 5).

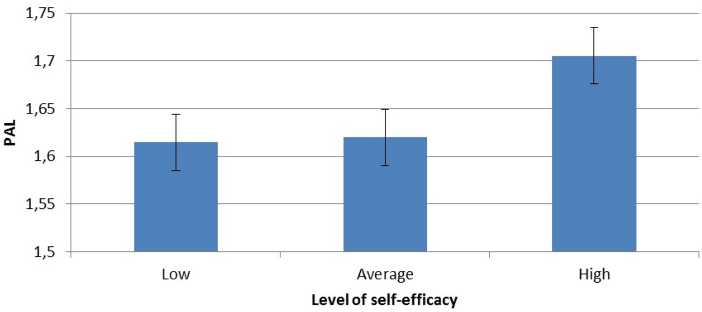

Figure 5. Average level of physical activity per category of self-efficacy.

DISCUSSION

The primary aim of this study was to investigate (1) the relation between self-efficacy and objectively measured level of physical activity, (2) the relation between stage of change and objectively measured level of physical activity, and (3) compare level of physical activity between patients and healthy adults, in mobile physical activity interventions. Secondary, based on the results, typical users were identified and corresponding tailored feedback strategies were developed. Results show that the three factors are significantly related to objectively measured physical activity: self-efficacy, stage of change and being healthy or suffering from a disease.

With respect to self-efficacy, higher levels of self-efficacy are related to higher levels of physical activity. The more participants believe that being sufficiently physically active is within their control, the higher their level of physical activity. These findings are consistent with traditional physical activity research, which shows that participants who have not started to exercise regularly show low levels of self-efficacy, whereas those who have started show high levels of self-efficacy Marcus, Selby, Niaura, & Rossi, 1992).

Having a chronic disease also influences level of physical activity. Patients are less active and show a steeper decline in level of physical activity over the day than healthy participants. Research suggests that patients tend to do all must-tasks (e.g. cleaning, groceries) in the morning, leaving them with little energy to do social and fun activities in the evening (Van Weering et al., 2011; Tabak et al., 2012)

With respect to stage of change, patients in the maintenance stage of change are more active than patients in other stages of change; they are as active as healthy participants. However, patients in the maintenance stage of change show an equally large drop in level of physical activity over the day as other patients and, as such, have an improper activity pattern.

Based on these results, participants can be categorized into eight typical personas, which should receive different coaching strategies based upon the three important variables stage of change, self- efficacy and level of physical activity (Tables 2 and 3). Based on stage of change, participants can be categorized as either having (contemplation, preparation, action) or not having (precontemplation, maintenance) an intention to change behaviour. Based on the activity pattern, participants can show a proper or improper level of physical activity. A proper level of physical activity means sufficient physical activity and a balanced physical activity pattern; improper indicates insufficient physical activity or an imbalanced pattern. Regarding self-efficacy, participants can be categorized as having ‘low to average’ or ‘high’ self-efficacy. Low and average levels of self-efficacy were taken together, as these participants did not show differences in level of physical activity. Ideally, scores on these constructs should be assessed regularly to identify whether they are still categorized as the correct persona, or if they have changed to, for example, a higher level of self-efficacy, for which an adjustment of the coaching strategy is needed.

Table 2. Personas with intention to change

Self-efficacy	Level of activity	
	Proper	Improper
Low-average	Persona 1	Persona 2
High	Persona 3	Persona 4

Table 3. Personas without intention to change

Self-efficacy	Level of activity	
	Proper	Improper
Low-average	Persona 5	Persona 6
High	Persona 7	Persona 8

The personas described above can be used to develop corresponding feedback strategies that can be included into new mobile physical activity applications. It is clear that coaching should at least be tailored to users' level of self-efficacy, stage of change and physical activity pattern. As high self-efficacy not only increases intention, but also leads to actual performance of the target behaviour (Gist, & Mitchell, 1992), much research has focused on how self-efficacy can be influenced and especially on how to increase it. Bandura (1994) describes four sources that can be used to increase self-efficacy: mastery experience, vicarious experience, social persuasion and physiological and emotional states. Regarding personas 1, 2, 5, and 6, who have low levels of self-efficacy, mastery experience could be implemented by setting challenging but attainable, personalized goals (Locke, & Latham, 2002), leading to success experiences. Adding optional data sharing leads to vicarious experience and additionally sending persuasive feedback messages makes for higher exerted effort of users to achieve their goal. A meta-analysis showed that of these four strategies to increase self-efficacy, feedback on previous performance or previous performance of similar others cause the highest effect sizes, followed by vicarious experience (Ashford, Edmunds, & French, 2010). As such, this might also be hypothesized to be the most effective strategy to include in mobile physical activity applications.

Regarding stage of change, ten specific strategies to move from stage to stage, or processes of change, have received much attention and empirical support (Velicer, Prochaska, Fava, Norman, & Redding, 1998). Five can be identified as experiential processes (increasing awareness, emotional arousal, social reappraisal, social liberation, and self-reappraisal), and the other five are referred to as behavioural processes (stimulus control, social support, counter conditioning, rewarding, committing). Experiential processes are primarily used for early stages, while behavioural processes are recommended for later stages (Bandura, 1994). Therefore, coaching for personas 1, 2, 3, and 4 should focus on behavioural processes of change, whereas coaching for personas 5, 6, 7, and 8 should focus on experiential processes.

The coaching strategies were implemented into the AC (Figure 1) and are currently tested in a field study. First, level of self-efficacy, stage of change and level of physical activity are assessed at baseline, after which participants are automatically identified as one of the eight personas, which determines what feedback messages they will receive during the intervention; different personas receive different feedback messages.

CONCLUSION

Just as traditional physical activity interventions, modern-day mobile physical activity applications should include adaptation and tailored feedback strategies into their coaching, which might lead to increased effectiveness and hopefully to even better intervention adherence, and adherence to physical activity guidelines. This is not yet known. However, this study can be regarded as first step towards testing this. It identifies personas and provides guidelines for development of feed- back that takes into account individual scores on constructs from behavioural sciences. The next step is to test these findings in daily life. Additionally, there are many other factors associated with physical activity (e.g. social support, benefits, barriers, etc.), and as such, future research should investigate further adaptation and tailoring of feedback strategies in mobile physical activity interventions using knowledge from social cognition models.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Chapter 3

The influence of success experience on self-efficacy when providing feedback through technology

Published as Achterkamp, R., Hermens, H. J., & Vollenbroek-Hutten, M. M. R. (2015). The influence of success experience on self-efficacy when providing feedback through technology. *Computers in Human Behavior*, *52*, 419-423.

ABSTRACT

Background: as a high level of self-efficacy is associated with bigger behavioural changes as well as to higher levels of physical activity, the development and implementation of strategies that successfully improve self-efficacy are important to technological interventions. We performed an experiment to investigate whether using feedback strategies that focus on success experience and are provided through technology can influence self-efficacy regarding a specific task.

Method: subjects were asked to walk from A to B in exactly 14, 16 or 18 seconds, wearing scuba fins and a blindfold. The task guaranteed an equal level of task experience among all subjects at the start of the experiment and makes it difficult for subjects to estimate their performance accurately. This allowed us to manipulate feedback and success experience through technology-supported feedback.

Results: subjects' self-efficacy regarding the task decreases when experiencing little success and that self-efficacy regarding the task increases when experiencing success. This effect did not transfer to level of self-efficacy regarding physical activity in general. Graphical inspection of the data shows a trend towards a positive effect of success experience on task performance.

Conclusion: experiencing success is a promising strategy to use in technology-supported interventions that aim at changing behaviour, like mobile physical activity applications.

INTRODUCTION

More and more people live a sedentary lifestyle, resulting in a decrease in health and posing a risk for various diseases (e.g. Bankoski et al., 2011; Warren et al., 2010). On the other hand, a physically active lifestyle has significant positive effects on prevention of chronic diseases, such as cardiovascular disease, diabetes and cancer (Warburton, Nicol & Bredin, 2006). Also, a sufficient level of physical activity has positive effects on mental health condition through reduced perceived stress and lower levels of burnout, depression and anxiety (Jonsdottir et al., 2010). Numerous interventions have already been developed to improve the level of physical activity in the general population (e.g. Marcus et al., 1998; Dishman & Buckworth, 1996). They are usually delivered through public media, flyers, e-mails, or consist of face to face (group) consultations, and show moderate effect sizes (Dishman & Buckworth, 1996).

A recent development regarding physical activity interventions is using mobile, technology-supported applications to achieve the desired effect. Examples include UbiFit Garden (Consolvo et al., 2008), BeWell+ (Lin et al., 2012) and Move2Play (Bielik et al., 2012). A study by Op den Akker et al. (2014) concluded that many interventions apply tailoring, i.e. personalization of information or feedback, which increases the effect of the intervention (Hawkins et al., 2008). The most common technique is to provide previously obtained information about the individual and some also include a tailored goal and tailored inter-human interaction. Although the effectiveness of tailoring based on constructs from behavioural science – or adaptation (Hawkins et al., 2008) – has been proven, Op den Akker et al. (2014) show that none of the interventions used adaptation as a tailoring strategy. Such lack of adaptation in technology-supported physical activity interventions was also noticed by Achterkamp et al. (2015), who developed specific feedback strategies for these types of intervention. Four of the six feedback strategies include a focus on increasing self-efficacy, making it an important aspect when designing mobile activity coaches (Achterkamp et al., 2015).

The concept op tailoring information or feedback enhances relevance for the individual and increases the impact of the message; guidelines for designing effective physical activity interventions strongly recommend tailoring feedback (Greaves et al., 2011). Traditional, non-technology-supported interventions that apply adaptation, e.g. by providing tailored information based on subjects' attitudes, stage of change, social support or processes of change, show significantly larger effect sizes than interventions that do not tailor on these constructs (Noar, Benac, & Harris, 2007). Additionally, self-efficacy seems of major importance (Hawkins et al., 2008); a construct that is common in models and theories that explain behaviour and behavioural change. High self-efficacy not only increases intention to perform the target behaviour, it also leads to actual performance of the target behaviour (Gist & Mitchell, 1992). Additionally, Achterkamp et al. (2015) showed that the level of self-efficacy is related to 1) level of activity at baseline: the higher the subjects' level of self-efficacy, the higher their level of physical activity; and 2) the percentage of change as a result of a twelve week intervention: for subjects who are inactive at the start of the intervention, a higher level of self-efficacy is associated with a higher level of increase in physical activity. Bandura (1994) describes four sources of self-efficacy:

- Mastery experience: the subject successfully performs the target behaviour.
- Vicarious experience: the subject observes a similar other perform the target behaviour.
- Verbal (or social) persuasion: expressing faith in the subject's capabilities.
- Physiological / affective states: correcting misinterpretations of bodily states.

A systematic review with meta-analysis (Ashford, Edmunds & French, 2010) shows that the most successful strategy to increase self-efficacy for physical activity is using enactive mastery experience, including feedback about previous performance/successes, followed by vicarious experience and feedback about similar others' performance.

So, traditional non-technology-supported interventions emphasize the importance of increasing self-efficacy to maximize the chance of positive results, but this knowledge is rarely applied in technology-supported interventions and it is not yet clear how this should be done. Therefore, the aim of the current study is to investigate whether experiencing success also leads to an increase in self-efficacy when using technology-supported feedback strategies. To our knowledge, no such experiment has been performed until now. Specifically, we aim to answer the following questions: what is the effect of a feedback strategy that focuses on success experience on 1) level of self-efficacy regarding a specific task, 2) level of self-efficacy regarding physical activity, and 3) task performance?

METHOD

Participants

The call for participation was distributed through e-mail, social media and the involved researchers personally. Subjects were included if they were Dutch-speaking and did not have walking disabilities. These criteria were necessary considering instructions were in Dutch and, as much as, possible rule out the influence of walking ability.

Fifteen subjects were included and participated in the study; nine women and six men. Age ranged from 22 to 36 years and averaged 27 years (SD=4). All participants signed an informed consent. A local ethics committee reviewed and approved the study.

Procedure

The study used a repeated measures design. Subjects came to the lab of Roessingh Research and Development three times, with an interval of approximately seven days. During their first visit, subjects signed an informed consent, after which they completed a questionnaire assessing demographical variables and stage of change. Stage of change was assessed using the questionnaire by Prochaska and DiClemente (1983). A modified version of the

Multidimensional self-efficacy for Exercise Scale was used to assess self-efficacy (Rodgers et al., 2008). Next, subjects received information about the task they would have to perform. They were then asked to put on scuba fins and were allowed to practice walking in a straight line. Next, the subjects were asked to put on a blindfold and could again practice walking. Following this introduction, subjects completed a total of 15 trials of the task (see below). They were then asked to complete a self-efficacy questionnaire, after which the subject had to complete another six trials. The procedure during the second and third visit of the subject was equal to the first visit, except for signing the informed consent.

Task

Subjects were asked to walk from one side of the lab to the other (8 meters), in exactly 14, 16, or 18 seconds (target time), wearing scuba fins and a blindfold. Subjects were told that the goal was to get as close to the target time as possible; the closer they were, the higher their reward would be. The reward was given after every trial, in the form of applause, ranging from 0 to 10 claps. Subjects started between a red light laser and reflector, which functioned as a starting gate on one side of the lab. A second laser and reflector combination functioned as a finishing gate and was placed at the other side of the lab. The distance from start to finish was approximately eight meters. The sensors were linked to the PC to measure the exact time subjects needed to reach the finishing gate. Subjects were reassured that the experimenter would correct their course if they deviated too much. Otherwise, the experimenter did not intervene during the task; the instructions for every trial and the feedback were provided automatically through speakers.

At the start of every trial, the subjects were asked the following automated question via the speakers: “To what extend do you think you can successfully accomplish this task on a scale of 0 to 100?” The experimenter entered the subject’s answer in the PC. Next, the following automated message sounded: “After the countdown, walk to the other side of the lab in exactly X seconds”. X corresponded to 14, 16 or 18 seconds. The PC randomly picked on of the three options, such that every target time was prompted five times. These times were chosen based on results of a pilot study that showed that they corresponded to fast, normal, and slow walking speeds respectively. Following the countdown, the subject walked from the starting gate to the finishing gate. Upon reaching the finishing gate, another automated message would sound: “stop, you have reached the destination.” After this, the subject was given feedback about their performance; how close were they to the target time. The number of claps depended on the condition they were in.

In the *positive feedback condition*, subjects only received feedback as if they performed well, leading to the experience of success. Subjects always heard 6 to 9 claps, independent of their actual performance.

In the *negative feedback condition*, subjects only received feedback as if they performed badly, leading to the experience of failure. Subjects always heard 1 to 3 claps, independent of their actual performance.

In the *correct feedback condition*, subjects received correct feedback: higher deviation from the target time lead to lower rewards and vice versa. See Table 1 for the deviations and their corresponding rewards. This condition functioned as a control group.

Subjects did not receive information about whether they were too slow or too fast in any condition. After hearing the reward, the trial ended and the subject was allowed to remove the blindfold and prepare for the following trial. After 15 of these trials, the subject completed the self-efficacy questionnaire, which was followed by another 6 trials without feedback, functioning as retention trials.

Each subject completed all three conditions during the three separate different visits. The order of the conditions was randomized.

Table 1. Percentage of deviation from target time and the corresponding rewards per target time

Deviation from target	Reward	Target 14 sec.	Target 16 sec.	Target 18 sec.
->100%	0	-	-	-
-100-90%	1	0.0 – 1.4	0.0 – 1.6	0.0 – 1.8
-90-80%	2	1.4 – 2.8	1.6 – 3.2	1.8 – 3.6
-80-70%	3	2.8 – 4.2	3.2 – 4.8	3.6 – 5.4
-70-60%	4	4.2 – 5.6	4.8 – 6.4	5.4 – 7.2
-60-50%	5	5.6 – 7.0	6.4 – 8.0	7.2 – 9.0
-50-40%	6	7.0 – 8.4	8.0 – 9.6	9.0 –10.8
-40-30%	7	8.4 – 9.8	9.6 – 8.0	10.8 – 12.6
-30-20%	8	9.8 – 11.2	11.2 – 12.8	12.6 – 14.4
-20-10%	9	11.2 – 12.6	12.8 – 14.4	14.4 – 16.2
-10-0-10%	10	12.6 – 14 – 15.4	14.4 – 16 – 17.6	16.2 – 18.0 – 19.8
10-20%	9	15.4 – 16.8	17.6 – 19.2	19.8 – 21.6
20-30%	8	16.8 – 18.2	19.2 – 20.8	21.6 – 23.4
30-40%	7	18.2 – 19.6	20.8 – 22.4	23.4 – 25.2
40-50%	6	19.6 – 21.0	22.4 – 24.0	25.2 – 27.0
50-60%	5	21.0 – 22.4	24.0 – 25.6	27.0 – 28.8
60-70%	4	22.4 – 23.8	25.6 – 27.2	28.8 – 30.6
70-80%	3	23.8 – 25.2	27.2 – 28.8	30.6 – 32.4
80-90%	2	25.2 – 26.6	28.8 – 30.4	32.4 – 34.2
90-100%	1	26.6 – 28.0	30.4 – 32.0	34.2 – 36.0
>100%	0	>28.0	>32.0	>36.0

Data Analysis

The three main outcome parameters are: 1) self-efficacy regarding the task, 2) self-efficacy regarding physical activity, and 3) performance.

1) Task-specific self-efficacy was calculated by averaging the answers to the question that was prompted at the start of every trial per condition.
2) Self-efficacy regarding physical activity was calculated by averaging the scores on the self-efficacy questionnaire per condition.
3) Performance was measured by calculating the difference between the target time and the time the subject took to walk from the starting gate to the finishing gate in milliseconds.

Statistical Analysis

A Repeated Measures Analysis of Variance was performed to test the effect of success experience (Condition) on level of task-specific self-efficacy, self-efficacy regarding physical activity and task performance. We did not correct for age or gender.

RESULTS

The average level of task-specific self-efficacy on the trials with feedback was 58.69 (SD=23.00), 31.49 (SD=18.75), and 59.11 (SD=21.59) for the correct, negative and positive feedback conditions respectively. The Repeated Measures ANOVA shows a main effect for task-specific self-efficacy (F(2,28)=37.37, p<.001). Figure 1 clearly shows that in the negative feedback condition the task-specific self-efficacy decreases, initially steeply, whereas it increases in the positive and correct feedback condition. After three to four trials, the effect of the feedback on level of self-efficacy regarding the task stabilizes. Level of task-specific self-efficacy during the retention trials did not change significantly and was not different from level of task-specific self-efficacy during the first 15 trials, indicating retention of behaviour.

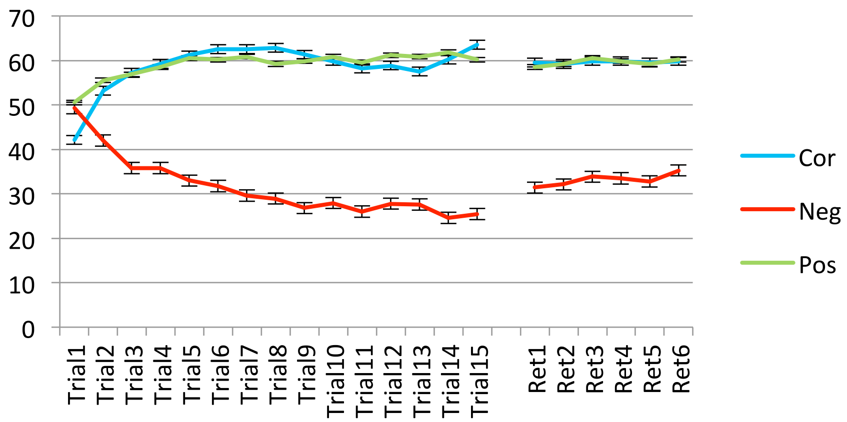

Figure 1. Self-efficacy regarding the task over time per condition.

The Repeated Measures ANOVA to test the effect of the various conditions on self-efficacy regarding physical activity in general was not significant; the scores for the correct, negative and positive feedback conditions averaged 70.33 (SD=18.44), 70.29 (SD=16.63), and 72.46 (SD=13.85) respectively (F(2,28)=1.673, p=.206).

Task performance did not vary significantly per condition (F(2,28)=.557, p=.579). However, Figure 2 shows an interesting trend: performance (actual time in milliseconds minus target time) was best in the correct feedback condition (mean=-141, SD=5460) and worst in the negative feedback condition (mean=595, SD=4319). In the positive feedback condition, subjects gradually shifted from walking too fast in the beginning to walking too slow in the end (mean=-184, SD=5216). Regarding the retention trials, deviation from the target time was lowest in the correct feedback condition (mean=-12, SD=2132), followed by the negative (mean=268, SD=1581) and positive (mean=447, SD=2340) feedback condition. This effect was not significant (F(2,28)=.481, p=.623).

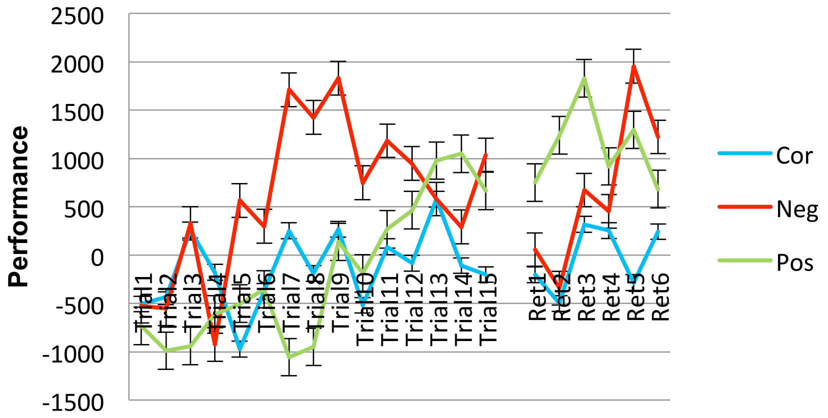

Figure 2. Deviation from target time (performance) over time per condition

DISCUSSION

The main aim of the current study was to investigate whether experiencing success leads to an increase in self-efficacy when using technology-supported feedback strategies. Specifically, we focused on the effect of a feedback strategy that focuses on success experience on 1) level of self-efficacy regarding a specific task, 2) level of self-efficacy regarding physical activity, and 3) task performance. The task was to walk from A to B (eight meters), in exactly 14, 16, or 18 seconds (target time), wearing scuba fins and a blindfold. Subjects were told that the closer they were to the target time, the higher their reward would be. Feedback was manipulated to simulate success experience and failure. Additionally, a ‘correct feedback’ condition was included.

Results show that it is possible to manipulate task-specific self-efficacy using specific feedback (1). When subjects were asked to perform a new task, self-efficacy regarding the task rapidly decreased and stayed low when subjects did not experience success. On the other hand, self-efficacy regarding the task rapidly increases and stays high when subjects do experience success. This is in accordance with theory by Bandura (1994); failure and success lead to decreased and increased sense of self-efficacy respectively.

The effect of the feedback on level of self-efficacy regarding the task did not transfer to self-efficacy regarding physical activity in general (2). Self-efficacy is known to be task specific (Bandura, 1986; Bandura, 1989), but also to transfer to tasks on related domains under the following conditions: 1) when the task relies on similar sub-skills, 2) when skills in various domains are developed together (co-development), and 3) through extremely powerful mastery experiences (Woodruff and Cashman, 1993; Bandura, 1997). Apparently, these principles did not apply enough to the task in the current study to transfer to a high level of self-efficacy regarding physical activity; subjects developed skills during the experiment that were not similar enough to skills that are relevant to physical activity in general.

However, the goal of the current study required that subjects had equal task experience at the start of the experiment and difficulty to estimate performance, leading to the somewhat unusual task. A different, less artificial task that is more closely related to physical activity should be investigated if establishing this transfer is the main goal.

Results indicate that the feedback did not significantly influence subjects' task performance measured by the deviation (in milliseconds) from the target time (3). So, as opposed to research that shows that changes in self-efficacy lead to changes in behaviour (Gist & Mitchell, 1992), the amount of success subjects experienced did not change performance. However, results do show a trend when looking at the correct and negative feedback conditions: the less success subjects experience, the more they deviate from the target time. Subjects seem to base their strategy for the oncoming trial on the feedback they received after the previous trial; when this indicates bad performance, as in the negative feedback condition, subjects change their behaviour into a new approach. Contrarily, subjects only slightly change their behaviour in the correct feedback condition. The same conclusion can be drawn when looking at the positive feedback condition. However, performance in the positive feedback condition does deteriorate due to an inability to accurately estimate actual performance and change behaviour in the correct direction. In other words, it seems that experiencing success leads to increased self-efficacy even when performance is not optimal. This would mean that, to achieve increased self-efficacy and optimal performance, feedback should be as positive as possible, but at the same time also be correct. The lack of a significant effect could be explained by the low number of subjects in the current study, insufficient difficulty of the task, or too small differences between conditions.

Summarizing, incorporating mastery experience in technology-supported interventions can potentially increase self-efficacy and possibly even effectiveness in the same way as in of non-technology-supported interventions, indicating that adaptation might indeed be of added value. Applying these feedback strategies leads to increased self-efficacy and could possibly lead to changes in behaviour. However, it does not mean only positive feedback should be provided; results tend to show it is most effective to only let users experience their success at the moment they performed well, otherwise self-efficacy might increase while performance is not optimal (see Figure 1 and Figure 2).

Whether these results can be replicated in an ecologically valid environment or daily life is still a topic for future research. One example to apply adaptation in mobile activity coaches is to prompt a questionnaire to assess level of self-efficacy at baseline, after which subjects receive feedback based on their score on the questionnaire. Achterkamp et al. (2015) does describe a set up and plans for testing such adaptation versus no adaptation in a certain mobile activity coach, but no results are published yet. Furthermore, Arteaga et al. (2010) tested a form of adaptation in a system in which subjects' personality traits, like extraversion and openness, determined which games they received. However, the authors did not include a control group that received the games at random, meaning no statements can be made about the effectiveness of adding this type of adaptation.

Future research should also investigate feedback strategies that aim at other sources of self-efficacy regarding physical activity to maximize effectiveness of technology-supported interventions, i.e. vicarious feedback, verbal persuasion and interpretation of physiological states (Bandura, 1994). Indeed, verbal persuasion is already applied in many interventions through providing motivational messages (Op den Akker 2014), but often without the explicit goal to increase self-efficacy. Although vicarious feedback is not frequently implemented, it is relatively easy to apply, for example by showing successful performance of similar others on a (mobile) device before performing the task. This is also easily combined with verbal persuasion and mastery experience; apart from the effect of these concepts separately, it is interesting to investigate the combined effect of these sources in technology-supported interventions. Regarding 'interpretation of physiological states', subjects with low self-efficacy regarding physical activity might benefit from information about the effects of (sufficient) physical activity on fatigue or muscle soreness. However, research identifies this source as the least important source of self-efficacy (Chowdhury, Endres and Lanis, 2002).

CONCLUSION

Self-efficacy can be influenced when using technology-supported feedback strategies. This study is a first step towards adaptation of technology-supported interventions, it shows self-efficacy can indeed be increased by experiencing success; the next step is to incorporate this knowledge into tailored feedback strategies of mobile activity coaches and test its effect on both level of self-efficacy and performance. Overall, the role of self-efficacy in these types of intervention deserves more attention and it is clear that there is still much to be investigated regarding this relation.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Chapter 4

The influence of vicarious experience provided through mobile technology on self-efficacy when learning new tasks

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ABSTRACT

Background: A high level of self-efficacy is a major contributor to the effectiveness of physical activity interventions. However, it is insufficiently known whether techniques that are used to influence self-efficacy in face-to-face or printed text interventions can also be successfully incorporated in modern-day, mobile technology-supported interventions. We performed an experiment to investigate whether self-efficacy regarding a specific task can be influenced through vicarious experience provided through mobile technology.

Method: 36 subjects were asked to walk from A to B in exactly 14, 16, or 18 seconds, wearing scuba fins and a blindfold. The task guaranteed equal level of task experience at the start of the experiment. Before every trial, subjects in group 1 viewed a video on a smartphone of a subject successfully performing the task, subjects in group 2 did not view a video.

Results and conclusion: although subjects found the video helpful for successful performance of the task and reported high perceived similarity, subjects' level of self-efficacy regarding the task, as well as task performance did not differ significantly between the two groups. However, a secondary outcome parameter did indicate a possible difference between how subjects walked forward while wearing the scuba fins (either shuffling forward, or raising their knees high up). Future studies should investigate whether such instructional videos can contribute to higher levels of self-efficacy in mobile, technology-supported interventions in more ecologically valid settings.

INTRODUCTION

Smartphones and other mobile technologies like activity sensors are used more and more in coaching programs to improve physical activity patterns (Bielik et al., 2012; Consolvo et al., 2008; Lin et al., 2012). However, the present coaching programs hardly take into account knowledge from behavioural science, which is hypothesized to improve interventions in terms of persuasiveness and adherence (Achterkamp et al., submitted for publication). One way of doing this is by incorporation of tailoring, i.e. personalization of feedback or coaching based on information from the individual (Hawkins, Kreuter, Resnicow, Fishbein, & Dijkstra, 2008). Op den Akker et al. (2014) describe a literature survey about coaching in mobile physical activity applications in relation to techniques to apply tailoring, which have repeatedly been associated with higher effect sizes of interventions (Noar, Benac, & Harris, 2007). The techniques Op den Akker et al. (2014) identified are: feedback, inter-human interaction, adaptation, user targeting, goal setting, context awareness, and self-learning. The most interesting finding: whereas the tailoring technique described as adaptation – i.e. tailoring based on constructs from behavioural science – is a common technique in traditional, non-technology supported interventions, the authors show that this specific tailoring technique is rarely applied in modern-day mobile, technology supported physical activity interventions (op den Akker, Jones, & Hermens, 2014).

Constructs that are used for adaptation in traditional interventions include, for example, attitudes towards the target behaviour, stage of change, social support, processes of change and self-efficacy (Noar, et al., 2007). For example: adaptation of interventions based on stage of change means that subjects in the maintenance stage of change receive different information or feedback than subjects in the contemplation stage of change; subjects receive information based on their stage of change. Among the constructs used for adaptation, especially self-efficacy seems of major importance (Achterkamp et al., submitted for publication). Self-efficacy is defined as “one’s belief in one’s ability to succeed in specific situations” (Bandura, Adams, & Beyer, 1977). Higher levels of self-efficacy are associated with higher levels of physical activity, and the percentage increase in physical activity in a twelve week intervention period is higher when self-efficacy is high (e.g. (Achterkamp, et al., submitted for publication; Trost, Kerr, Ward, & Pate, 2001). Furthermore, research shows that self-efficacy is a powerful predictor of actual performance of the desired behaviour (e.g. (Bandura, 1994; Gist & Mitchell, 1992; Roach et al., 2003). So, when self-efficacy is low, it suggests that it should be increased to achieve optimal result of the intervention; Bandura (1994) describes four sources of self-efficacy that can be used to achieve this:

- Mastery experience: the subject successfully performs the target behaviour;
- Vicarious experience: the subject observes a similar other perform the target behaviour;
- Verbal (or social) persuasion: verbally expressed faith in the subject’s capabilities by others;

- Physiological / affective states: (mis)interpretations of bodily states.

Ashford, Edmunds and French (2010) showed that using mastery experience is the most powerful source to increase self-efficacy, followed by vicarious experience. Although little is known about applying these techniques in mobile, technology supported interventions, recent research does indicate that mastery experience can indeed be an effective source to influence self-efficacy in these types of intervention (Achterkamp, Hermens, & Vollenbroek-Hutten, 2015). Considering that the systematic review with meta-analysis by Ashford et al. (2010) indicates vicarious experience as the most powerful source to influence self-efficacy after mastery experience (Ashford, Edmunds, & French, 2010), the goal of the current study is to investigate whether it is possible to successfully apply vicarious experience when using mobile, technology supported feedback strategies.

Regarding vicarious experience, traditional face-to-face interventions typically involve a model and an observer. The observer learns from the model who demonstrates how the task should be performed. By observing the model, the observer can identify certain principles, rules or responses relevant for successful performance (Strecher, McEvoy DeVellis, Becker, & Rosenstock, 1986). Bandura (1977) states that through this observation of others, subjects obtain knowledge about how new behavioural patterns are formed, which they can then use when performing the new behaviour themselves. Two aspects are of major importance for this to lead to an actual increase in self-efficacy:

1) The model should be similar to the observer, so that the observer can identify with the model; comparable age, gender and appearance are crucial (Bandura, et al., 1977; Kassin, Fein, & Markus, 2010; Strecher, et al., 1986).
2) The model should perform the target behaviour with some difficulty; research shows that phobic subjects benefit more from observing models who overcome their problem by exerting effort than from models who overcome their problem easily (Bandura, et al., 1977).

The aim of the current study is to investigate whether vicarious experience leads to an increase in self-efficacy when using technology-supported feedback strategies. Specifically, we designed a lab experiment in which two groups were compared: subjects in group 1 viewed an instructional video before performing a new task, whereas subjects in goup 2 did not view this video. Thereby, the aim is to answer the following questions: what is the effect of a feedback strategy that incorporates vicarious experience and is delivered through technology on 1) self-efficacy regarding a specific task, and 2) task performance?

METHOD

Participants

The call for participation was distributed through e-mail, social media and the involved researchers personally. Subjects were included if they were Dutch-speaking and did not have walking disabilities.

In total, 36 subjects were included; 17 women and 19 men. Age ranged from 19 to 61 years and averaged 25.6 (SD=7.2). All participants signed an informed consent. A local ethics committee reviewed and approved the study.

Procedure

The study used a repeated measures design. Subjects came to the lab of Roessingh Research and Development once, but performed the required task six times. Subjects first signed an informed consent, after which they completed a questionnaire assessing demographical variables. Hereafter, they were randomly assigned to one of two groups.

- Group 1 – vicarious experience: subjects in this group viewed a video of a same sex model who successfully performs the task before the start of every trial.
- Group 2 – control: subjects in this group did not view a video. Otherwise the procedure was equal to group 1.

Next, subjects received information about the task they would have to perform. See below for a detailed description. The goal was to walk from A to B in exactly 14, 16, or 18 seconds, wearing scuba fins and a blindfold. They were asked to put on scuba fins and were allowed to practice walking in a straight line, after which the subjects were asked to put on a blindfold and could again practice walking. Following this introduction, subjects completed a total of six trials of the task.

Task

Subjects were asked to walk from one side of the lab to the other (8 meters), in exactly 14, 16, or 18 seconds (target time), wearing scuba fins and a blindfold. Subjects were explained that the goal was to get as close to the target time as possible; the closer they were, the better they performed. However, subjects did not receive feedback after trials. Subjects started between a red light laser and reflector, which functioned as a starting gate on one side of the lab. A second laser and reflector combination functioned as a finishing gate and was placed at the other side of the lab. The distance from start to finish was approximately eight meters. The sensors were linked to a computer to measure the exact time subject needed to reach the finishing gate. Subjects were reassured that the experimenter would correct their course if they deviated too much. Otherwise, the experimenter did not intervene during the task; the instructions for every trial were provided through the smartphone and speakers.

Subjects in group 1 would start by viewing the example of successful performance on the smartphone. Hereafter, all subjects were asked the following automated question via speakers: “To what extend do you think you can successfully accomplish this task on a scale of 0 to 100”. The experimenter entered the subject’s answer in the computer. Next, the following automated message sounded: “After the countdown, walk to the other side of the lab in exactly X seconds”, where X corresponded to 14, 16 or 18 seconds. The computer randomly picked on of the three options, such that every target time was prompted two times. These times were chosen based on results of a pilot study that showed that these target times corresponded to fast, normal, and slow walking speeds respectively. Following the countdown, the subject walked from the starting gate to the finishing gate. Upon reaching the finishing gate, another automated message would sound: “stop, you have reached the destination.” After this, the speakers prompted: “prepare for the following attempt.”

To eliminate the effect of mastery experience on level of self-efficacy, subjects in none of the two groups received information after each trial about how close they were to the target time or whether they were too slow or too fast. After hearing the message “prepare for the following attempt”, subjects in group 1 would proceed to again view the video of a successful attempt on the smartphone, whereas subjects in group 2 would not view this video and simply prepare for the following attempt. Subjects were allowed to remove the blindfold while preparing for the following trial. This procedure was equal for all following trials.

Data Analysis

The two primary outcome parameters were:

1) Self-efficacy regarding the task: the answer to the question “To what extend do you think you can successfully accomplish this task on a scale of 0 to 100” that was prompted at the start of every trial.
2) Performance: measured by calculating the difference between the target time and the time the subject took to walk from the starting gate to the finishing gate in milliseconds.

Secondary outcome parameters (qualitative):

1) Identification with model: subjects in the vicarious experience group were asked to rate to what extend they could identify themselves with the model on a scale of 0 to 100 and what lead them to give this score.
2) Helpfulness of video: subjects in the vicarious experience group were asked whether viewing the model helped them perform the task and which aspects they thought were most important for that.
3) Walking strategy: after the instructional videos were shot we noticed that the two models used different techniques of walking with scuba fins. The male model shuffled his feet forward with the scuba fins on the ground, whereas the female model bent her knee and raised her feet up high in front of her to step forward. Although this was unintentional, it was decided to include this as a last qualitative

variable. Subjects in the group with vicarious experience were categorized as either matching, or not matching the model's technique.

Statistical Analysis

A Repeated Measures Analysis of Variance was performed to test the effect of Group (vicarious experience vs. control), Time (trial 1 to 6) and the interaction between Group and Time on level of self-efficacy and task performance. We did not correct for age or gender.

RESULTS

Primary outcome parameters

The average level of task-specific self-efficacy did not differ significantly between the group with vicarious experience and the control group (F(1,34)=.678, p=.416): the group with vicarious experience scored 66.2 (SD=17.4) on average, while the control group scored 60.7 (SD=22.3). The main effect of time was also non-significant (F(5,30)=1.175, p=.345), meaning self-efficacy scores did not differ per trial. Furthermore, the RM ANOVA showed that the interaction between group and time was non-significant (F(5,30)=1.359, p=.267), indicating that in this experiment, no difference existed between how subjects responded over time per condition. These results are summarized in Figure 1, which clearly shows that the differences are small.

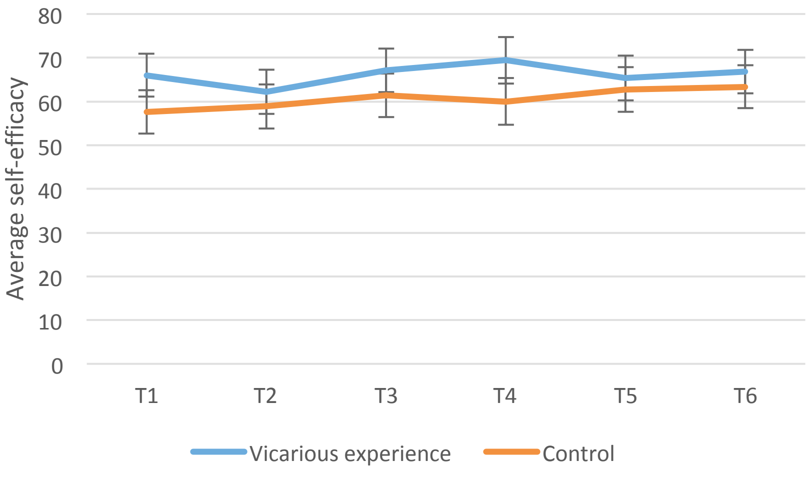

Figure 1. Self-efficacy regarding the task over time per condition including Standard Error bars.

Task performance, as measured by the deviation from the target time in milliseconds, did not vary significantly over time (F(5,30)=.950, p=.463) or per condition (F(1,34)=.508, p=.481). The interaction was also non-significant (F(5,30)=1.008, p=.430). However, Figure 2 does show an interesting trend: performance seems better in the group with vicarious experience (mean=9, SD=3030) than in the control group (mean=917, SD=4473), especially when looking at the first three trials. Whereas the group with vicarious experience shifts towards a lower deviation from the target time, the deviation from the target time in the control group increases over time.

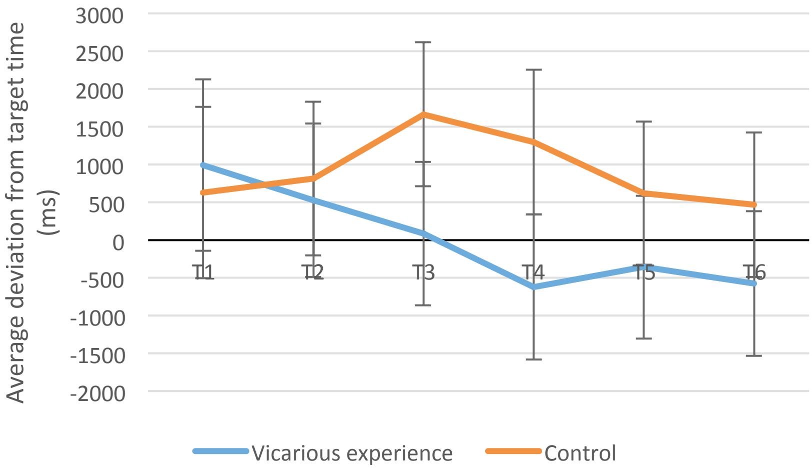

Figure 2. Deviation from target time (performance) over time per condition including Standard Error bars.

Secondary outcome parameters

With respect to the vicarious experience group, male and female subjects indicated to moderately identify with the model, showing mean scores of 71,7 (SD=14.7), and 71,4 (SD=19.0) respectively. Subjects named several factors that contributed to higher identification: equal gender (mentioned by 15 subjects), comparable age (mentioned by 9 subjects), comparable length (mentioned by 5 subjects) and comparable body composition (mentioned by 4 subjects). Subjects also named factors that negatively influenced identification with the model: different walking strategy (mentioned by 3 subjects), higher perceived confidence of the model (mentioned by 2 subjects), different clothing style (mentioned by 2 subjects), different age (mentioned by 1 subject) and different hair color (mentioned by 1 subject).

Of the eighteen subjects in the vicarious feedback group, twelve found the videos helpful for successful performance of the task. Subjects named various factors that could be distilled from the video which helped them while executing the task: number of steps necessary to walk from A to B (mentioned by 10 subjects), estimating how many steps to take per second (mentioned by 5 subjects), step length (mentioned by 5 subjects) and the rhythm of the sound of the scuba fins (mentioned by 5 subjects). Six subjects rated the videos unhelpful, because the model had a different walking strategy (mentioned by 3 subjects) or because subjects mistakenly thought that the same video was presented six times, but with a different target time presented on the screen (mentioned by 3 subjects).

Regarding walking strategy, fifteen out of eighteen subjects matched the walking strategy of the model during all trials, while three out of eighteen inconsistently switched between strategies. Specifically, six out of seven male subject and nine out of eleven female subjects used the same walking strategy as the model they viewed in the video before every trial.

Post-hoc analyses

A post-hoc RM ANOVA was performed to investigate differences in performance between subjects with a lower level of self-efficacy and subjects with a higher level of self-efficacy. As suggested by literature (Schwarzer & Jerusalem, 1995), the median level of self-efficacy was used to categorize subjects into two groups: (1) subjects with a score below the median level of self-efficacy over all trials (67.03), and (2) subjects with a score above this median. Results, however, do not indicate a significant main effect of group ($F(1,34)=2.755$, $p=.106$), nor a significant interaction effect ($F(5,30)=.705$, $p=.624$); in this experiment, subjects with a lower level of self-efficacy did not show a different level of performance than subjects with a higher level of self-efficacy. Also, performance over time does not differ significantly between the two groups (see Figure 3).

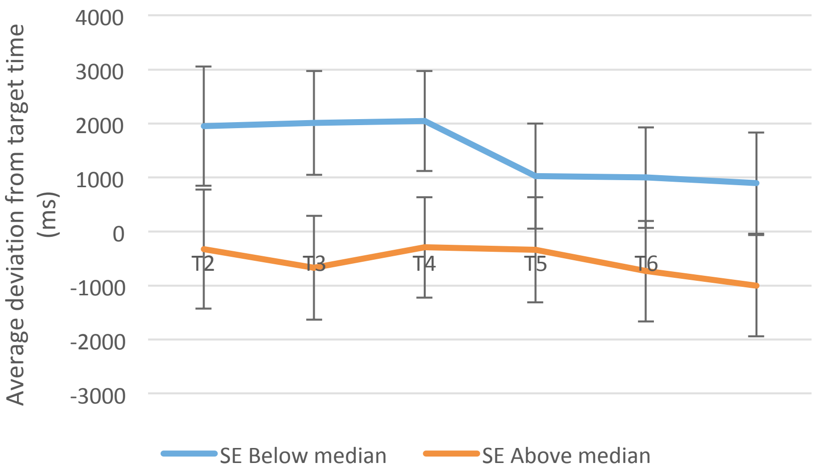

Figure 3. Deviation from target time (performance) over time per level of self-efficacy including Standard Error bars

DISCUSSION

The main aim of the current experiment was to investigate whether vicarious experience leads to an increase in self-efficacy when using technology-supported feedback strategies. Specifically, we focused on the effect of a feedback strategy that used vicarious experience on 1) level of self-efficacy regarding a specific task, and 2) task performance. The task was to walk from A to B (eight meters), in exactly 14, 16, or 18 seconds (target time), wearing scuba fins and a blindfold. The subjects' goal was to get as close to the target time as possible. A group in which subjects viewed a video in which a model performs the task successfully (vicarious experience) was compared to a control group in which subjects did not view a model perform the task.

Results indicate partial success. Although Figure 1 and Figure 2 do indicate a difference between the two groups in the expected direction, the differences are too small in relation to the inter-subject variability to be significant. As such the vicarious experience strategy was unsuccessful in influencing both self-efficacy (1) and task performance (2). This is contrary to theory from Bandura (1994) who states that observing a model leads to an increase in self-efficacy and changes in task performance or behaviour. Traditional face-to-face or TV/video, interventions frequently successfully apply these techniques (Bautista, 2011; Hagen, Gutkin, Wilson, & Oats, 1998). The lack of a significant effect in the current experiment cannot be attributed to too low similarity between observer and model; average to high identification scores were reported by all subjects in the vicarious experience group and subjects named many factors that increased their perceived similarity and only few factors that negatively influenced it. Furthermore, two thirds of the subjects indicated the video as helpful for successful performance of the task. Why vicarious experience did not lead to the expected effect might be due to several reasons:

- The task that was used is rather artificial and has a low ecological validity. Therefore it might not be comparable to the traditional interventions. The reason for choosing this specific task was to guarantee equal task experience of subjects at the start of the experiment and thereby increase comparability of the two groups.
- Bandura (1977) states that vicarious experience is most powerful when subjects see that the model is rewarded upon finishing the task. This was intentionally left out of the current experiment to exclusively focus on vicarious experience and not mastery experience.
- Other factors such as: the low number of participants per condition, high inter-subject variability, too small differences between conditions, insufficient difficulty of the task, or, considering the relatively high self-efficacy scores on the first trials, a ceiling effect regarding self-efficacy.

Although the primary outcome parameters indicated no significant effect of vicarious experience, one of the secondary outcome parameters seems interesting: 83% of the subjects in the group with vicarious experience copied the walking strategy of the model in the video they viewed before the start of every trial, indicating that subjects might have picked up some elements from the video and incorporated these in their strategy. Male subjects tended to shuffle forward, whereas female subjects raised their knees up high and stepped forward, corresponding to the model in the video male and female subjects viewed. Although Strecher et al. (1986) do indicate that observers may identify and use only certain principles that are demonstrated by a model, alternative explanations cannot be ruled out and should be investigated more thoroughly in a future experiment in which, for example, subjects are randomly assigned to either a group viewing a model performing the task shuffling or a group viewing a model that uses an alternative strategy.

Overall, future studies should investigate whether vicarious experience can contribute to higher levels of self-efficacy in modern day mobile, technology-supported physical activity interventions, but in a more ecologically valid setting than the case in the current experiment. For example, it would be interesting to investigate whether providing a video that shows instructions for physical activity, instead of providing coaching through text messages, is more effective when applied in daily life physical activity interventions. Earlier research on study behaviour of students already showed that showing an animated version or a live video of task performance by a model is more effective than providing spoken text (van Gog & Rummel, 2010).

CONCLUSION

This study aimed to influence self-efficacy and task performance through vicarious experience using mobile, technology-supported feedback strategies. Results indicate partial success; self-efficacy and task performance did not change significantly, although a trend in improvement of task performance was present. Secondary outcome parameters indicate that vicarious experience could have contributed to differences in walking strategy. Future research should investigate this finding more thoroughly and in a more ecologically valid setting.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Chapter 5

Goal achievement, self-efficacy and level of physical activity of overweight adults during two-week use of a mobile tailored physical activity application

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ABSTRACT

Background: Mobile physical activity monitoring and feedback applications used as self-management tool without professional face-to-face contact are scarcely investigated in overweight subjects. The goal of this exploratory study is to obtain insights regarding goal achievement, self-efficacy regarding physical activity, and daily level of physical activity of overweight adults using a mobile physical activity application. Secondarily, differences between effects of feedback tailored to self-efficacy versus general feedback messages are described.

Method: fourteen days, thirty overweight subjects used a mobile physical activity application that provides automated, real-time feedback messages based on physical activity.

Results: subject achieved their goal 77 times over all feedback days. Subjects with low levels of self-efficacy at the start reported higher levels of self-efficacy at the end of the two weeks.

Conclusion: Overall goal achievement was moderate. The increase in level of self-efficacy is promising considering its strong mediating role in achieving a sufficient level of physical activity.

INTRODUCTION

In 2015, 43 percent of the Dutch population above four years of age was overweight or even obese (Centraal Bureau voor de Statistiek, 2016). This is no exception, most developed countries show comparable prevalence (OECD, 2010) or even as high as 68.8% in the USA (National Institute of Health, 2012). Not only does overweight and obesity form a major risk for (cardiovascular) diseases and chronic illnesses (Freedman, Dietz, Srinivasan, & Berenson, 1999), it also leads to enormous costs in healthcare (Finkelstein, Fiebelkorn, & Wang, 2003). A successful strategy for targeting overweight lies in interventions that aim to improve physical activity levels and are in this regard extremely important; a sufficient level of physical activity has not only repeatedly been associated with a reduced chance of overweight and obesity, but also, among others, a reduced chance of cardiovascular disease and diabetes (Warburton, Nicol, & Bredin, 2006), and higher levels of mental wellbeing (Jonsdottir, Rödjer, Hadzibajramovic, Börjesson, & Ahlborg Jr, 2010). Recent technological advancements led to an enormous increase in research on mobile, technology-supported physical activity interventions or applications that measure physical activity throughout the day through built-in smartphone technology or using external sensors (Bort-Roig, Gilson, Puig-Ribera, Contreras, and Trost, 2014). The ubiquitous nature of modern-day technology is promising and sensors nowadays provide very detailed information for precise measurement of physical activity.

Interestingly, research on mobile, technology-supported physical activity monitoring and feedback applications in overweight subject samples is scarce; interventions targeting overweight through increasing level of physical activity still mostly rely on face-to-face sessions with healthcare professionals or therapists. Recent interventions do measure objective level of physical activity, but only as a means to evaluate effectiveness of the intervention, i.e. to assess level of physical activity pre- and post-intervention (e.g. Bäcklund, Sundelin, & Larsson, 2011; Siwik et al., 2013; Beavers et al., 2014; Heiss, 2015). In other words, while showing promising positive effects in the general population (Goode et al., 2017), technology-supported physical activity interventions in overweight subject samples that do not comprise face-to-face contact are scarce, and technology-supported measurement of daily level of physical activity including real-time feedback is rarely applied as intervention itself to increase level of physical activity in overweight adults.

Non-technology-supported physical activity interventions frequently apply theories and models from behavioural sciences that describe the constructs thought to underlie behavioural change to determine the content of feedback and other information (Conner & Norman, 2005), which has repeatedly been associated with higher effect sizes of the interventions (e.g. Spittaels, De Bourdeaudhuij, Brug, & Vandelanotte, 2007). Op den Akker et al. (2014) categorize the possibilities to provide information to individual users of real-time, technology-supported physical activity applications in seven categories of so-called “tailoring” – feedback, inter-human interaction, adaptation, user targeting, goal setting, context awareness, and self-learning – and show that adaptation, i.e. tailoring of feedback based on individuals' scores on constructs from behavioural sciences, is rarely applied in modern-day, mobile physical activity applications (Op den Akker et al., 2014). Based on these findings, we suggest implementation of tailored feedback strategies in technology-supported physical activity applications that provide real-time feedback, and we emphasize the need to focus on increasing self-efficacy (Achterkamp et al., 2016a); "one's belief in one's ability to succeed in specific situations" (Bandura, Adams, & Beyer, 1977). Higher levels of self-efficacy regarding physical activity are associated with higher levels of physical activity, and the percentage of increase in physical activity in a twelve week intervention period is higher when self-efficacy is high (e.g. (Achterkamp, et al. 2016a; Trost, Kerr, Ward, & Pate, 2001). Additionally, high self-efficacy has not only been associated to successfully achieving, but also to maintaining a sufficient level of physical activity, up to nine months post-intervention (Whipple, Kinney, and Kattenbraker, 2008; Neupert, Lachman, and Whitbourne, 2009; McAuley, Szabo, Gothe, and Olson, 2011). As such, self-efficacy regarding physical activity should indeed be regarded a key construct in technology-supported physical activity applications and when low, the focus should be on increasing it, e.g. through tailored feedback messages (Achterkamp et al., 2016a).

Based on the findings above and that, to our knowledge, no studies in this regard are available, we set up a study to look into daily level of physical activity of overweight subjects. In accordance with the renewed framework for evaluation of telemedicine (Jansen-Kosterink, Vollenbroek-Hutten, & Hermens, 2016) based on the staged approach to evaluation of telemedicine (DeChant, Tohme, Mun, Hayes, and Schulman, 1996), the current study was categorized as a Stage II evaluative study. The goal in these types of study is to evaluate specific system objectives to further improve the application, for example by means of a small-scale cohort study. So-called Stage II evaluation endpoints are recommended to focus on potential added value of the telemedicine service regarding both the technology and its clinical purpose (Jansen-Kosterink, Vollenbroek-Hutten, & Hermens, 2016). For comparison, Stage I evaluation focuses on usability and feasibility of the technology, whereas Stage III and IV evaluation focuses on effectiveness, adoption and business models. Considering the above, a small cohort of overweight subjects was recruited to explore whether two week use of a mobile, technology-supported physical activity application that provides frequent, automated, real-time feedback messages leads to: 1) achieving a personalized daily goal, 2) changes in level of self-efficacy regarding physical activity over time, and 3) changes in daily level of physical activity over time. Additionally, we investigated differences between providing feedback according to feedback strategies as suggested by Achterkamp et al. (2016a), as compared to providing feedback as in previous versions of the system. Considering available research we expect that goal achievement, level of self-efficacy, and daily level of physical activity will increase during the two weeks and we expect a trend towards a more positive effect when using tailored feedback strategies.

Additionally, with respect to daily level of physical activity over time, we investigate differences between subjects with low versus high levels of self-efficacy at first use of the application. We expect that subjects with a high level of self-efficacy are more active during the two weeks and increase their level of physical activity more than subjects with a low level of self-efficacy.

METHOD

Participants

The call for participants was distributed through e-mail, social media, flyers and the involved researchers personally. Subjects were included if they were Dutch-speaking adults and overweight. Overweight was defined as having a Body Mass Index (BMI) of 25 or higher. BMI was calculated through dividing subjects' mass in kilogram by their squared height in meters.

Thirty subjects were included and participated in the study; 22 women and 8 men. Age ranged from 24 to 69 years of age and averaged 49.8 (SD=13.6). BMI ranged from 25 to 42.28, with an average of 28.99 (SD=3.93). All participants signed an informed consent. An ethics committee reviewed and approved the study.

Equipment

The Activity Coach (AC) (Figure 1) was used to monitor physical activity throughout the day. The AC system consists of a sensor (Inertia ProMove-3D) and a smartphone (HTC). The sensor includes a tri-axial accelerometer, which is used to measure physical activity. It is worn on the hip and sends data to the smartphone through a Bluetooth™® connection. The accelerometer calculates the average amount of the Integral of the Modulus of the Accelerometer (IMA) counts per minute (CPM) as output, which was processed in MATLAB to gain insight in the daily level of physical activity. Op den Akker et al. (2012) provides a complete description of all technical specifications of the system.

Figure 1. The Activity Coach.

Treatment

All participants wore the AC for fourteen consecutive days. The first seven days were used to obtain a baseline level of physical activity; users did not receive any information about their level of physical activity or feedback during this period. During the second period of seven days, subjects were presented 1) a graph that showed: the day from 08:00 hours up and until 22:00 hours, a tailored daily goal line based on level of physical activity during the baseline week, and the subject's real-time, cumulative level of physical activity, 2) the percentage of deviation from their goal line, and 3) hourly textual feedback messages.

The AC automatically calculated the daily goal by adding ten percent to the average level of physical activity during the baseline week of the individual subject. This percentage was chosen based on the Goal-Setting Theory, stating that behavioural change is more likely to occur when setting specific and small but achievable goals (Locke, & Latham, 2002).

The database of messages was split into three categories:

1) Encouraging messages: to encourage physical activity so that subjects would achieve their daily goal;
2) Neutral messages: prompted when subjects were on course to achieve their daily goal;
3) Discouraging messages: to discourage physical activity, e.g. when subjects would be too active in the morning and maybe not have any energy left in the evening, so that a balanced level of physical activity would be achieved.

Participants in the experimental condition received tailored feedback messages based on their baseline level of physical activity, level of self-efficacy at baseline and stage of change at baseline (Achterkamp et al., 2016a). Participants in the control condition received general feedback messages as used in previous versions of the system.

Procedure

Participants were in- or excluded based on a questionnaire assessing BMI and demographics. Upon inclusion, participants were randomly assigned to either an experimental condition or control condition (see below) and an appointment was made to hand out the AC system and explain instructions of use. During this appointment users were also asked to complete a stage of change (Prochaska & DiClemente, 1983) and self-efficacy (Rodgers, Wilson, Hall, Fraser, & Murray, 2008) questionnaire, which were automatically prompted upon first start of the AC. The outcome of these questionnaires were used to determine the correct feedback strategy, as defined by Achterkamp et al. (2016a). After fourteen days the AC system was collected and participants again completed the stage of change and self-efficacy questionnaires.

Data analysis

Daily level of physical activity was calculated per day by adding up all averages of IMA counts per minute and dividing this number by the number of measured minutes per day. The first seven days of use of the application were categorized as baseline measurement days, these were averaged and included as one measurement day in further analyses, since no differences are expected during the first week of use. Additionally, this approach leads to less tests and thereby higher power. The measurement days during the second week were categorized and included in analyses per day, and named “feedback days”.

Feedback days were categorized as “goal achieved” when the daily average of IMA counts per minute was at least ten percent higher than the average IMA counts per minute of that subject during baseline period. Feedback days were categorized as “goal not achieved” when this was not the case.

Self-efficacy regarding physical activity was calculated by averaging the answers to the questions on the self-efficacy questionnaire. As suggested by literature (Schwarzer & Jerusalem, 1995), the median level of self-efficacy of the current sample (56.88) was used to categorize subjects into a group of subjects with a low level of self-efficacy at baseline or a group of subjects with a high level of self-efficacy at baseline, to investigate differences in changes in daily level of physical activity over time between these two groups.

Sex, age, BMI, and working status were analysed for a possible confounding role in the analyses. Working status comprised three categories: 1) unemployed: working less than 12 hours a week; 2) part-time: working between 12 and 36 hours a week; and 3) full-time: working 36 hours a week or more.

Statistical analysis

Regarding goal-achievement, a Cochran’s Q test was performed to analyze differences in the percentage of subjects who achieve their goal over the seven feedback days.

Regarding self-efficacy and level of physical activity, three mixed model analyses of variance were performed. The first tested the effect of Time (baseline days versus feedback days), Group (self-efficacy below vs. above median at baseline), and the interaction between Time and Group, on level of self-efficacy. The second tested the effect of Group and the interaction between Time and Group, on daily level of physical activity (average IMA counts per minute). The third tested the effect of Time (baseline days versus feedback days), Condition (tailored feedback strategies versus general feedback), and the interaction between Time and Condition, on daily level of physical activity (average IMA counts per minute).

Table 1 shows no confounding effects of sex, age, BMI, or working status and were therefore not included in any of the analyses. Data were judged sufficiently normally distributed, also by an epidemiologist from Roessingh Research and Development.

Table 1. Analysis of possible confounding variables for Condition and Group

	Experimental vs. Control	Self-efficacy below vs. above median
Sex	Fisher’s Exact Test: p=1.0	Fisher’s Exact Test: p=1.0
Working status	$\chi^2(2)$=.800, p=.67	$\chi^2(2)$=.800, p=.67
Age	t(28)=1.172, p=.251	t(28)=-1.257, p=.219
BMI	t(28)=-.308, p=.760	t(28)=1.388, p=.176

RESULTS

To obtain a general impression of the level of physical activity of the current sample, this section starts with a comparison between average level of physical activity of the current sample and that of subject samples of earlier research. Three subsections follow this comparison. Subsection 3.1 provides information about the number of times subjects achieved their individual daily goal, and whether this number of goal-achievers changes over time. Subsection 3.2 is about the effect of use of the application on level of self-efficacy over time. Lastly, subsection 3.3 states results regarding level of physical activity in terms of IMA counts per minute during the two weeks, and provides information about the level of physical activity of the current sample compared to a sample of patients and a sample of healthy control subjects.

Overall, compared to research that used a similar system as in the current study (Tabak, Vollenbroek-Hutten, Van der Valk, Van der Palen, Tönis, and Hermens, 2012; Dekker-van Weering, Vollenbroek-Hutten, and Hermens, 2012; Achterkamp et al., 2016b), subjects in the current sample were as active as patients with chronic obstructive pulmonary disease (COPD), chronic low back pain (CLBP), and cancer, and less active than a group of healthy control subjects, during the seven day baseline period. See table 2 for an overview.

Table 2. Average IMA during a seven day baseline period for overweight subjects (current sample), patients, and control subjects.

	Number of subjects	Average IMA counts per minute during baseline	SD
Overweight	30	928,3	180,8
Patients	82	947,8	283,6
Healthy	57	1089,6	311,24

Results regarding daily goal

Over the seven feedback days on which the thirty subjects could achieve their goal (n=210), subjects succeeded a total of 77 times, versus 133 times not achieving their daily goal. In other words, the daily goal was achieved on 36.7% of all feedback days.

The percentage of subjects that achieved their daily goal per feedback day shows an increase towards the end of the feedback week (Figure 2). However, Cochran's Q test determined that this difference over time was not significant ($\chi^2(6)=8.930$, p=.178).

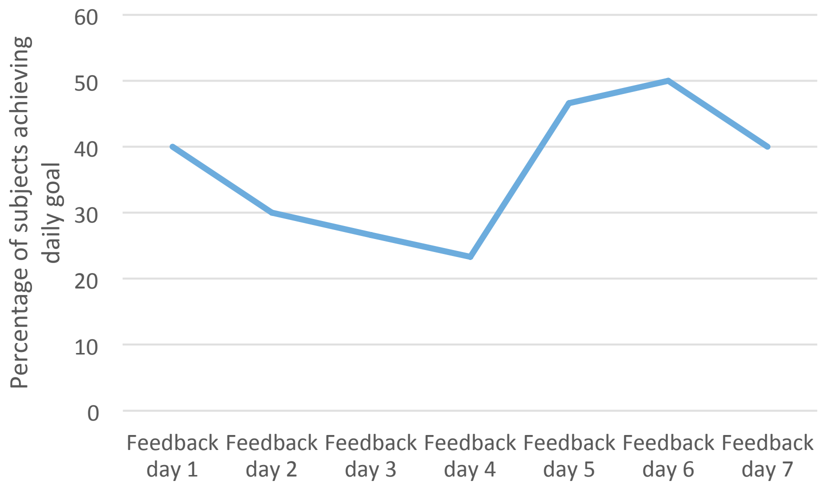

Figure 2. Percentage of subjects that achieved their daily goal per feedback day.

The group that received feedback according to feedback strategies achieved their daily goal on 40.95% of all feedback days, whereas the group of subjects that received feedback as in previous versions of the system achieved their goal on 32.38% of all feedback days. Subjects with a level of self-efficacy below the median of the current sample achieved their goal on 35.24% of all feedback days, whereas subjects with a level of self-efficacy above this median achieved their daily goal on 38.10% of all feedback days.

Results regarding self-efficacy over time

The main effect of Time on level of self-efficacy was found not significant ($F(1,28)=3.177$, $p=.086$); use of the application did not lead to an increase, or decrease, in level of self-efficacy over time. The main effect of Group was significant ($F(1,28)=45.575$, $p<.001$). This makes sense as this variable was constructed to create two groups with different levels of self-efficacy. More interestingly is the significant interaction effect between Time and Group ($F(1,28)=4.587$, $p=.041$): the increase in level of self-efficacy is significantly different for subjects with a level of self-efficacy below median than for subjects with a level of self-efficacy above median. Figure 3 shows that level of self-efficacy increases in subjects with a level of self-efficacy below median at the start of the two weeks, while this is not true for subjects with a level of self-efficacy above median at the start of the two weeks.

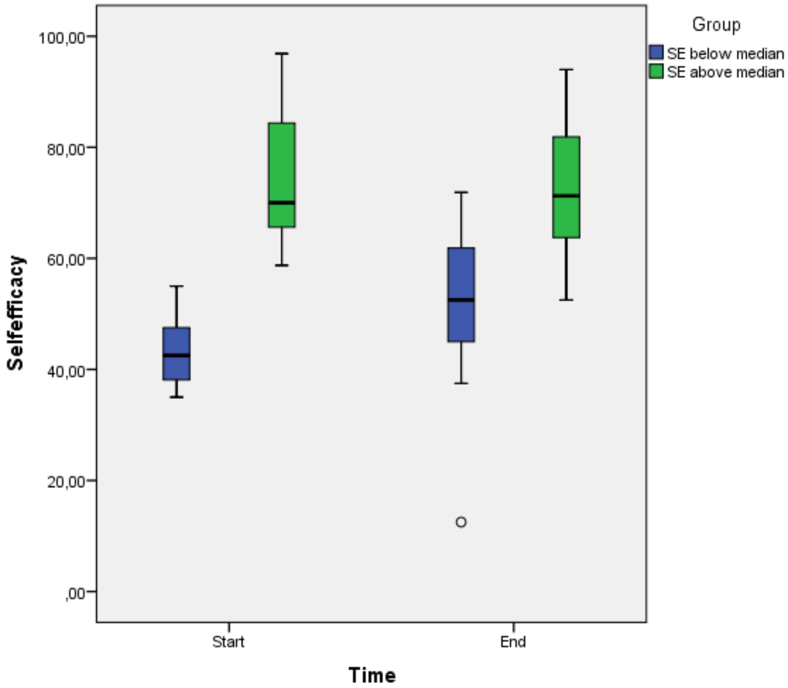

Figure 3. Average score of self-efficacy at the start and at the end of the two weeks for subjects with a level of self-efficacy below median and above median.

Results regarding IMA

Average IMA did not differ significantly over time (F(7;29,082)=.911, p=.512), meaning the level of physical activity does not differ significantly between measurement days. This includes that, in this study, there is no significant difference between level of physical activity at baseline and level of physical activity during feedback days. Looking into differences between conditions, an increasing trend in activity is seen in the experimental condition, which is less notable in the control condition (Figure 4). However, no significant differences were found for the main effect of Condition (F(1;28,027)=.091, p=.765); daily level of physical activity does not differ significantly between experimental and control condition. Furthermore, difference in IMA over baseline and feedback days does not differ significantly between the experimental and control condition (F(7;28,094)=.484, p=.838). Figure 4 summarizes the previous findings, also showing high levels of variability of mean IMA per Time.

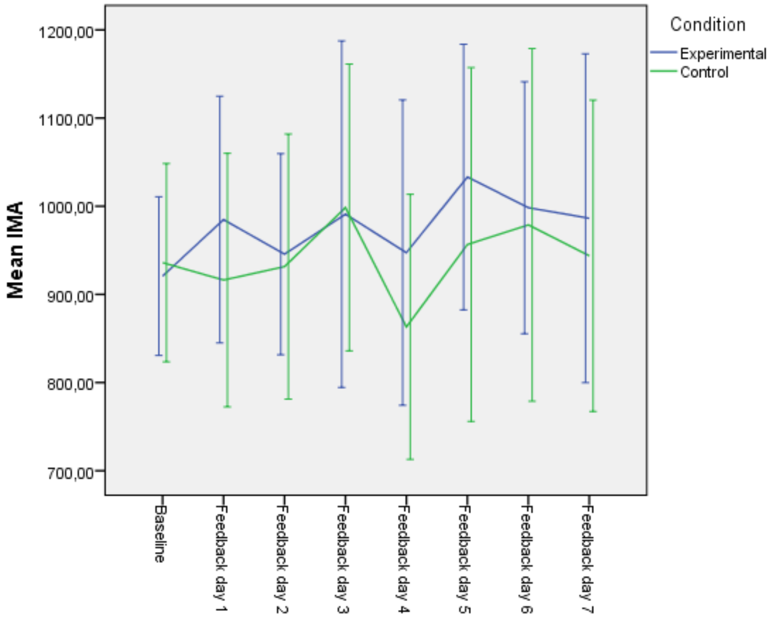

Figure 4. Average IMA during baseline and feedback days for subjects in the experimental and control condition, error bars indicating 95% confidence intervals.

Regarding IMA and self-efficacy, the trend does show higher levels of physical activity over the day of subjects with a level of self-efficacy above median than of subjects with a level of self-efficacy below the median, but the main effect of Group on average IMA was found non-significant (F(1;28,036)=2.876, p=.101). The interaction effect between Time and Group was also found non-significant (F=(7;28,065)=.638, p=.721); in the current study, with respect to IMA counts per minute, subjects with a level of self-efficacy below the median do not respond different to the application over time than subjects with a level of self-efficacy above the median. Results are summarized in figure 5.

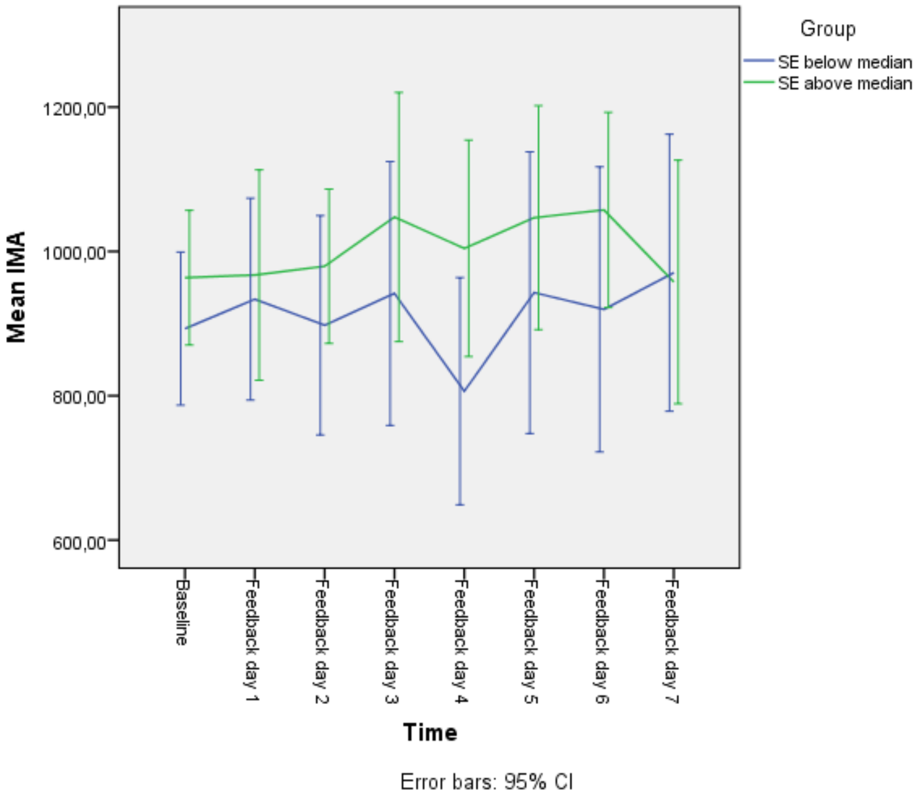

Figure 5. Average IMA during baseline and feedback days for subjects with a level of self-efficacy below median and above median, error bars indicating 95% confidence intervals.

DISCUSSION

The main aim of the current experiment was to explore goal achievement, level of self-efficacy regarding physical activity and daily level of physical activity over time in an overweight subject sample using a two week, mobile and tailored physical activity monitoring and feedback application. Secondly, we investigated whether implementation of tailored feedback strategies leads to other effects in this regard than feedback as usual, and looked into changes in activity levels over time between subjects with low versus high levels of self-efficacy at the start of use of the application. Overweight subjects used the Activity Coach (AC) (Figure 1) fourteen consecutive days; the first seven days where used as baseline measurement, during which the AC only measured activity over the day and did not provide any form of information or feedback to subjects. During the second week, subjects received real-time information about their level of physical activity, a tailored daily goal which was ten percent higher than level of physical activity during baseline week, and hourly feedback messages to help reach their daily goal.

In total, the daily goal was achieved on 36.7% of all feedback days, meaning subjects increased their daily level of physical activity by at least ten percent relative to their baseline activity on just over one third of all feedback days, which is regarded a moderately successful result. Compared to other research, one study regarding a physical activity application shows lower percentages as the case in the current study, where subjects met their goals on 14 to 22 percent of measurement days (Munson & Consolvo, 2012). However, these goals were self-set, and, importantly, activities had to be logged manually by subjects, instead of tracked automatically. Another study showed that 75% of subjects rated their self-set goal as achieved by 50% or more at the end of the study (Knittle et al., 2011). Wing et al. (2004) found a comparable percentage using self-rating: 74% of subjects reported to have achieved their goal of 150 minutes of physical activity per week after an extensive, 16 session physical activity intervention (Wing et al., 2004). Also in this case, level of physical activity and goal achievement were based on self-report, which is known to lead to overestimation of both amount and intensity of level of physical activity (Hagstromer, Ainsworth, Oja, & Sjostrom, 2010). One application used in a randomized controlled trial by Vorrink, Kort, Troosters, Zanen, and Lammers (2016) does look comparable to the Activity Coach; the authors investigated effectiveness of a mobile application that measures step count, which included a personalized goal based on one week baseline activity data. The daily goal was automatically calculated by the application by adding twenty percent to the average daily step count during baseline. Subjects were COPD patients and were supervised by a physiotherapist who could adjust goals of subjects through a web based portal if necessary. Their adherence with respect to wearing the smartphone was high at 89%, and goal achievement was moderate with subjects achieving their goal on 34% of all measurement days; although based on step count and using a goal that was twenty percent higher than baseline, this percentage of goal achievers is comparable to results from the current study. Importantly, the current study reached this percentage without including physiotherapist supervision. However, due to methodological differences with respect to e.g. duration of the intervention, goal height, and measure of physical activity, it remains difficult to directly compare current results to results from other mobile applications or face-to-face interventions, and to make firm conclusions accordingly.

With respect to self-efficacy regarding physical activity over time, use of the application did indeed lead to a significant increase in level of self-efficacy in subjects with a low level of self-efficacy at the start of use of the application (Figure 3). This is promising, considering research that shows that self-efficacy is a powerful predictor of actual performance of the desired behaviour, and higher levels of self-efficacy are associated with higher levels of physical activity and larger benefits from physical activity interventions (e.g. Bandura, 1994; Gist & Mitchell, 1992; Trost, Kerr, Ward, & Pate, 2001; Roach, Yadrick, Johnston, Boudreaux, Forsythe, and Billon, 2003). In the current study, however, this increase in level of self-efficacy did not translate to a significant increase in daily level of physical activity for these subjects.

In accordance with earlier research that shows negative correlations between BMI and level of physical activity (Scheers et al., 2012), the current sample of overweight subjects is less active than a group of healthy control subjects (Achterkamp et al., 2016b). Interestingly however, subjects in the current sample show a daily level of physical activity during baseline that is as low as daily level of physical activity of a group of patients with COPD, CLBP or cancer (Tabak, Vollenbroek-Hutten, Van der Valk, Van der Palen, Tönis, and Hermens, 2012; Dekker-van Weering, Vollenbroek-Hutten, and Hermens, 2012). Table 2 provides an overview of averages and standard deviations per subject group; there is still much to be gained for overweight subjects regarding daily level of physical activity.

Results regarding IMA show that, although Figure 4 shows an increasing trend, use of the AC did not lead to a significant increase in daily level of physical activity over time. Results regarding differences in daily level of physical activity between conditions – tailored versus feedback as usual – and groups – low versus high self-efficacy – were also non-significant. The reasons why use of the application did not lead to significant changes in the expected directions with respect to physical activity in terms of IMA are diverse. Firstly, the stage II approach led to a short duration of the study: fourteen days, of which only seven days were feedback-days in which subjects were supposed to change behaviour. Studies that do find significant changes in behaviour report durations of one to more than twelve months (e.g. Teixeira et al., 2015; McAuley, 1993), making seven days of feedback a too short period. Secondly, the stage II approach also led to a small subject sample, thereby suffering high inter-subject variability. Thirdly, considering this high variability and that subjects were encouraged to increase their daily level of physical activity by at least ten percent, it might be that ten percent is a too low goal to identify significant differences in IMA on group level. Lastly, other research states that frequently applied tailoring techniques may be effective for younger adults, but not for older adults (French, Olander, Chisholm, & Mc Sharry, 2014); thus suggesting age as an important mediator in modern-day, technology-supported physical activity applications. With respect to non-significant findings regarding differences between tailored feedback versus feedback as usual, the two conditions might not have contrasted sufficiently. Other research shows that providing two pages of tailored information does lead to higher likeliness to increase physical activities of daily living than providing two pages of general information (Bull, Kreuter, & Scharff, 1999); varying only short text messages might not be a large enough difference. Furthermore, research suggests that tailoring should not only focus on implementation of feedback based on constructs from behavioural sciences, but should also focus on implementation of other tailoring techniques (Op den Akker, Jones, and Hermens, 2014) and comprise reflective feedback messages (Lee, Kim, Forlizzi, & Kiesler, 2015). Reflective messages were taken up in the message database of the current study, but this was not the primary focus of any of the implemented feedback strategies.

Future research to increase level of physical activity of overweight adults through mobile applications should aim at further improving automatic goal-setting: how to achieve optimal commitment, in what timeframe should goals be achieved, when to set new goals? The framework for goal setting process can help in this regard (Shilts, Horowitz, Townsend, & Townsend, 2004). Additionally, with respect to self-efficacy, other aspects that are known to increase self-efficacy in non-technology-supported interventions, such as mastery experience and vicarious experience (Bandura, 1994) deserve attention. Research on incorporation of these strategies in technology-supported applications shows promising results (Achterkamp, 2015; Achterkamp 2016b). For example, it would be interesting to investigate whether incorporation of in-application videos showing several options for light-intensive activities performed by similar others has a positive effect on self-efficacy and level of physical activity, and to investigate whether this effect is different from providing textual feedback or through graphs. Other research on study behaviour of students already showed that showing an animated version or a live video of task performance by a model is more effective than providing spoken text (van Gog & Rummel, 2010).

Overall, also in light of the high variability in the current study, we should look into individual results and characteristics in more detail, instead of on group level, as the case in the current study, to identify for which subjects the application is effective and for which it is not. Future research regarding mobile, technology-supported physical activity applications as self-management tool should continue to identify working mechanisms and potential effect of these types of application in overweight subjects; stage III evaluation is still a long way to go.

CONCLUSION

We explored goal achievement, level of self-efficacy and daily level of physical activity over time while using a mobile, tailored, physical activity monitoring and feedback application in an overweight subject sample over a two week period. Goal achievement was moderate with 36.7% of subjects achieving their goal. Subjects with low levels of self-efficacy at the start of use of the application reported significantly higher levels of self-efficacy at the end of the two weeks. This is promising considering the strong relationship between self-efficacy regarding target behaviour and actual performance of target behaviour. Although trends are in the expected direction, use of the application did not lead to significantly higher levels of daily level of physical activity over time. Future research should aim at further incorporation of automated goal-setting and continue to identify and incorporate aspects from behavioural sciences in mobile, technology-supported physical activity applications for overweight subjects.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Chapter 6

The influence of real-time and tailored feedback messages on objectively measured level of physical activity in an overweight subject sample

Achterkamp, R., Tönis, T., Hermens, H.J., & Vollenbroek-Hutten, M. M. R., Submitted for publication.

ABSTRACT

Background: Mobile physical activity monitoring and feedback applications are seldom applied without face-to-face contact in overweight subjects. This study investigates the added value of textual feedback messages.

Method: Thirty overweight subjects used a mobile, technology-supported physical activity monitoring and feedback application that provides encouraging, neutral or discouraging feedback messages based on level of physical activity. The first week was used as baseline. During the second week, users received feedback based on a personalized goal.

Results: Feedback messages led to significant changes in level of physical activity in an interval of fifteen minutes after the message was prompted to subjects. No differences were found between the effect of messages based on tailored feedback strategies and messages not based on these strategies.

Conclusion: Real-time textual feedback messages based on objective level of physical activity are smart options to incorporate in mobile, technology-supported physical activity monitoring and feedback applications for overweight adults.

INTRODUCTION

Maintaining a sufficient level of physical activity has repeatedly been associated with a reduced chance of overweight and obesity, but also, among others, a reduced chance of cardiovascular disease and diabetes (Warburton, Nicol, & Bredin, 2006). As such, interventions that are aimed at improving level of physical activity are important. Recent technological advancements led to an enormous increase in research on objective monitoring of physical activity throughout the day. Well-known examples of such devices include Fitbit (Fitbit, 2017) and Samsung Gear Fit (Samsung, 2017). Much research has focused on accurate objective monitoring of physical activity, which led to many interventions in overweight subject samples to apply objective monitoring of physical activity as a means to evaluate effectiveness of face-to-face interventions to increase level of physical activity (e.g. Bäcklund, Sundelin, & Larsson, 2011; Siwik et al., 2013; Beavers et al., 2014; Heiss, 2015). However, mobile, technology-supported physical activity applications are seldom investigated as self-management application itself in overweight subject samples, while research in the general population shows promising results (Goode et al., 2017). However, also in the general population, it is still unclear how exactly to provide the most effective feedback based on these accurate measurements (Op Den Akker, Jones, Hermens, Hermens, & Jones, 2014). Earlier research on non-mobile or face-to-face physical activity interventions does provide evidence that incorporation of tailoring, i.e. personalization of information, increases the effect of the intervention; research shows significantly larger effect sizes when communication is tailored on e.g. subjects' attitudes, stage of change, social support or processes of change than when tailoring is not applied (Hawkins et al., 2008); tailoring enhances relevance for the individual and thereby increases the impact of communication. Also guidelines for designing effective physical activity interventions strongly recommend tailoring feedback (Greaves et al., 2011) Till now, these tailoring techniques are seldom applied in mobile, technology-supported physical activity applications (Op Den Akker, Jones, Hermens, Hermens, & Jones, 2014). Exploratory lab studies on this topic show that letting subjects experience success leads to an increase in self-efficacy – i.e. "one's belief in one's ability to succeed in specific situations" (Bandura, Adams, & Beyer, 1977) – when providing feedback through technology (Achterkamp, Hermens, & Vollenbroek-Hutten, 2015) and that viewing a model perform the desired behaviour on a mobile phone before task performance is promising in this regard (Achterkamp, Hermens, & Vollenbroek-Hutten, 2016a). However, both these studies did not lead to actual behavioural changes and were performed in a lab setting instead of daily life. One ecologically more valid study using an overweight subject sample did show that use of a mobile, tailored technology-supported physical activity monitoring and feedback application led to changes in level of self-efficacy regarding physical activity, but not to a significant increase of daily level of physical activity over a two week period (Achterkamp, Hermens, and Vollenbroek-Hutten, submitted for publication). Still, this can be regarded as promising, as self-efficacy is thought of as a major contributor to actual performance of target behaviour, or in this case, a sufficient level of physical activity over the day (e.g. Trost, Kerr, Ward, & Pate, 2001; Whipple, Kinney, and Kattenbraker, 2008; Neupert, Lachman, and Whitbourne, 2009; McAuley, Szabo, Gothe, and Olson, 2011).

The aim of this study is to explore whether short textual feedback messages are smart options to incorporate in such technology-supported physical activity applications for overweight adults by investigating the immediate effects of textual feedback messages. Specifically, we investigate differences between level of physical activity in an interval of fifteen minutes before, and fifteen minutes after having provided a textual feedback message based on real-time level of physical activity in overweight subjects.

Secondarily, knowing that tailored feedback strategies to increase self-efficacy and achieve optimal effectiveness of interventions are seldom applied in mobile, technology-supported applications (Op den Akker, Jones, & Hermens, 2014), but found effective in non-technology-supported interventions (e.g. Spittaels, De Bourdeaudhuij, Brug, & Vandelanotte, 2007), the aim was to explore whether the immediate effect of the feedback messages was different when providing textual feedback messages based on tailored feedback strategies by Achterkamp et al. (2016b), instead of providing feedback messages that are not based on these strategies. It is hypothesized that textual messages that are based on tailored feedback strategies lead to larger changes in level of physical activity than feedback messages that are not based on these strategies.

METHOD

Participants

The call for participants was distributed through e-mail, social media, flyers and the involved researchers personally. Subjects were included if they were Dutch-speaking adults and overweight. Overweight was defined as having a Body Mass Index (BMI) of 25 or higher. BMI was calculated through dividing subjects' mass in kilogram by their squared height in meters.

Thirty subjects were included and participated in the study; 22 women and 8 men. Age ranged from 24 to 69 years of age and averaged 49.8 (SD=13.6). BMI ranged from 25 to 42.28, with an average of 28.99 (SD=3.93). All participants signed an informed consent. An ethics committee reviewed and approved the study.

Equipment

The Activity Coach (AC) (see Figure 1) was used to monitor physical activity throughout the day. The AC system consists of a sensor (Inertia ProMove-3D) and a smartphone (HTC). The sensor includes a tri-axial accelerometer, which is used to measure physical activity. It is worn on the hip and sends data to the smartphone through a Bluetooth™® connection. The accelerometer calculates the average amount of the Integral of the Modulus of the Accelerometer (IMA) counts per minute (CPM) as output, which was processed in MATLAB to gain insight in the daily level of physical activity. Op den Akker et al. (2012) provide a complete description of all technical specifications of the system.

Figure 1. The Activity Coach.

Treatment

All participants wore the AC for fourteen consecutive days. The first seven days were used to obtain a baseline level of physical activity; users did not receive any information about their level of physical activity or feedback during this period. During the second period of seven days, subjects were presented 1) a graph that showed: the day from 08:00 hours up and until 22:00 hours, a tailored daily goal line based on level of physical activity during the baseline week, and the subject's real-time, cumulative level of physical activity, 2) the percentage of deviation from their goal line, and 3) hourly textual feedback messages.

The AC automatically calculated the daily goal by adding ten percent to the average level of physical activity during the baseline week of the individual subject. This percentage was chosen based on the Goal-Setting Theory, stating that behavioural change is more likely to occur when setting specific and small but achievable goals (Locke, & Latham, 2002).

The database of messages was split into three message types and varied depending on the percentage of deviation from the goal line at the moment of providing the message:

1) Encouraging messages, to encourage physical activity so that subjects would achieve their daily goal, were prompted to subjects if their level of activity deviated more than ten percent below their goal line;
2) Neutral messages, prompted when subjects showed a deviation from their goal line of less than ten percent – either above or below their goal line – indicating subjects were on course to achieve their goal;
3) Discouraging messages, to discourage physical activity, e.g. when subjects would be too active in the morning and maybe not have any energy left in the evening, so that a balanced level of physical activity would be achieved, were prompted to subjects when level of activity was more than ten percent higher than the goal line.

Participants were assigned to either:

A. An experimental condition in which subjects received tailored feedback messages based on their baseline level of physical activity, level of self-efficacy at baseline and stage of change at baseline (Achterkamp et al., 2016a), or;

B. A control condition in which subjects received general feedback messages as used in previous versions of the system.

Procedure

Participants were in- or excluded based on a questionnaire assessing BMI and demographics. Upon inclusion, participants were randomly assigned to either an experimental condition or control condition and an appointment was made to hand out the AC system and explain instructions of use. During this appointment users were also asked to complete a stage of change (Prochaska & DiClemente, 1983) and self-efficacy (Rodgers, Wilson, Hall, Fraser, & Murray, 2008) questionnaire, which were automatically prompted upon first start of the AC. For subjects in the experimental condition, the outcome of these questionnaires were used to determine the correct feedback strategy, as defined by Achterkamp et al. (2016a). After fourteen days the AC system was collected and participants again completed the stage of change and self-efficacy questionnaires.

Data analysis

The primary outcome parameter "change in level of physical activity after a feedback message" was defined by subtracting the average IMA of an interval of fifteen minutes after the message was provided, from the average IMA of an interval of fifteen minutes before the message was provided. Figure 2 shows a hypothetical illustration if change in level of physical activity after an encouraging feedback message. The IMA values of fifteen minutes after the message was prompted are summed and divided by fifteen, this is also done for the fifteen minutes before the message was prompted. Next, these two numbers are subtracted, leaving the change in level of physical activity.

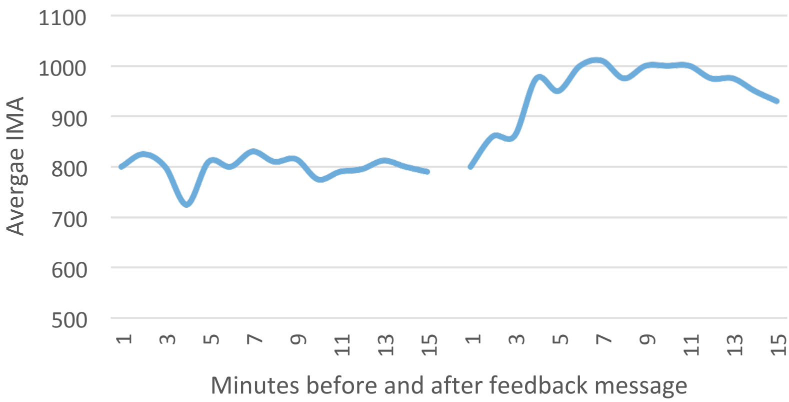

Figure 2. Hypothetical illustration of change in level of physical activity after an encouraging feedback message.

Self-efficacy regarding physical activity was calculated by averaging the answers to the questions on the self-efficacy questionnaire.

Sex, age, BMI, and working status were analyzed for a possible confounding role in the analyses. Working status comprised three categories: 1) unemployed: working less than 12 hours a week; 2) part-time: working between 12 and 36 hours a week; and 3) full-time: working 36 hours a week or more.

Total number of messages was calculated for each message category per feedback day.

Statistical analyses

A mixed model analysis of variance was performed to test the effect of Condition (experimental versus control), Message category (encouraging, neutral, discouraging) and the interaction between Condition and Message category on change in level of physical activity after a feedback message. Message category was regarded a repeated measure, as messages were presented to subjects more than once.

The non-parametric Friedman Test was performed to analyze changes in the number of messages that were prompted to subjects per feedback day. This was calculated for each message category separately.

Table 1 shows no confounding effects of sex, age, BMI, or working status and were therefore not included in further analyses.

Table 1. Analysis of possible confounding variables

	Condition	Group
Sex	Fisher's Exact Test: p=1.0	Fisher's Exact Test: p=1.0
Working status	$\chi^2(2)=.800$, p=.67	$\chi^2(2)=.800$, p=.67
Age	t(28)=1.172, p=.251	t(28)=-1.257, p=.219
BMI	t(28)=-.308, p=.760	t(28)=1.388, p=.176

RESULTS

A total of 1641 feedback messages were sent to and read by subjects during the seven feedback days; 390 of these were encouraging, 598 were neutral, and 653 were discouraging (Figure 3). The experimental group received 883 messages in total and the control group received a total of 758 feedback messages. Total number of messages per message category is shown in figure 3, for both experimental and control condition. Figure 4 shows the number of messages per message category per day.

Graphical inspection of the relation between feedback day and number of messages per feedback category shows decreasing trends for encouraging and neutral messages over time, and an increasing trend for discouraging messages. Analysis using a non-parametric Friedman Test show results regarding encouraging and discouraging messages were not significant ($\chi^2(6)=8.612$, p=.197; $\chi^2(6)=2.649$, p=.851, respectively). The number of neutral messages did differ significantly per feedback day ($\chi^2(6)=15.705$, p=.015). A follow up analysis comparing number of messages per feedback day, with the last feedback day as reference category and applying Holm-Bonferroni correction, showed a significant difference in number of neutral messages between the second feedback day and the last (Z=-3.141, p=.002).

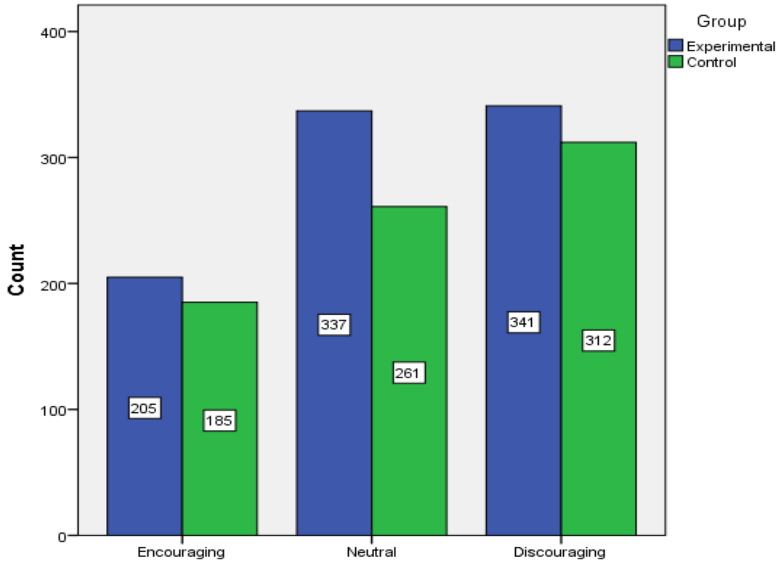

Figure 3. Total number of messages per message category for both groups.

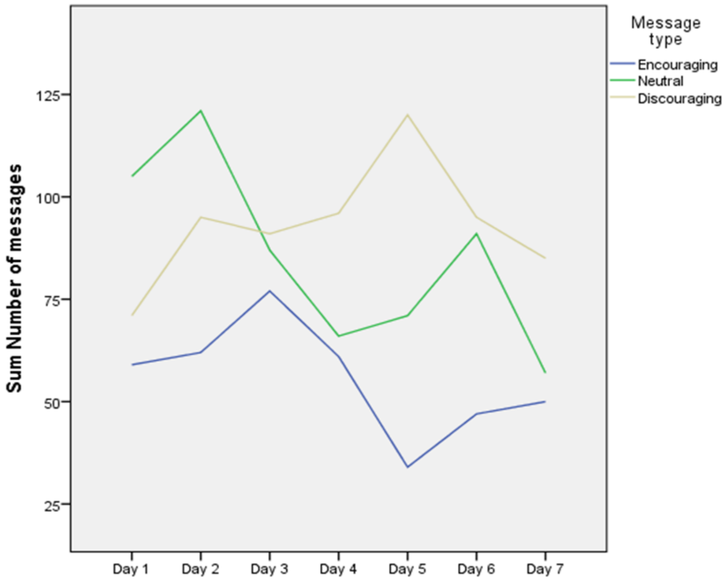

Figure 4. Total number of messages per day and message type.

Results regarding the change in level of physical activity after a feedback message show significant differences between message categories (F(2;26.515)=12.559, p<.001); the effect of encouraging messages (95%-CI: 19.97 – 325.54, SE=74.67) is different than the effect of neutral (95%-CI:-281.96 – -.52, SE=68.64) (p=.005 (Sidak)) and discouraging (95%-CI: -441.09 – -150.46) (p<.001(Sidak)) messages. This is also illustrated in Figure 5: on average, encouraging messages lead to an increase in level of physical activity, whereas neutral and discouraging messages lead to a decrease. The effect of the feedback messages did not differ significantly between the experimental and the control condition (F(1;24.89)=.0.47, p=.831): change in activity in the tailored feedback condition averaged -98.56 (SE=69.47), while it averaged -77.61 (SE=67.57) in the control condition. Also, no significant difference was found between how subjects responded to the encouraging, neutral and discouraging messages in the experimental condition versus how they responded to the messages in the control condition (F(2;25,512)=.474, p=.628). Results are summarized in Figure 5. IMA data are not investigated comparing the interaction between feedback day and message category since these are both repeated measures.

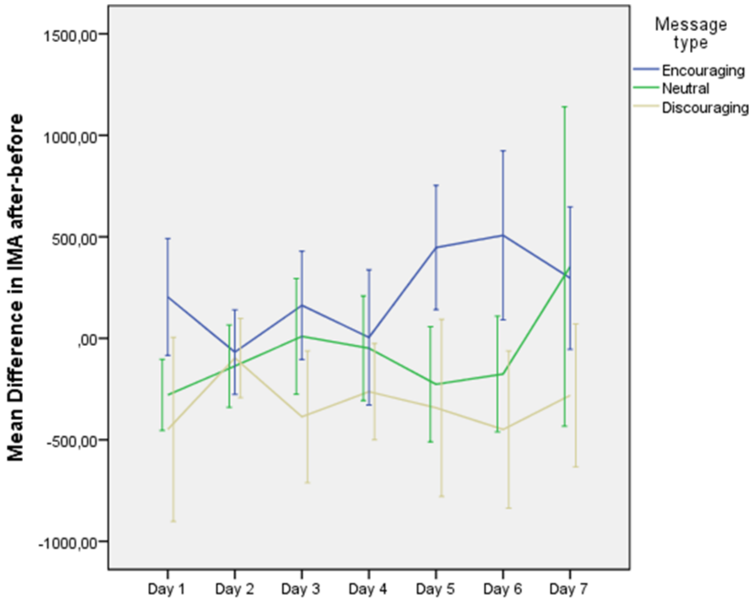

Figure 5. Change in IMA after feedback message per day for the three message categories.

Descriptive data and post hoc analyses

The figures and analyses described below are exploratory and were included in the current paper for providing directions for future research. Figure 6 shows the relation between average changes in IMA after a feedback message, per message category, on days when the daily goal was achieved versus when the daily goal was not achieved. Feedback days were categorized as “goal achieved” when the daily average of IMA counts per minute was at least ten percent higher than the average IMA counts per minute of that subject during baseline period. Feedback days were categorized as “goal not achieved” when this was not the case. Considering that both message type and goal achievement are repeated measures, no statistical analyses were performed to investigate this relation. However, Figure 6 does show that, with respect to encouraging messages, difference in IMA seems higher on days on which subjects achieved their goal than on days on which subjects did not achieve their daily goal. This difference is less visible for neutral and discouraging messages. The above could indicate that, indeed, encouraging feedback messages contribute positively to goal-achievement.

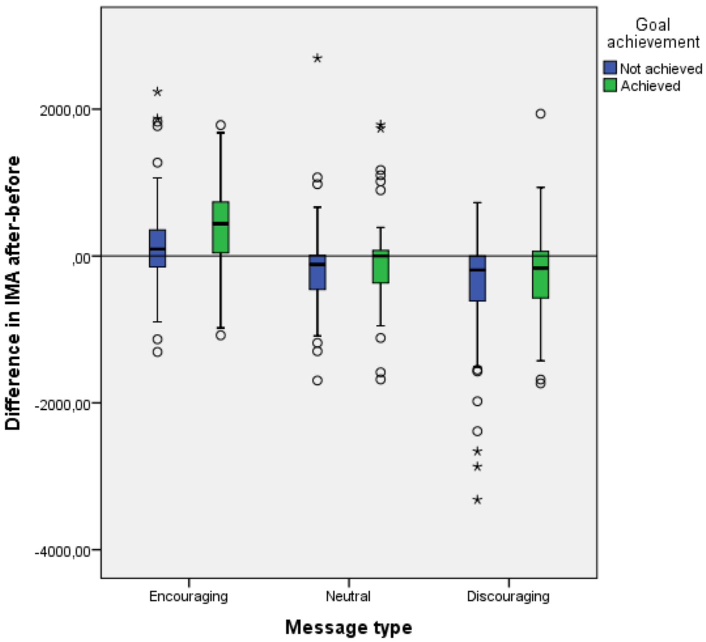

Figure 6. Average change in IMA after a feedback message per message category on days when the daily goal was achieved versus when the daily goal was not achieved.

Lastly, correlations were calculated to explore the relation between level of self-efficacy at first use of the application and change in objectively measured level of physical activity after a feedback message to investigate differences in responses of subjects with different levels of self-efficacy; a positive correlation was hypothesized. Table 2 shows that subjects with a lower level of self-efficacy did not respond significantly different to encouraging, neutral or discouraging messages than subjects with a higher level of self-efficacy at baseline or vice versa.

Table 2. Correlation between self-efficacy at baseline and change in activity after a feedback message per message category.

Message category	Correlation between self-efficacy at baseline and change in level of physical activity
Encouraging messages	r=.-231 (p=.219)
Neutral messages	r=.-084 (p=.665)
Discouraging messages	r=.255 (p=.191)

DISCUSSION

The main aim of the current experiment was to investigate changes in level of physical activity in an interval of fifteen minutes after having provided a textual feedback message that is based on real-time level of physical activity in an overweight subject sample to explore whether short textual feedback messages are smart options to incorporate in mobile, technology-supported physical activity monitoring and feedback applications for overweight adults. Secondly, we explored differences in this effect between providing feedback messages as in previous versions of the system and tailored feedback messages based on level of self-efficacy, stage of change, and level of physical activity during baseline assessment. Overweight subjects used the Activity Coach (AC) fourteen consecutive days; the first seven days where used as baseline measurement, during which the AC only measured activity over the day and did not provide any form of information or feedback to subjects. During the second week, subjects received a tailored daily goal based on their level of physical activity during the baseline week, real-time information about their level of physical activity and hourly feedback messages to help reach their daily goal.

Results show that messages that are framed to encourage physical activity lead to a significant increase in level of physical activity in an interval of fifteen minutes after it was sent, whereas neutral and discouraging feedback messages lead to an average decrease in physical activity. This is in accordance with earlier research in different populations, e.g. COPD patients (Tabak, Op den Akker, & Hermens, 2014), strengthening evidence that textual feedback messages based on real-time level of physical activity are indeed important to incorporate in mobile, technology-supported physical activity promoting applications, also in overweight subjects. These are interesting findings in respect to other research showing that shifting time spent in sedentary behaviour to time spent in light intensive physical activity leads to reduced waist circumference and BMI (Healy et al., 2015). However, current results need further investigation. For example, it is not clear whether subjects indeed shifted time from sedentary behaviour to light intensive physical activity or that they were already active and increased their activity level after an encouraging feedback message. Additionally, descriptive data shows that it is interesting to investigate the effect of these types of feedback messages on goal achievement. The design of the current experiment did not allow for statistical analyses, however, graphical inspection of data shows promising results; higher responses to encouraging messages in terms of IMA, on days on which subjects achieved their daily goal. Future research might focus on aspects that contribute to goal achievement and the effect of feedback messages.

In contrast to hypothesized, providing tailored feedback messages based on level of self-efficacy at baseline, stage of change, and level of physical activity during baseline did not lead to a larger effect than providing feedback messages as in previous versions of the system. Also, whereas overweight subjects with a low level of self-efficacy at baseline do tend to be less physically active during two week use of the Activity Coach than subjects with higher levels of self-efficacy at baseline (Achterkamp, Hermens, & Vollenbroek-Hutten, submitted for publication), current results do not show comparable differences in immediate responses to feedback messages. One explanation is that the two feedback conditions contrasted too little. Research that compared the effect of providing two pages of tailored information to the effect of providing two pages of general information did find significant differences in likeliness to increase physical activities of daily living (Bull, Kreuter, & Scharff, 1999); the current application only used short textual feedback messages. Another explanation is the exploratory study design, which made for a small subject sample, and high inter-subject variability.

Although the current study did not show significant differences between the influence of feedback based on tailored feedback strategies and feedback that was not based on these strategies on level of physical activity, we suggest future research should continue to investigate how to increase impact and relevance of feedback in these types of application. For example, Van Gog and Rummel (2010) conclude that regarding study behaviour, showing a video of task performance by a model is more effective than providing spoken text, which can also be implemented relatively easy in mobile applications. Furthermore, research shows that subjects prefer combinations of ipsative and normative feedback (Hirvonen et al., 2015), whereas the current experiment only provided ipsative feedback. Normative feedback regards to how subjects perform in relation to other subjects; in this regard, subjects' performance is preferably compared to performance of similar others, e.g. with comparable age, gender and appearance (Kassin, Fein, Markus, 2010; Schunk, DiBenedetto, 2016). Another suggestion is to include reflective feedback messages as suggested by other research regarding goal-setting (Lee, Kim, Forlizzi, & Kiesler, 2015).

CONCLUSION

Real-time textual feedback messages based on objective level of physical activity lead to significant changes in level of physical activity in an interval of fifteen minutes after the message is prompted, and are therefore smart options to incorporate in future mobile, technology-supported physical activity monitoring and feedback applications for overweight adults. No differences were found between the effect of messages based on tailored feedback strategies versus feedback messages not based on these strategies, and no significant relation was found between self-efficacy at first use of the application and change in level of physical activity after a feedback message. Future research on these types of application is recommended to include textual feedback messages, alongside other types of tailored feedback, such as e.g. in-application videos, normative feedback, and reflective feedback messages.

Declaration of conflicting interests

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Chapter 7

General discussion

The main aim of this thesis was to increase our understanding about whether it is useful to incorporate tailoring in mobile, technology-supported physical activity enhancing applications, if so, how to incorporate this, and to provide first insights in what happens on physical activity and self-efficacy levels, when overweight subjects are provided with such an application. The current chapter is where these results are combined and critically discussed. It starts with an overview of the general conclusions and discussion of results of the current thesis. Next, future steps for tailoring and implications for clinical practice are discussed. The chapter concludes with general directions for future research.

GENERAL CONCLUSIONS AND DISCUSSION OF RESULTS

With respect to the overall aim, it is concluded that results presented in the current thesis partly support the hypothesis that mobile, technology-supported physical activity enhancing applications can be improved by incorporating feedback based on individuals' scores on constructs from behavioural sciences, being self-efficacy and stage of change.

Firstly, we conclude that this type of tailoring is needed since different personas show different activity patterns, which thus have different needs and therefore require a different approach (Chapter 2). We showed that subjects with low levels of self-efficacy are less physically active over the day than subjects with higher levels of self-efficacy, and subjects in different stages of change show different levels of physical activity over the day: patients in precontemplation, contemplation, preparation, and action stages of change are less active than healthy controls. Interestingly, patients in the maintenance stage of change are as active as healthy control subjects, but their level of physical activity over the day shows a large drop in activity towards the end of the day, still indicating an improper activity pattern. Considering these differences, tailoring is needed, which should at least be based on self-efficacy and stage of change.

Secondly, our lab studies and field studies delivered evidence that self-efficacy increasing techniques are effective in mobile applications and are therefore smart options to incorporate in future applications (Chapter 3 and Chapter 4). Specifically, in our first lab study we found that technology-supported interventions using mastery experience– i.e. the experience of success – leads to an increase in self-efficacy regarding a specific task (Chapter 3). Regarding our second lab study (Chapter 4), results did not support our hypothesis that vicarious experience leads to differences in self-efficacy or task-performance. However, qualitative inspection of data showed that walking strategy did differ between two subgroups. Most importantly, results of the field study (Chapter 5 and Chapter 6), showed an increase in self-efficacy after a two-week period of activity monitoring including one week with feedback (Chapter 5). This is an important finding as self-efficacy is considered a powerful predictor of actual performance of the desired behaviour, but also since higher levels of self-efficacy are associated with higher levels of physical activity and larger benefits from physical activity interventions (e.g. Bandura, 1994; Gist & Mitchell, 1992; Trost, Kerr, Ward, & Pate, 2001; Roach et al., 2003). This means that tailoring based on constructs from behavioural sciences should be incorporated in feedback strategies, and that strategies to influence self-efficacy that are used in non-mobile or face-to-face interventions can also be successfully used to tailor feedback and coaching of mobile, technology-supported physical activity interventions.

Thirdly, next to the effect of the Activity Coach on level of self-efficacy, we investigated the effect of tailored feedback messages on level of physical activity (Chapter 5 and Chapter 6). We showed that goal-achievement was moderate with subjects achieving their goals on 37% of all feedback days (Chapter 5). In addition, encouraging, discouraging, and neutrally framed feedback messages are smart options to include in mobile, technology-supported physical activity applications for overweight subjects as the level of physical activity significantly increased in an interval of fifteen minutes after an encouraging feedback message was prompted to the subject, while it significantly decreased after neutral and discouraging messages (Chapter 6).

Despite the findings above, we also found results not in line with our hypotheses. Firstly, in the first lab study, the change in self-efficacy did not transfer to significant changes in task performance. Secondly, in the lab study on the effect of vicarious experience in mobile, technology-supported interventions, results did not show significant differences between viewing a video prior to performance and not viewing this video with respect to self-efficacy or task performance. Thirdly, in the field studies, daily physical activity levels did not change significantly over two weeks, and results did not show significant differences between the effect of tailored feedback strategies versus feedback as in previous versions of the activity coach, with respect to changes in both level of physical activity and level of self-efficacy.

Regarding the lab studies, possible explanations for the insignificant differences could lie in the rather artificial nature of the task, the low number of subjects, high inter-subject variability, insufficient difficulty of the task, or too small differences between conditions. In the lab study, task instructions and goals were very clear, duration was relatively short, feedback was immediate and clear, and subjects knew exactly what they needed to do and how to perform well. These are all factors that increase the chance of influencing self-efficacy; earlier research also shows that the more concrete goals and tasks are, the higher the likeliness that goals are achieved and self-efficacy will increase (Michie. Abraham, Whittington, McAteer, & Gupta, 2009). The framework for goal setting process confirms these statements (Shilts, Horowitz, & Townsend, 2004). This framework emphasizes that influence of the individual subject on e.g. height or duration of the goal increases sense of commitment towards achieving their goal. Increased commitment leads to higher motivation to achieve goals, leading to a higher chance that goals will be achieved, which in turn leads to mastery experience and thereby an increase in self-efficacy. This might have been insufficiently addressed in the field study, where daily goals for the second week were automatically set ten percent higher than the subjects' level of physical activity during the first week. Furthermore, the exploratory character of the field study made that the total duration of the study was relatively short, the sample size small, and the inter-subject variability high. Major limitations indeed. With respect to the non-significant findings regarding differences between tailored feedback versus feedback as usual, the two conditions might not have contrasted sufficiently. To increase the contrast between conditions, more tailoring techniques as defined by Op den Akker, Jones, and Hermens (2014), could be implemented next to adaptation, and be tested against a group that receives information tailored to none of these techniques.

All in all, we conclude that results of the studies are promising, considering the increase in self-efficacy in both lab and field study, trends towards the expected effects in both study settings, differences in walking strategy depending on the video subjects viewed prior to performance of a task, a daily goal achievement of 37% in the field study, which tended to increase over time, and positive effects of encouraging and discouraging feedback messages on level of physical activity. However, how exactly this feedback should be formulated to achieve significant differences between tailored feedback and feedback as usual remains unclear.

FUTURE STEPS FOR TAILORING

Building on the Activity Coach, a future application should include more intelligent and interactive features, and further adapt to the current status of the subject than was the case in the current thesis. One way to do this is by further implementation of aspects of behavioural sciences. As mentioned in Chapter 1, many theories and models on behaviour change are available, and many of these theories and models overlap. More recent research proposes to integrate these models into a more comprehensive behaviour change model. Two examples of such models are the I-Change and the Combi model, which explicitly focus on modern-day technology supported interventions. Firstly, the “Integrated model for explaining motivational and behavioural change”, or I-Change model (De Vries et al., 2003; De Vries, 2017), derives from the Attitude - Social Influence - Self-Efficacy model (De Vries, 1988), and integrates the Theory of Planned Behaviour (Ajzen, 1991), Social Cognitive Theory (Bandura, 1986), the Transtheoretical Model (Prochaska & DiClemente, 1983) (see Chapter 1), the Health Belief Model (Janz, 1984) and goal setting theories. The second model, the “Computerized Behaviour Intervention model”, or Combi model (see Figure X) (Klein, Mogles, & Van Wissen, 2011), can be regarded a further specification of the I-Change model. The authors of the Combi model state that the I-Change model fails to explicate how the factors that influence behavioural change interact; the Combi model attempts to delineate the causal relations between the various factors and can be regarded a computational model based on theoretical frameworks of behaviour change.

Both the I-Change and Combi model can be used by an intelligent support system to understand human behaviour, but also to detect the cause of why unhealthy behaviour is continued and where and how to intervene, creating a detailed framework for providing highly tailored information aimed at behaviour change. For example, according to the Combi model (see Figure 1), a mobile health application could start with a questionnaire assessing stage of change, which determines whether the application will target 1) awareness, 2) motivation, or 3) commitment. An example of what this could look like is described below.

If a subject is identified as in the contemplation stage of change, the application should focus on increasing 1) awareness. Subjects should create a sense of susceptibility to e.g. a disease and think of the consequences of continuing unhealthy behaviour as sufficiently severe. This information can be provided through feedback messages e.g. confronting the subject with their low level of physical activity and the impact of this on health status, creating a sense of a threat in the subject and thereby increasing awareness and motivation to change behaviour. According to the Combi model, this will lead to a transition in stage of change from contemplation to the preparation stage.

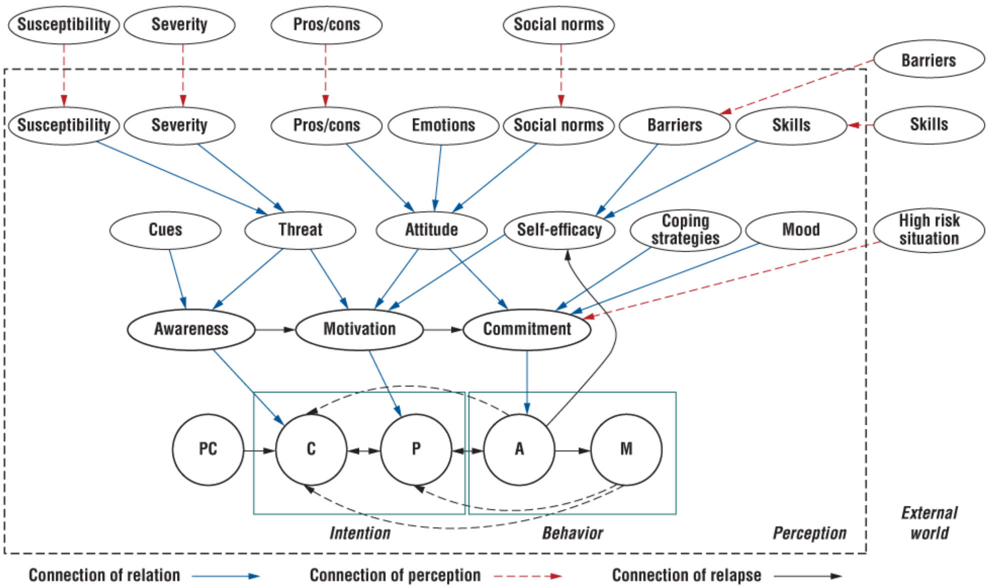

Figure 1. The Computerized Behaviour Intervention (Combi) Model.

When in the preparation stage of change, the application should focus on increasing 2) motivation to perform the healthy behaviour. Threats of unhealthy behaviour should still be under attention, but importantly, successes should be emphasized, increasing a sense of skill and thereby increasing self-efficacy. Mastery experience, vicarious experience and goal setting are important aspects in this stage. Also, internal and external barriers should be mapped and addressed, for example by use of the perceived barriers to physical activity questionnaire (Arzu, Tuzun, & Eker, 2006), which can be implemented in the application and prompted to subjects. A database of feedback messages on how to address different types of barriers should be developed, which can then be used to provide feedback to overcome those barriers that subjects reported to experience. In this regard, including a self-learning component in the application is necessary (Op den Akker, Moualed, Jones, & Hermens, 2011). A self-learning component enables automatic assessment of which messages are most effective for an individual, and accordingly provides only those with the best effects. Next, the subject's attitude towards the behaviour influences motivation, which in turn is influenced by the subject's perception of pros and cons of performing the healthy behaviour; in this stage, advantages of the behaviour should thus be emphasized through feedback of the application. Furthermore, the desired behaviour should be associated with positive emotions, which might be achieved through gamification (e.g. Robson, Plangger, Kietzmann, McCarthy, & Pitt, 2015); one option is to incorporate various games in the application and determine which works best for the individual using Ecological Momentary Assessment (EMA). Another factor that influences motivation is "Social norms". These are not easily changed through persuasion or motivational messages. However, a social module that enables e.g. data sharing and contact with friends is a must in health applications (Oinas-Kukkonen, & Harjumaa, 2018), which could lead to changes in social norms of users.

With respect to the action stage of change, the focus should shift to increasing and maintaining 3) commitment. In this stage, coping strategies are of importance, for example regarding relapse. It is not unthinkable that the application detects relapse and accordingly provides support in development of adequate coping strategies so that subjects return to previously achieved levels of physical activity. One option to incorporate this is using Just-in-Time Adaptive Interventions (JITAIs). JITAIs are defined as mobile health interventions that deliver the right intervention components at the right time and location to optimally support individuals' health behaviours (Klasnia et al., 2015). Thus, when relapse is detected, the application can prompt a specific relapse module to overcome this. Mood also plays an important role in commitment to perform healthy behaviour. Happiness in known to lead to healthy behaviour, health and well-being (Veenhoven, 2008), but current mood of subjects can also provide information that can be used to identify how to frame messages, which can be assessed using e.g. EMA techniques. Another option is to use facial expression recognition software of modern-day smartphones. This does however raise the question whether users would agree to provide such private information, which requires continuous registration of facial expression by a front facing smartphone camera. Another interesting challenge regards to transitions in stage of change and changes in self-efficacy over time; can these be measured automatically? And if not, in what interval should questionnaires be prompted or should EMA techniques be implemented? Furthermore, apart from these subject specific factors, other contextual factors should be taken into account, such as weather, agenda, location, mode of transport, nearby family or friends, etcetera.

IMPLICATIONS FOR CLINICAL PRACTICE

Applications such as the Activity Coach seem promising with respect to clinical settings and future interventions for improving level of physical activity of e.g. overweight subjects. One way to implement these systems in clinical settings is not as stand-alone self-management tool as in our intervention, but combined with guidance from a health care professional, as part of a so-called *blended care* therapy. In blended care interventions, technology-supported systems as the Activity Coach are combined with contact with a professional therapist. This contact is mostly set-up as face-to-face contact (Wentzel, Van der Vaart, Bohlmeijer, & Van Gemert-Pijnen, 2016), but various blends are imaginable; besides face-to-face, contact can take place through a web-based portal, a mobile application or e-mail for example. Wolvers (2017) tested such a system in a randomized controlled trial in a group of patients that report fatigue after cancer. The intervention comprised nine weeks use of a system like the Activity Coach, but additionally, subjects received e-mail guidance, and help with setting goals by physiotherapists. The authors conclude that 66 percent of all subjects showed a clinically significant reduction in subjectively reported fatigue after the intervention; a relatively high percentage, and a much higher percentage than in the other two conditions, in which subjects received psychologist-guided web-based mindfulness-based cognitive therapy, or psycho-educational e-mails. In the mindfulness-based intervention, 49 percent of subjects reported a clinically significant reduction in fatigue, versus only twelve percent in the psycho-educational group (Bruggeman-Everts, Wolvers, Van de Schoot, Vollenbroek-Hutten, & Van der Lee, 2017). This shows that blended care interventions *without* face-to-face contact – apart from handing out the system – can also be successful in achieving clinically significant results, but what works for whom needs further attention (Wentzel, Van der Vaart, Bohlmeijer, & Van Gemert-Pijnen, 2016; Wolvers, 2017).

The above is a good example that shows that blended care is where research regarding technology supported physical activity interventions in our opinion has most potential with respect to clinical practice in short term. However, in the long term, it is not unimaginable that these types of mobile, technology-supported system are handed out by a healthcare professional and thereafter function as stand-alone, self-management application, with all aspects as baseline measurements, goal-setting, feedback and coaching programmed into an adaptive, learning and personalized physical activity application.

THE FUTURE: TOWARDS A BALANCED AND ACTIVE LIFESTYLE?

Taking into account context, an application of the future could suggest using a desk-bike, or automatically suggest activation of the stand-function of a sit-stand-desk, which are only two options that are both known to reduce sedentary behaviour, not influence productivity negatively, and to improve concentration (Dutta, Koepp, Stovitz, Levine, & Pereira, 2014; Torbeyns et al., 2016). However, physical activity is not the only factor in a healthy lifestyle; it is one of many. In our opinion, with respect to the previous sections, this adaptive, learning and personalized application of the future should not only aim at changing levels of physical activity. It should aim at, and take into account, biological, psychological, and social factors. Therefore, the application should comprise more modules than only a physical activity module. Think of a food module; automatically registering what you ate last week based on fridge content, what you still have in your fridge at home, and suggesting meals according to your preferences with the option of letting additional groceries be delivered to your house. Next, it should include components that aim to improve mental health and support subjects in work contexts. For example, a stress module should be included, e.g. registering what tasks a knowledge worker is performing, providing a filter for an optimal workflow (Sappelli, 2016), and suggesting mindfulness exercises at the right time. Subjects should be allowed to use several modules alongside each other and set goals for each separate module, or choose to focus on just one. Including more than one module is also beneficial to adherence, since this allows subjects to choose which aspect of their well-being they want to change first, and to start with the module they have most motivation for. Additionally, in this way, the application is useful for a broad spectrum of subjects and not only designed for specific patient groups such as overweight subjects, or subjects with chronic low back pain or chronic fatigue. Everyone interested in assessment or improvement of their health or well-being can use the application, start with whatever behaviour they want to improve, and set goals regarding the behaviour that subjects want to perform, instead of following a goal imposed by the application. Our hypothesis is that once subjects start using one module, motivation to change other health behaviour will increase and use of other modules will follow.

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Appendices

SUMMARY

The main aim of this thesis was to increase our understanding about whether it is useful to incorporate tailoring in mobile, technology-supported physical activity enhancing applications, if so, how to incorporate this, and to provide first insights in what happens on physical activity and self-efficacy levels, when overweight subjects are provided with such an application. More specific, we aim to answer the following three research questions:

1) What is the relation between self-efficacy, stage of change, and objectively measured level of physical activity in patients and healthy adults, and can typical users be identified?
2) What is the effect of a feedback strategy that is delivered through technology and applies self-efficacy increasing techniques on self-efficacy and task performance?
3) Does two-week use of a mobile, technology-supported physical activity application by overweight adults lead to changes in goal achievement, self-efficacy, or level of physical activity over a two-week period or in an interval of fifteen minutes after a feedback message has been prompted?

To answer these questions four studies were performed: one on data previously retrieved in various observational cohort studies, two experimental laboratory-setting studies, and one small cohort field study.

Chapter 1 started with a description of the central problem in this thesis; the number of overweight subjects is increasing to alarming levels. Improving level of physical activity is presented as a solution, for which a definition was presented. Interventions aimed to increase level of physical activity were discussed and showed that in overweight subject samples, the majority of the physical activity interventions are designed as face-to-face interventions, only using accelerometers to assess effectiveness of face-to-face interventions, and not as part of a stand-alone self-management intervention. Furthermore, it was found that interventions for general subject samples that did include accelerometer data and set up interventions as self-management, did not tailor feedback to constructs from behavioural sciences, which was hypothesized a flaw and an opportunity for improvement; earlier research, not using (mobile) technology, had already proven the effectiveness of tailored feedback based on construct from behavioural sciences. Finally, various behavioural change theories and constructs were presented and discussed, of which self-efficacy was identified as an important component that needs to be assessed at the start of an intervention and if necessary, be increased.

Regarding RQ 1, in **Chapter 2**, relations between self-efficacy, stage of change and physical activity were investigated, in order to define the constructs on which feedback should be tailored and to develop feedback strategies that can be used to further improve the effectiveness of mobile physical activity coaching and feedback interventions. To this end, data from previously performed experiments using 3D-accelerometry were used. Results showed that higher self-efficacy was related to higher activity levels. Patients were less active

than healthy controls and showed a larger drop in physical activity over the day. Patients in the maintenance stage of change were more active than patients in lower stages of change, but showed an equally large drop in level of physical activity at the end of the day. The above lead to the statement that coaching should at least be tailored to level of self-efficacy, stage of change and physical activity pattern. Eight typical users were identified, for which six feedback strategies were developed.

As a first step to test aspects of the developed feedback strategies in practice and with respect to RQ 2, **Chapter 3** describes a laboratory setting study. The experiment was designed to test whether using feedback strategies that focus on success experience and are provided through technology can influence self-efficacy regarding a specific task, just as in non-technology-supported interventions. Subjects were asked to walk from A to B in exactly 14, 16 or 18 seconds, wearing scuba fins and a blindfold. The task guaranteed an equal level of task experience among all subjects at the start of the experiment and made it difficult for subjects to estimate their performance accurately. This allowed for manipulation of feedback and success experience through technology-supported feedback. Results showed that subjects' self-efficacy regarding the task decreased when experiencing little success and that self-efficacy regarding the task increased when experiencing success. This effect did not transfer to level of self-efficacy regarding physical activity in general. The above lead to the conclusion that mastery experience, i.e. experiencing success, is a promising strategy to use in technology-supported interventions that aims at changing behaviour, like mobile physical activity applications.

Next to mastery experience, vicarious experience is a known effective technique in traditional, non-technology-supported interventions, to influence self-efficacy. Regarding RQ 2, **Chapter 4** builds on the experiment described in Chapter 3, this time investigating whether self-efficacy regarding a specific task can be influenced through vicarious experience provided through mobile technology. Subjects were again asked to walk from A to B in exactly 14, 16, or 18 seconds, wearing scuba fins and a blindfold, but before each trial, subjects in the experimental group viewed a video on a smartphone of a subject successfully performing the task, whereas subjects in the control group did not view a video. Results showed that despite that subjects found the video helpful to perform the task, subjects' level of self-efficacy regarding the task, as well as task performance, did not differ significantly between the two groups. However, a secondary outcome parameter did indicate a possible difference between how subjects walked forward while wearing the scuba fins; either shuffling forward, or raising their knees high up, depending on the strategy that the model in the instructional video applied.

Results from the two laboratory studies were promising. However, they were not close to a representation of daily life. As such, a field study in a more ecologically valid setting was designed regarding RQ 3. In **Chapter 5**, results are presented from a study on a mobile physical activity monitoring and feedback application used as self-management tool, without professional face-to-face contact. The goal of this exploratory study was to obtain insights regarding goal achievement, self-efficacy regarding physical activity, and daily level of physical activity of overweight adults using a mobile physical activity application. Secondarily, differences between the effects of feedback tailored to self-efficacy versus general feedback messages were investigated. For fourteen days, thirty overweight subjects used a mobile, technology-supported physical activity application that provides frequent, automated, real-time feedback messages to subjects based on their level of physical activity. The first seven days were used as baseline measurement. During the second period of seven days subjects received a personalized daily goal that was ten percent higher than their baseline level of physical activity and motivational feedback messages to achieve their goal. Results showed that over the seven feedback days on which the thirty subjects could achieve their goal (n=210), subjects succeeded a total of 77 times (36.7%) and the number of subjects achieving their goal increased over time. The conclusion stated that overall goal achievement was moderate, but importantly, subjects' level of self-efficacy increased during the two-week intervention; this is promising considering the strong mediating role of self-efficacy in achieving a sufficient level of physical activity. Self-efficacy precedes increased levels of physical activity, but we hypothesized that two weeks is a too short period to demonstrate according changes in level of physical activity.

Whereas Chapter 5 focuses on global intervention parameters such as increase in self-efficacy over two weeks, and changes in level of physical activity over two weeks, **Chapter 6** focuses on the immediate effect of feedback messages, as part of RQ 3. Specifically, the primary outcome parameter was the difference between level of physical activity in an interval of fifteen minutes before, and fifteen minutes after having provided a textual feedback message based on real-time level of physical activity. The same method and data sample was used as presented in Chapter 5. Only data from the second week of measurement, the intervention week, was used in this study. Results showed that feedback messages led to significant changes in level of physical activity in an interval of fifteen minutes after the message was prompted to subjects; encouraging messages led to an increase, whereas neutral and discouraging messages led to a decrease. No differences were found between the effect of messages based on tailored feedback strategies and messages not based on these strategies. Considering this, it was concluded that real-time textual feedback messages based on objective level of physical activity are smart options to incorporate in mobile, technology-supported physical activity monitoring and feedback applications for overweight adults, but we failed to identify significant differences between tailored feedback versus general feedback.

In **Chapter 7,** general conclusions of the research presented in the current thesis were summarized and critically discussed. Three subsections followed, firstly describing future steps for tailoring; we concluded that self-efficacy increasing techniques should be incorporated alongside, or as part of, other known effective theories or models from behavioural sciences in modern-day physical activity applications or interventions. Two examples of such models are presented and we presented suggestions on how to incorporate these into modern day physical activity applications. Secondly, implications and recommendations for daily practice were discussed, in which it was stated that, in our opinion, blended care has most potential with respect to clinical practice in short term. However, in the long term, it is not unimaginable that these types of technology-supported systems are handed out by a healthcare professional and thereafter function as stand-alone, self-management application, with all aspects as baseline measurements, goal-setting, feedback and coaching programmed into an adaptive, learning and personalized physical activity application. Lastly, we proposed that health applications of the future not only focus on physical activity, but also take into account, biological, psychological, and social factors.

SAMENVATTING

Het hoofddoel van deze dissertatie was om nieuwe inzichten op te doen over of het zinvol is om personalisatie te implementeren in mobiele, door technologie ondersteunde applicaties die zich richten op verbetering van niveau van lichamelijke activiteit over de dag, zo ja, hoe dit te doen, en om te bezien wat er gebeurt met niveau van lichamelijke activiteit en *self-efficacy* wanneer mensen met overgewicht een dergelijk systeem twee weken lang gebruiken. Meer specifiek hebben we ons gericht op het beantwoorden van de volgende drie onderzoeksvragen:

1) Wat is de relatie tussen *self-efficacy*, *stage of change* en objectief gemeten niveau van lichamelijke activiteit van patiënten en gezonde volwassenen, en kunnen typische gebruikers worden geïdentificeerd?
2) Wat is het effect van een feedback strategie, die door middel van technologie wordt aangeboden en technieken toepast om *self-efficacy* te vergroten, op *self-efficacy* en taakprestatie?
3) Leidt gebruik van een mobiele, door technologie ondersteunde applicatie die zich richt op het verbeteren van lichamelijke activiteit van mensen met overgewicht tot veranderingen in het bereiken van doelen, *self-efficacy*, of niveau van lichamelijke activiteit in een periode van twee weken, of in een interval van vijftien minuten nadat een feedbackbericht is aangeboden?

Hoofdstuk 1 begon met een beschrijving van het centrale probleem: het aantal mensen met overgewicht stijgt naar alarmerende hoogtes. Het verbeteren van het niveau van lichamelijke activiteit wordt voorgesteld als een oplossing hiervoor, waarna allereerst het begrip “lichamelijke activiteit” werd gedefinieerd. Eerdere interventies gericht op het verbeteren van lichamelijke activiteit worden besproken, waaruit blijkt dat bij experimenten met deelnemers met overgewicht, de meerderheid van de interventies ontworpen zijn als *face-to-face* interventies, waarbij accelerometers vooral worden gebruikt om de effectiviteit van de interventie te meten, en niet onderdeel zijn van een op zichzelf staande zelfmanagement interventie. Voorts werd bevonden dat interventies voor het algemene publiek die wél waren opgezet als zelfmanagement interventie, de feedback niet altijd personaliseerden op basis van theorieën vanuit gedragswetenschappen. Het voorgaande werd verondersteld als een kans voor verbetering; in eerder onderzoek waarbij geen mobiele technologie werd gebruikt was al aangetoond dat de effectiviteit van interventies groter was wanneer feedback werd gepersonaliseerd op basis van deze theorieën. Hierna werden verschillende gedragswetenschappelijke theorieën besproken, waarbij *self-efficacy* werd geïdentificeerd als een belangrijke variabele die bij het begin van een interventie gemeten dient te worden, en welke zo nodig vergroot moet worden.

Wat betreft onderzoeksvraag 1, werd in **Hoofdstuk 2** de relatie tussen *self-efficacy, stage of change*, en lichamelijke activiteit onderzocht om te bepalen welke variabelen te gebruiken bij personalisatie van feedback en om specifieke feedback strategieën te ontwikkelen die gebruikt kunnen worden om interventies gericht op lichamelijke activiteit verder te verbeteren. Hiertoe werden data gebruikt van eerder uitgevoerde experimenten met 3D-accelerometers. De resultaten toonden dat een hoger niveau van *self-efficacy* gerelateerd was aan een hoger niveau van lichamelijke activiteit. Hiernaast waren patiënten minder actief dan gezonde controles en toonden patiënten een groter verval in lichamelijke activiteit over de dag. Patiënten in de *maintenance stage of change* waren meer actief dan patiënten die zich in eerdere *stages of change* bevonden, maar zij vertoonden een even groot verval over de dag wat betreft lichamelijke activiteit. Het voorgaande leidde tot de uitspraak dat feedback ten minste gepersonaliseerd moet worden op het niveau van *self-efficacy, stage of change* en patroon van lichamelijke activiteit over de dag van de individuele gebruiker. Tot slot worden acht typische gebruikers geïdentificeerd, voor wie zes feedbackstrategieën werden ontwikkeld.

Als een eerste stap om aspecten van de ontwikkelde feedbackstrategieën in de praktijk te testen, en met betrekking tot onderzoeksvraag 2, beschrijft **Hoofdstuk 3** een experiment in een laboratorium omgeving. Het experiment was ontworpen om te onderzoek of feedbackstrategieën die zich richten op het ervaren van succes en door middel van technologie worden geleverd het niveau van *self-efficacy* van een individu ten opzichte van een taak op een gelijke manier kan beïnvloeden als in interventies waarbij geen mobiele technologie wordt gebruikt. Deelnemers werd gevraagd om van A naar B te lopen in exact 14, 16, of 18 seconden, terwijl zij zwemvliezen en een blinddoek droegen. Deze taak garandeerde een gelijk niveau van ervaring met de taak voor alle deelnemers en maakte het voor hen moeilijk om hun prestatie accuraat te schatten. Het voorgaande was een voorwaarde om feedback op taakprestatie en het ervaren van succes te kunnen manipuleren. Resultaten toonden dat het niveau van *self-efficacy* ten opzichte van de taak afnam wanneer men weinig succes ervoer en dat het juist toenam wanneer men wel succes ervoer. Het effect vertaalde zich niet naar een verandering in niveau van *self-efficacy* ten opzichte van lichamelijke activiteit in het algemeen. De conclusie was dat *mastery experience*, c.q. het ervaren van succes, een veelbelovende strategie is om te gebruiken in mobiele, door technologie ondersteunde interventies die zich richten op gedragsverandering, zoals bij interventies gericht op het verbeteren van het niveau van lichamelijke activiteit.

Naast *mastery experience*, is *vicarious experience* een bewezen effectieve techniek in traditionele, niet door technologie ondersteunde interventies om *self-efficacy* te beïnvloeden. Met betrekking tot onderzoeksvraag 2, bouwt **Hoofdstuk 4** voort op het experiment dat is beschreven in het voorgaande hoofdstuk, waarbij dit keer werd onderzocht of *self-efficacy* ten opzichte van een specifieke taak kan worden beïnvloed door *vicarious experience* wanneer dit wordt geleverd via mobiele technologie. Opnieuw werd deelnemers gevraagd om van A naar B te lopen in exact 14, 16 of 18 seconden terwijl zij zwemvliezen en een blinddoek droegen. Echter dit maal bekeken deelnemers in de experimentele groep voor iedere poging een video op een smartphone waarin een succesvolle poging werd vertoond. Deelnemers in de controlegroep bekeken geen video. Ondanks dat de deelnemers de video behulpzaam vonden om de taak uit te voeren, toonden de resultaten dat niveau van *self-efficacy* en taakprestatie niet significant verschilden tussen de twee groepen. Een secundaire uitkomstmaat toonde wel een mogelijk verschil in hoe deelnemers vooruitliepen; of schuifelend, of door middel van het hoog optrekken van de knieën, afhankelijk van de strategie die het model in de instructievideo gebruikte.

Resultaten van de twee hierboven beschreven experimenten waren veelbelovend, maar kwamen niet in de buurt van een representatie van het dagelijks leven. Hierom werd een veldstudie in een meer ecologisch valide omgeving uitgevoerd met betrekking tot onderzoeksvraag 3. In **Hoofdstuk 5** werden de resultaten gepresenteerd van een onderzoek naar een zelfmanagement, coaching en feedback applicatie die zich richt op lichamelijke activiteit, zonder face-to-face contact. Het doel van dit explorerende onderzoek was om inzicht te verkrijgen in veranderingen in het behalen van doelen, *self-efficacy* ten opzichte van lichamelijke activiteit, en dagelijks niveau van lichamelijke activiteit van personen met overgewicht. Secundair werden verschillen onderzocht tussen het effect van gepersonaliseerde feedback en het effect van generieke feedback. Dertig deelnemers met overgewicht gebruikten veertien dagen een mobiele applicatie die frequent, automatisch en *real-time* feedback berichten stuurde gebaseerd op het actuele niveau van lichamelijke activiteit. De eerste zeven dagen warden gebruikt als nulmeting. Gedurende de tweede periode van zeven dagen ontvingen deelnemers een gepersonaliseerd dagelijks doel dat tien procent hoger lag dan hun gemiddelde dagelijkse activiteit gedurende de nulmeting en motiverende feedback berichten om hun dagelijkse doel te bereiken. In de zeven dagen waarop de dertig deelnemers hun doel konden bereiken (n=210), lukte hen dat in totaal 77 keer (36,7%); een matig resultaat. Het aantal deelnemers dat hun doel bereikte steeg gedurende de zeven dagen. Belangrijker was de conclusie dat het niveau van *self-efficacy* van deelnemers significant steeg gedurende de twee weken van de interventie. Gezien de sterke mediërende rol van *self-efficacy* in het bereiken van een voldoende niveau van lichamelijke activiteit is dit een interessante bevinding; verondersteld wordt dat een toename van *self-efficacy* voorafgaat aan veranderingen in lichamelijke activiteit, maar de hypothese is dat twee weken een te korte periode is om dergelijke gedragsveranderingen aan te tonen.

Waar Hoofdstuk 5 zich richtte op globale parameters van de data zoals toename van *self-efficacy* gedurende de twee weken en veranderingen in niveau van lichamelijke activiteit gedurende twee weken, richtte **Hoofdstuk 6** zich op het onmiddellijke effect van feedback berichten, als onderdeel van onderzoeksvraag 3. De primaire uitkomstmaat betrof het verschil in niveau van lichamelijke activiteit in een interval van vijftien minuten voor en vijftien minuten na het aanbieden van een feedbackbericht gebaseerd op het actuele niveau van lichamelijke activiteit. Dezelfde methode en dataset als in Hoofdstuk werd gebruikt 5, met als enige verschil dat in het huidige hoofdstuk alleen lichamelijke activiteitendata van de tweede week van de meting werd gebruikt. Resultaten toonden dat de feedbackberichten tot een significant verschil leidden in niveau van lichamelijke activiteit in een interval van vijftien minuten na het aanbieden van het bericht; aanmoedigende berichten leidden tot een toename van lichamelijke activiteit, terwijl neutrale en ontmoedigende berichten tot een afname leidden. Er werd geen verschil gevonden tussen het effect van feedbackberichten gebaseerd op de gepersonaliseerde feedbackstrategieën en generieke feedbackberichten. Geconcludeerd werd dat het verstandig is om *real-time* feedbackberichten gebaseerd op actueel niveau van lichamelijke activiteit in te bouwen in mobiele, door technologie ondersteunde applicaties die zich richten op het meten en verbeteren van lichamelijke activiteit van personen met overgewicht. Er werd geen significant verschil gevonden tussen het effect van gepersonaliseerde feedback tegenover generieke feedback wat betreft onmiddellijke veranderingen in niveau van lichamelijke activiteit.

In **Hoofdstuk 7** werden de generieke conclusies van het huidige onderzoek samengevat en kritisch bediscussieerd. Drie onderwerpen werden verder uitgelicht. Ten eerste werden toekomstige stappen voor personalisatie beschreven; we concludeerden dat strategieën om *self-efficacy* te vergroten opgenomen zouden moeten worden in hedendaagse mobiele applicaties die zich richten op het vergroten van lichamelijke activiteit, naast andere reeds bewezen effectieve gedragswetenschappelijke theorieën of modellen. Twee voorbeelden van dergelijke modellen worden besproken en er werden suggesties gegeven over hoe dit te implementeren. Ten tweede werden implicaties voor de dagelijkse praktijk besproken, waar werd gesteld dat *blended care* het meest potentie heeft op de korte termijn. Echter op de lange termijn is het denkbaar dat dit type applicaties wordt uitgedeeld door een professional in de gezondheidszorg, waarna ze vervolgens functioneren als een op zichzelf staande, zelfmanagement applicatie, waarbij alle aspecten als nulmeting, doelen stellen, feedback en coaching voorgeprogrammeerd zijn in een adaptieve, zelflerende en gepersonaliseerde applicatie die zich richt op het verbeteren van lichamelijke activiteit. Ten slotte stelden we voor dat applicaties die zich richten op gezondheid zich niet alleen richten op lichamelijke activiteit, maar rekening houden met biologische, psychologische en sociale factoren.

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ABOUT THE AUTHOR

Reinoud Achterkamp was born on November 14th 1987, in Enschede, The Netherlands. He received his high school diploma from Scholengemeenschap Zuid in 2006 and, after a year of traveling, started his study in psychology at the University of Groningen in 2007. He obtained his bachelor's degree in 2010 and continued to study at the University of Groningen to further specialize in neuropsychology, obtaining a master's degree cum laude in 2011. Hereafter, Reinoud moved back to Enschede to work at Roessingh Research and Development, on the national project *Smart reasoning systems for well-being at work and well-being at home* (SWELL), as part of the COMMIT programme. Results of this work are presented in the current thesis. Reinoud is currently employed as a neuropsychologist at Roessingh, Centre for Rehabilitation, and Livio in Enschede, and hopes to graduate from the Radboud Centre for Social Sciences in September 2019, where he follows a two-year post-master study on healthcare psychology (opleiding tot GZ-psycholoog).

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