Health Self-Management Applications in the Workplace

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Multidisciplinary studies on worker behaviour and autonomy

Anne Bonvanie-Lenferink

“Would you tell me, please, which way I ought to go from here?”
“That depends a good deal on where you want to get to,” said the Cat.
“I don’t much care where—” said Alice.
“Then it doesn’t matter which way you go,” said the Cat.
“—so long as I get somewhere,” Alice added as an explanation.
“Oh, you’re sure to do that,” said the Cat, “if you only walk long enough.”

(Alice’s Adventures in Wonderland – Lewis Caroll)

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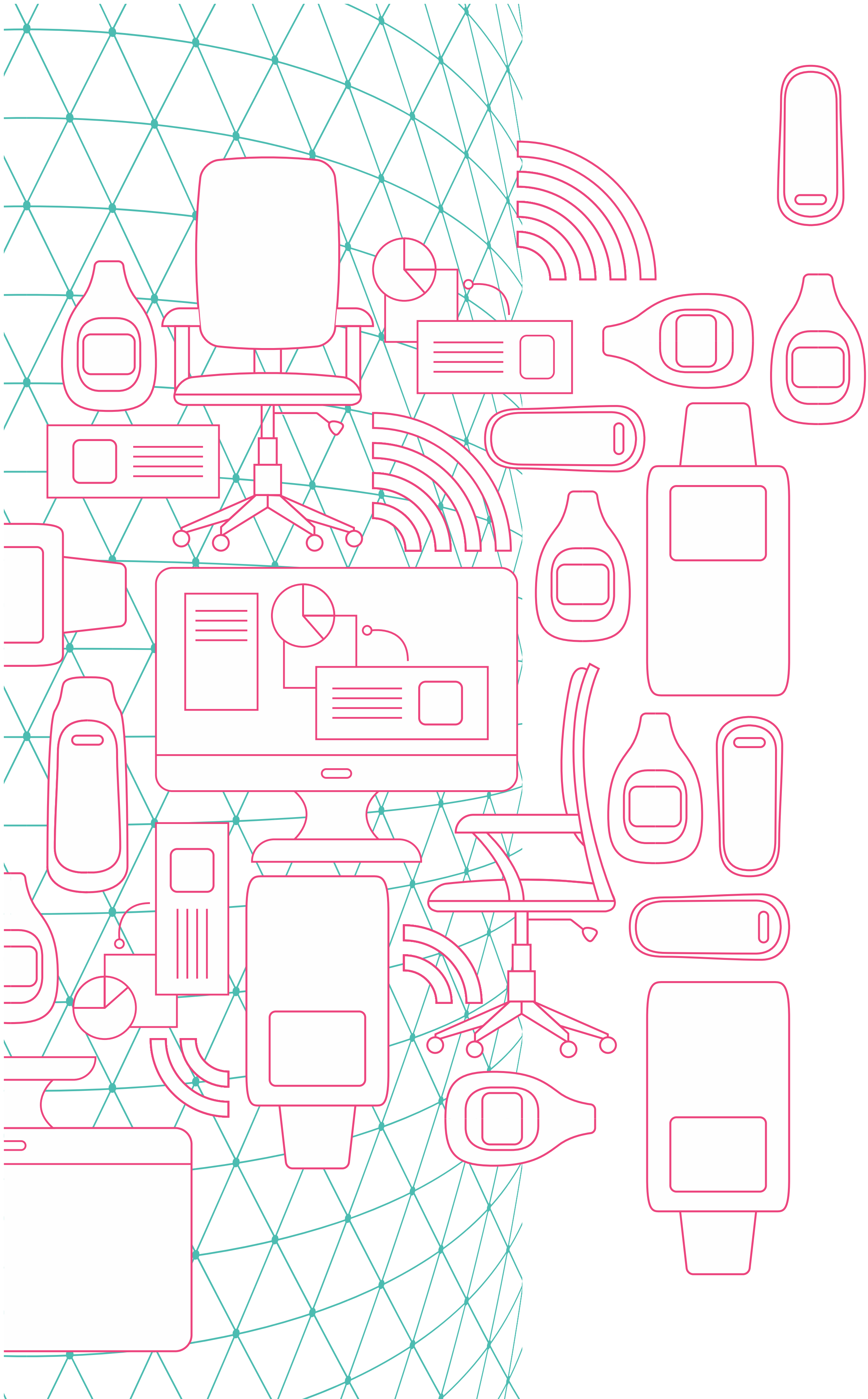


1

General Introduction

Health Self-management Applications (HSMAs) are sensor and intervention technologies that provide individual users with key metrics about their bodily functioning and personal health-related behaviours. Examples are activity trackers or heartrate monitors. Since the introduction of HSMAs to the consumer market, the use of such tools has rapidly grown (Kalantari, 2017). This growth is also seen in the work environment, where employers include options to use HSMAs in their health programs to stimulate and facilitate their workers to become relatively more healthy and to remain healthy (Jacobs et al., 2019). HSMAs are often welcomed enthusiastically by both employers and employees. For employers it seems like a simple and relatively low-cost way to contribute to a more healthy work environment and to support healthy behaviour in the work place (Huang, Benford, & Blake, 2019). Besides, workers often see it as a nice gadget that is easy to use which increases the acceptance of the HSMA (Jacobs et al., 2019). The responsible development and use of HSMAs in the work environment however is a niche that has not received the scientific attention it should, given the societal relevance.

The increased use of HSMAs, both in the work environment and in the consumer market (Kalantari, 2017), has reinforced that the workings and effectiveness of HSMAs are popular subjects of study. Research into the effectiveness of HSMAs in non-work settings, such as in healthcare and the consumer market, shows reason to be optimistic. For example, HSMAs improve disease management (Lorig, Sobel, Ritter, Laurent, & Hobbs, 2001; Lorig et al., 1999) and reduce health risks (de Vries, Kooiman, van Ittersum, van Brussel, & de Groot, 2016; Jakicic et al., 2016). Consumers using HSMAs show an increased physical activity (de Vries et al., 2016) and lower BMIs (Jakicic et al., 2016). These positive outcomes are encouraging, and triggered employers to include the use of HSMAs in their health enhancement programs (Kalantari, 2017). Yet, the effectiveness of HSMAs in the workplace seems lower. Previous research shows that the use of technologies such as HSMAs in the workplace is subject to high dropout rates (Eysenbach, 2005) and seems not effective in reducing sick leave (Linden, Muschalla, Hansmeier, & Sandner, 2014).

It seems that an effective use of HSMAs requires more than just wearing a sensor, it also implies that feedback information should be adequately reacted upon and workers should change their health-related behaviour. Even though there is much known about the effectiveness of feedback on all sorts of worker behaviour (Kluger & DeNisi, 1996), little research attention was given to the ways to influence the effectiveness of feedback information on health-related behaviour of workers provided by HSMAs in the work environment.

While the addition of 'self-management' in the name of these sensor technologies suggests that their use enlarge the users' autonomy in regulating their own health behaviour, recent research has questioned this and argues that the use of sensor technologies in the workplace might decline the perceived autonomy of employees (Leclercq-Vandelannoitte, 2017). This is a very unfavourable effect, because a loss of general job autonomy is at the root of many issues such as decline of job satisfaction (Thompson & Prottas, 2006) and productivity (Parker & Ohly, 2008), but when the autonomy is specifically related to the health domain, a loss of autonomy may negatively impact workers' health both inside and outside the work environment. This loss of autonomy might be enlarged due to the experienced pressure to comply with built-in norms of HSMAs, such as the 10.000 steps per day and inclusion of HSMAs in employers' health promotion programs, which might diffuse the division of responsibilities for employee health in the workplace between employer and worker. Employees might appreciate receiving HSMAs from their employer to monitor their healthy behaviour, but continuation of monitoring during off-work time might feel as an intrusion of the employer in their personal life (Leclercq-Vandelannoitte, 2017; Martin & Freeman, 2003).

The lack of knowledge on the effective use of HSMAs in the workplace, as well as the questions regarding impact on worker autonomy, show that despite the societal relevance and increasing use, HSMAs in the workplace have not sufficiently been studied from a multidisciplinary perspective. We therefore aim to answer questions about how HSMAs can responsibly and effectively be developed and used to stimulate workers to engage in more healthy work behaviours. This is the central theme of this research.

The working of HSMAs is based on the well-known principle that feedback about current health-relevant behaviour in the work setting can stimulate employees to self-regulate and adjust their behaviour (Ryan & Deci, 2000, 2006) and to meet desired standards. HSMAs such as activity trackers show users how many steps they took, how many stairs they climbed, and what their heart rate was while walking and climbing stairs. This feedback information enables the user to reflect on their current behaviour and to decide to alter their behaviour or not. For example, the norm of 10.000 steps per day is widely known (Johnman, Mackie, & Sim, 2017), the activity tracker (HSMA) registers and displays this information, and this insight in the actual amount of steps allows users to reflect on their current performance, and to change behaviours to reach this norm.

Feedback on health-related behaviour can be designed in many ways, altering characteristics such as timing, actionability, and the focus of feedback. Previous studies have investigated the impact of real-time (that is, administered at the time the behaviour occurs) (Roossien et al., 2017) or actionable feedback (that is, timely, individualized, non-punitive, and customizable) (Larouche et al., 2018), but not the joint effect. The effectiveness of this actionable feedback could probably be improved by giving this type of feedback real-time (Kluger & DeNisi, 1996; Kulik & Kulik, 1988; Luke & Alavosius, 2011), because a shorter time between the occurrence of behaviour and feedback on the behaviour improves the motivation of users to improve (Luke & Alavosius, 2011). Therefore, the first aim of this research is to examine the effects of HSMAs that provide both real-time and actionable feedback on worker’s health-related behaviour.

An important assumption of HSMAs is that they provide users with feedback information, which subsequently can be used to decide autonomously how to respond to this feedback. Following self-determination theory (SDT) (Ryan & Deci, 2000, 2006), it is assumed that HSMAs promote a sense of autonomy through which workers become intrinsically motivated to self-regulate their health-related behaviour. Yet, the use of HSMAs may also undermine the perceived autonomy of workers because they subject users to norms and values that are unlike their own (Owens & Cribb, 2017)). The second aim of this study therefore is to examine how using an HSMA in the workplace impacts the perceived autonomy to self-regulate the health-related behaviour of workers.

In order to protect the perceived autonomy of users as well as the privacy of data, it is important to know that sensor technologies are never value neutral (Martin & Freeman, 2003). The introduction of HSMAs in the workplace may affect worker privacy (Damman, van der Beek, & Timmermans, 2015) and autonomy (Damman et al., 2015; Leclercq-Vandelannoitte, 2017), and the responsible use of technologies such as HSMAs is subject for debate (van Berkel et al., 2014). To improve and facilitate responsible use, guidelines for responsible research and innovation (RRI) have been developed (Stahl, 2013; Stilgoe, Owen, & Macnaghten, 2013). Multiple concerns remain about how responsible design and use can be integrated in the development of technologies such as HSMAs for the work environment (Leclercq-Vandelannoitte, 2017). Further, knowledge on the practical execution of responsible research and innovation is lacking (Jakobsen, Fløysand, & Overton, 2019).Therefore, our third research goal is to explore how sensor and intervention technologies such as HSMAs for the work environment can be responsibly developed and implemented.

Serving the main aim of this research to enhance insights how HSMAs can responsibly and effectively be developed and used to stimulate workers to show more healthy behaviours, first HSMAs will be introduced: what are HSMAs, what do they aim to achieve, and what is their working? Second, the scientific background of this research is provided through describing the main underlying mechanisms of HSMA: the provision of feedback, autonomous decision making and self-regulation. Third, the theoretical and practical motivation for this study is presented by identifying the main contributions of this research. Finally, the outline of this thesis is presented by shortly introducing the main chapters.

Health Self-Management Applications: a description

HSMAs monitor the behaviour of users, and provide the users with feedback information on their bodily functioning and health-related behaviour. Popular examples are activity trackers such as Fitbit and Jawbone, that keep track of the number of steps and other activities during the day, and smartphone apps such as Strava and Runkeeper that keep track of performance during running or cycling using GPS. The most important aspects of these HSMAs are that they use sensor technology to monitor certain aspects of daily life, and they return the data as feedback to the user, in order for the user to be able to alter the behaviour. Feedback given by HSMAs differs from general feedback in the sense that it only aims at behaviour that is associated with health, i.e. amount and intensity of exercise, heart rate, estimated calories burned, hours of sleep, et cetera. Often, there are general norms for these behaviours (i.e. walk 10.000 steps per day (Johnman et al., 2017), sleep 7-9 hours per night (Hirshkowitz et al., 2015)).

When providing feedback, HSMAs allow individuals to self-manage and regulate their health-related behaviour and health (Schermer, 2009). This makes it possible for individuals to alter their behaviour in order to reach personal goals, such as losing weight, running a marathon, or prevent disease. In the last decade, the focus of HSMAs has been shifting from curative to preventive approaches (Fjeldsoe, Marshall, & Miller, 2009), and the use of HSMAs has shifted from the field of medicine to lifestyle. This makes that HSMAs are relevant for a larger crowd, because many people could use some support in improving their lifestyle in order to prevent diseases such as cardiovascular disease, obesity, or diabetes (Miller, Balady, & Fletcher, 1997; Netz, Wu, Becker, & Tenenbaum, 2005). Moreover, usage has been extended to the work environment (Linden et al., 2014). A growing number of organizations equip their employees with HSMAs for health purposes (Linden et al., 2014; Ruitenburg, Plat, Frings-dresen, & Sluiter, 2015). The implicit assumption underlying the usage of HSMAs is that the feedback provided by HSMAs will be utilized by employees to self-manage and adapt their health-related behaviour, as these HSMAs in the work environment are also aimed at the prevention of disease (Jacobs et al., 2019). This makes that the effect of these HSMAs stretch into the private life of the worker. Prevention of disease is, after all, a lifestyle change, and such a change affects all parts of the user's life (Grady & Gough, 2014).

In recent years many employers have started to facilitate the use of HSMAs in the workplace (Kalantari, 2017). Often, HSMAs are part of the Workplace Health Promotion Program of the employer, in which other interventions such as health checks and a healthy cafeteria are also included. Employers started with the inclusion of relatively simple technologies in their health promotion programs, such as RSI prevention tools These HSMAs were simple, because they did not measure the behaviour of the user but used time-based breaks, and they did not provide feedback, but they demanded a certain action (i.e. users had to quit typing, or the computer would shut down). Currently, HSMAs that are used in the workplace have extended options on how and when to provide feedback and what kind of feedback. Especially in the last decade HSMAs have more advanced options, allowing real-time feedback, but also feedback that is adjusted to personal goals or norms instead of general guidelines (Bravata et al., 2007; Luke & Alavosius, 2011; Schermer, 2009). The advanced options of HSMAs facilitate the self-regulation of behaviour more than earlier HSMAs, because users have more autonomy in how and when they want to act on given feedback. In the workplace however, the norms regarding healthy behaviour are not only set by the user, but also by the employer and the work environment (Linden et al., 2014).

Theoretical background

The goal of this study is to answer questions about how HSMAs can responsibly and effectively be developed and used to stimulate workers to show more healthy behaviours. Therefore, we focus on the most relevant themes for this research in this theoretical background. First, we look into the research on feedback, more specifically feedback in the work environment, how feedback characteristics can improve behavioural alterations, and how this can be applied in HSMAs. Secondly, we focus on what is known about autonomy, how this relates to the use of HSMAs in the work environment, and how this affects the self-management capacities of individuals.

Feedback

Feedback refers to evaluative information about self-relevant attributes (i.e., abilities, performance) that aim to improve the self-managing capabilities of individuals by stimulating a process of reflection (Anseel, Lievens, & Schollaert, 2009; Sargeant, Mann, Van Der Vleuten, & Metsemakers, 2009). Feedback makes individuals reflect on the desired and actual behaviour and helps these individuals in planning to alter their behaviour (London & Smither, 1995; Steelman, Rutkowski, Steelman, & Rutkowski, 2004). The characteristics of feedback can differ extensively (Kluger & DeNisi, 1996). In this research, we focus on differences in type (i.e., performance versus developmental), timing, actionability, and frequency of feedback.

Type of feedback: performance and developmental feedback

Feedback can differ in focus, i.e. it can focus on past performance and the judgement of that performance, or on future development and strategies to get there. Performance feedback is aimed at only the actual performance, formulated retrospectively and only emphasizing the difference between goal and behaviour, and developmental feedback includes information that facilitates recipients to learn, develop, and make adaptive behavioural changes (Li, Harris, Boswell, & Xie, 2011; Zhou, 2003). Self-Determination Theory (SDT) suggests that developmental feedback may boost autonomy and intrinsic motivation for learning and improvement, whereas performance feedback may inhibit feelings of autonomy because it is formulated negatively and retrospectively (Ryan & Deci, 2006). Performance feedback on health behaviour is given in a data-only format, in which the user is provided feedback on their current behaviour, supplemented with the general norm ("You have walked 7738 steps today, the norm for daily exercise is 10.000 steps"). Developmental feedback on the other hand builds upon future-oriented goal-related feedback in order to improve users' behaviour ("If you take a lunch walk, you may take 2262 steps and reach your goal!"). The effect of performance vs. developmental feedback is studied in Chapter 3.

Real-time actionable feedback

Feedback Intervention Theory shows that feedback is more effective if there is less time between the behaviour and a feedback signal. This effectiveness of real-time feedback is explained by the increased direct attention to the causes for behaviour, and the motivations to alter this behaviour (Kluger & DeNisi, 1996; Kulik & Kulik, 1988; Luke & Alavosius, 2011). Modern HSMAs mainly give real-time feedback, so the feedback message is sent at the time at which the deviating behaviour is signalled. In order to further optimize feedback outcomes, Hysong et al. (2006) show that actionable feedback (that is, feedback that is timely, individualized, non-punitive, and customizable) is more effective in altering behaviour. Due to the timely and individualized approach, the targeted behaviour can immediately be denominated, thereby increasing chances of direct action, after which the non-punitive and customizable character increase learning capacities of the receiver (Cannon & Witherspoon, 2005). The effect of real-time actionable feedback is studied in chapter 2.

Feedback frequency

Under normal circumstances, increased feedback frequency improves the effectiveness of the feedback (Kluger & DeNisi, 1996), because the receiver of the feedback is reminded more often of the potential improvements and has the opportunity to gradually improve (Lurie &

Swaminathan, 2009). This effect however fades when the feedback frequency is too high (Lam, DeRue, Karam, & Hollenbeck, 2011) because too frequent feedback overwhelms the cognitive capacity of the receivers, thereby invalidating them to improve their behaviour. This suggests an inverse U-shaped relation. This studies that describe this inverse U-shaped effect, however, only use imposed feedback frequencies (Lam et al., 2011). For self-controlled feedback frequencies, studies show that only subjects who are already improving, increase their frequency even more, thereby optimizing the feedback frequency for all individual participants (Chiviacowsky & Wulf, 2002). For HSMAs in the workplace, this self-controlled optimization of the feedback frequency could be very beneficial, because especially in the work environment, externally imposed feedback characteristics could lead to decrease of autonomy (Kukla, 2005) and loss of effectiveness of feedback (Alder, 2007).

Autonomy

In this section, we show what the relevant literature says about self-regulation of behaviour and the link with worker autonomy when using HSMAs or other monitoring technologies. We use the term 'perceived autonomy', because we study the perception of autonomy as experienced by the worker. Our study does not alter the conditions under which persons work, so no alterations in work routines or rules and regulations are put in place. Therefore, no objective changes in worker autonomy are caused. The perceived autonomy, however, can be very different, as is explained in this section.

Self-regulated behaviour

SDT (Ryan & Deci, 2000, 2006) is a widely used framework for the study of autonomy as enhancer of the self-regulation of health-related behaviour. SDT states that the motivation for regulating behaviour varies along a continuum from autonomous motivation to externally controlled motivation. Research shows that an increase in perceived autonomy promotes the cognitive, affective, and behavioural self-regulation of health-related behaviour (Chatzisarantis & Hagger, 2009; Fortier, Sweet, O'Sullivan, & Williams, 2007; Rose, Parfitt, & Williams, 2005; Silva et al., 2010; Williams, Gagné, Ryan, & Deci, 2002; Williams, McGregor, Zeldman, Freedman, & Deci, 2004). This self-regulation makes employees responsible for their own health and enables them to independently self-manage their health-related behaviour. Therefore, in order to allow workers to self-regulate their health behaviour, the autonomy of these workers needs to be ensured.

Worker autonomy

Autonomy refers to the say a worker has about their health-related behaviour in the work environment, and it reflects the extent to which a worker can make decisions on whether, how and when to alter behaviour without the involvement of others (Owens & Cribb, 2017). In this way, autonomous actions are those actions that are fully in line with the preferences and values of the individual (Ekstrom, 2005; Ricoeur, 1966). An important assumption of HSMAs is that using HSMAs increases the perceived autonomy of workers. HSMAs provide workers with feedback information that enables workers to decide autonomously whether to adapt or not their health behaviour, such as doing exercises, or change break-taking and sitting behaviour. In the context of HSMAs in the work environment, this means that a worker can for instance self-decide whether or not to take a walk during their break, or can work standing up instead of sitting down. It also enables workers to reach goals they have, for instance walking 10.000 steps per day, or perform moderately intensive exercise for 30 minutes per day. On the other hand, workers can perceive the feedback as pressing (Owens & Cribb, 2017), because they may agree on the values, but do not share the same norms for behaviour (i.e. 10.000 steps per day). They do not internalize these norms, and therefore do not perceive them as their own norms.

Imposed norms for behaviour, that are not internalized by the workers, make that the perceived autonomy to self-regulate health-related behaviour is under pressure. Workers may experience this pressure in the work environment, but also feel obligated to continue pursuing these goals at home. This therefore not only affects their autonomy at work, but also at home. The experienced pressure may increase when the worker is less healthy or shows less healthy behaviour: HMSAs that are provided in the work environment show that the employer values workers who are healthy and show healthy behaviour. Therefore, when the worker deviates from these values, the perceived pressure to alter behaviour may be higher.

Scientific contributions

This study uses a multidisciplinary approach to study the ways to responsibly develop and use HSMAs aimed at improving health-related behaviour of workers. Doing so, we aim to make two main contributions.

Firstly, this thesis contributes to the field of Workplace Health Promotion by applying insights from Feedback Intervention Theory and Self Determination Theory to the context of HSMAs in the workplace. By doing so, we study if real-time, actionable feedback improves worker health-related behaviour, and how the difference between performance and developmental feedback affects the perceived autonomy of the users of HSMAs. This knowledge adds to the field of Workplace Health Promotion, by showing how the alteration of feedback characteristics can support the improvement of health-related behaviour of workers, and gives insight in boundary conditions (i.e., type of feedback: performance vs developmental; health of users) that moderate the effects of HSMAs on the users' perceived autonomy in self-regulating their health-related behaviour.

Secondly, we aim to add knowledge to the field of Responsible Research and Innovation. We do so by examining how members of a multidisciplinary research team can co-operate in a continuous cycle of reflection on the stakeholders (i.e., developers, employers, users) and their values, in the design and use of sensor and intervention technology for promoting health work behaviour. We show how a context-sensitive ethics approach can identify effects on worker autonomy and privacy that would have gone unidentified in regular

RRI projects. Identifying these issues gives us the opportunity to overcome three issues, namely compartmentalization of development and use of HSMAs, generalization of ethical issues, and defining the responsibilities for responsible use for worker and employer.

Research questions and outline of this thesis

This thesis aims to examine how HSMAs can responsibly and effectively be developed and used to stimulate workers to show more healthy behaviours. These effects are examined in three chapters, for which the main research questions are:

How do HSMAs that provide both real-time and actionable feedback impact worker's health-related work behaviour? (Chapter 2)

Does the use of HSMAs in the workplace promote employees' perceptions of autonomy in self-regulating their health-related behaviour? (Chapter 3)

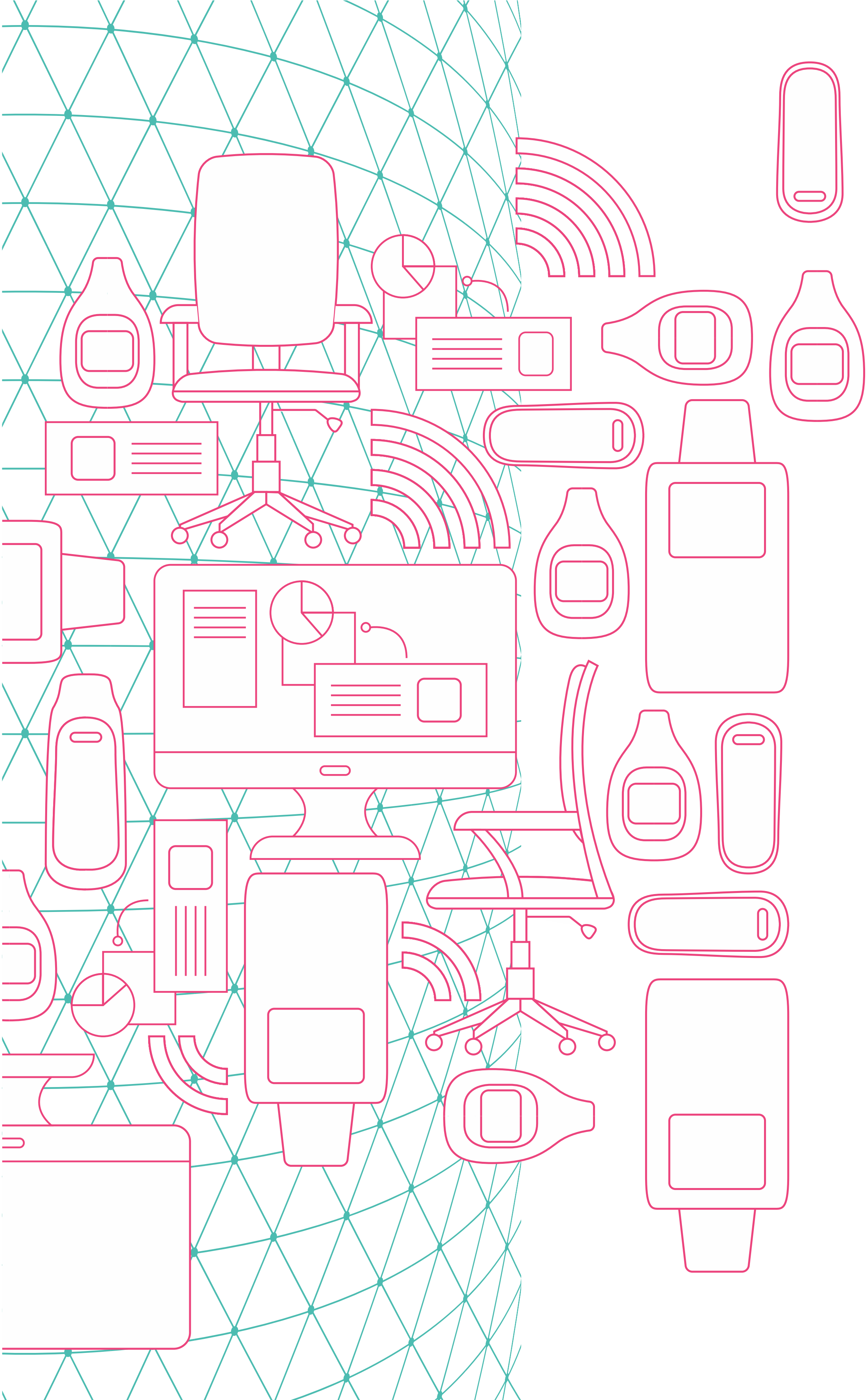
How can HSMAs for the work environment be responsibly developed, with attention for inherent values in and responsibilities for both design and implementation? (Chapter 4)

In Chapter 2, we report on our first experimental study. In this study we examine the effect of real-time actionable feedback on the behavioural change of office workers who use a set of sensor technologies (HSMAs) in the workplace. The behavioural health-related change is aimed at reducing prolonged sitting and preventing mental fatigue, which both are common issues for office workers, and in the long term may cause a range of health problems. To prevent office workers from sitting too long or becoming fatigued is a huge challenge, because workers are often unaware of their sitting behaviour and mental fatigue. The first goal of this chapter is to examine whether sending real-time actionable feedback messages to workers that sit for a long period of time, or who show signs of mental fatigue, improves their health behaviour. So, do workers stand up and/or take a break when they receive actionable real-time feedback about their behaviours. All workers had the opportunity to autonomously self-control the frequency at which the feedback was provided, and could choose and continuously alter their feedback frequency. This leads to the second goal of this chapter: to examine whether an increased self-controlled feedback frequency would strengthen the effects of real-time, actionable feedback on workers' health behaviour.

In Chapter 3, we describe the results from the second experimental study. In this chapter, we explain how the use of an HSMA (a Fitbit One activity tracker) in the work environment affects the perceived autonomy of workers. All workers received feedback on their daily activity, using the activity tracker and receiving feedback e-mails. This chapter investigates what the effect is of performance vs. developmental feedback on the changes in perceived autonomy of employees. Additionally, we investigate the differences between workers with a high BMI and workers with a medium or low BMI. The purpose of this investigation is to provide more insight in how the pre-experiment health condition of workers influences their perceived autonomy when using an HSMA. We use the data collected in the second field study to explore the actual effects on perceived autonomy of both healthy and less healthy workers, and have deepened our understanding of this phenomenon by conducting a series of interviews.

In Chapter 4, ethical issues are explored in relation to the use of HSMAs in the workplace. The project SPRINT@Work is used as a case study. SPRINT@Work aimed at developing and evaluating sensor and intervention technologies that contribute to keeping the aging worker healthy and effectively employable. In this project, 4 PhD candidates and their supervisors collaborated, and there was a continuous process of intervision with the 4 PhDs and an ethicist, in order to identify the ethical issues that occurred while developing and implementing these technologies for the workplace. Using SPRINT@Work as a case study, we show how the three main problems of Responsible Research and Innovation, mentioned above, materialize in practice. These problems centre around privacy and autonomy as ethical values. In this chapter we describe first the problem of compartmentalization: how current RRI studies often focus only on either the development of new technologies, or on the implementation of these technologies. At the same time, many of the issues that are relevant for these innovations, such as the values that are inherent to the design, are not bound to just one of these phases. Second, the problem of generalization is described: the work environment has a number of specific characteristics, that make general reflections on these values insufficient. Third, the responsibility problem is illustrated: the responsibilities of different stakeholders should be acknowledged by each stakeholder. To overcome these issues in the SPRINT@Work project, we have deepened our understanding of the relevant values using an approach of context-sensitive ethics. We have shown how a context-sensitive ethics can improve worker autonomy, how the balance between privacy and health can be improved, and how focusing on values in their context can improve the responsible use of technologies.

Lastly, in Chapter 5 we highlight the main findings from each study. Next, we sketch the most important implications for science and society. After outlining the limitations of the work and areas for future research, we finish with some final remarks underlining the scientific and societal relevance of this research.



2

Real-time, Actionable Feedback and Office Workers' Sitting Behaviour and Mental Fatigue

An Experimental Field Study

Abstract

Office workers are prone to developing work-related health problems because of their behaviour in the workplace. Two main causes for these health problems are prolonged sitting behaviour and mental fatigue. To improve worker sitting behaviour and mental fatigue, employers are increasingly adopting sensor technologies aimed at optimizing behaviour, but knowledge of the factors that drive effectiveness of these health self-management applications (HSMAs) is lacking. This paper empirically investigates the effects of real-time actionable feedback messages on employee health-related behaviour. The experimental field study contained a six-week intervention in which participants used a smart chair to monitor their sitting behaviour, and a keylogger while typing that registered their interkey interval as a proxy for mental fatigue. Participants were able to self-control the frequency at which the feedback was provided, and received feedback messages when standards for healthy behaviour regarding sitting or mental fatigue were exceeded. Findings show that receiving real-time actionable feedback messages on sitting behaviour does not impact the duration of the sitting event, whereas feedback messages on typing behaviour does influence participants in taking a break from typing. Over time in the experimental period, we observed a decrease in average sitting duration, but the average duration of a typing event did not change.

Introduction

Office workers are prone to developing several work-related health problems such as musculoskeletal problems (Mathiassen, 2006; Wilmot et al., 2012), cardiovascular disease (Wilmot et al., 2012), diabetes type 2 (Wilmot et al., 2012), obesity (Blair & Brodney, 1999; Puhl & Heuer, 2010), and mental sickness absence (Roelen et al., 2013). Two major causes of these work-related health problems are prolonged sitting behaviour and mental fatigue (Roelen et al., 2013; van Dijk, 2003; Wilmot et al., 2012). Employers have increasingly adopted workplace health promotion programs aiming at mitigating the adverse effects of prolonged sitting behaviour and mental fatigue. These programs include technical tools for employees that give them automated prompts for switching between seated and standing positions (Larouche et al., 2018) or for taking breaks from typing on a computer (de Korte, Huysmans, de Jong, van de Ven, & Ruijsendaal, 2012a).

To improve worker health and wellbeing in the workplace, giving feedback on current health-related work behaviour is an often-used strategy (Carter et al., 2011; Hermsen, Frost, Renes, & Kerkhof, 2016; Mattila et al., 2013). Feedback Intervention Theory states that the effectiveness of feedback in terms of improved behaviour and performance (Kluger & DeNisi, 1996)is influenced by the characteristics of the feedback provided. Earlier studies on feedback and worker behaviour show that feedback is more effective when it is actionable (Hysong et al., 2006) which means that customized advice is given on how to change the behaviour in question. Furthermore, feedback should be real-time, which means that the advice pertains to current behaviour, not past behaviour (Houde, Todd, Sudarshan, & Carrie Armel, 2013; Luke & Alavosius, 2011). Both the actionable and real-time aspect of feedback messages improves their effects on behaviour, which is evidenced by the effects of health self-management applications in the areas of patient (Lorig et al., 2001) and consumer behaviour (Macridis, Johnston, Johnson, & Vallance, 2018). Employers are seeing these benefits and are increasingly providing employees with smart devices that use real-time actionable feedback mechanism (Jacobs et al., 2019). However, it is unknown whether the real-time actionable feedback given by these smart devices actually leads to intended behavioural changes by employees (Mattila et al., 2013). Employees are different from consumers in that sense that they use health self-management tools in the workplace, where they are under pressure from deadlines and colleagues. This makes it more difficult to alter behaviour. Therefore, we aim to investigate the effects of real-time actionable feedback on employee health-related work sitting and typing behaviour

Specifically, our first research goal is to examine the effect of real-time, actionable feedback on prolonged sitting behaviour of office workers. Although the recommended maximum duration of consecutive sitting is 55 minutes (Ryan, Grant, Dall, & Granat, 2011), many office workers do not meet this recommendation (Netten, Van Der Doelen, & Goossens, 2013). One of the reasons for prolonged sitting is that people simply do not know that they are sitting too long (Shrestha et al., 2018). To increase this awareness, technical tools have been developed to provide real-time feedback on their sitting behaviour (Goossens, Netten, & Van der Doelen, 2012), that is, feedback given exactly when the behaviour should change, as opposed to retrospective feedback, where at the end of a period (e.g., half a day or a whole day) feedback over the whole period is given to determine which behaviours went well and which behaviours can be improved.

Some previous studies have examined the effectiveness of real-time feedback tools in reducing prolonged sitting behaviour, for example, in studies on smart chairs that send feedback signals when sitting for long periods or a bad posture are detected. In one study, employees received real-time feedback through chair vibrations and warning lights on a tab (Roossien et al., 2017). These feedback signals, however, had little to no effect on worker prolonged sitting behaviour, as the worker only received a tactile feedback signal indicating that something was wrong without clearly indicating what the harmful behaviour was and how it could be changed (Roossien et al., 2017).

The lack of actionability of the feedback made it difficult for workers to self-regulate their behaviour, because they first had to interpret the signal and compare it with the desired behaviour before they could figure out what to do. Receiving actionable feedback on how to change behaviour increases the effectiveness of feedback regarding prolonged sitting behaviour (Larouche et al., 2018), and therefore we aim to add actionable advice to the feedback signals given to workers to self-regulate their sitting behaviour.

Our second research goal is to examine whether real-time, actionable feedback on emerging mental fatigue that arises while typing on a computer can lead employees to take a break. Literature suggests that employees become less fatigued if they can regulate their work breaks autonomously (Trougakos, Hideg, Cheng, & Beal, 2014). Unlike pre-scheduled breaks, such as time-based breaks imposed by Repetitive Strain Injury (RSI)-prevention programs on a computer, real-time feedback enables workers to tailor their break-taking behaviour to their personal current state of mental fatigue.

Workers are often unable to notice their own mental fatigue at an early stage (Zhang, Gong, Miao, Zhu, & Yang, 2011), with the consequence that they keep working until there are signs of serious mental fatigue (such as delayed reactions and increased error rates). Providing workers with early-stage real-time feedback on mental fatigue, enabling self-regulation and containing actionable messages, requires validated tools that can measure emerging mental fatigue in an office environment without impeding the performance of work tasks. Recent research has yielded tools that measure keystroke intervals during typing and have used these intervals as a proxy of mental fatigue (de Jong, Jolij, Pimenta, & Lorist, 2018; Pimenta, Carneiro, Novais, & Neves, 2014). The value of these tools is above all that they can provide real-time feedback on mental fatigue at an early stage in the workplace. Real-time feedback can enable workers to change their typing behaviour to avoid the occurrence of severe mental fatigue. Therefore, our second goal is to examine whether real-time actionable feedback can prompt workers to take a break from typing early to recover from mental fatigue.

A third research goal of this study is to investigate the influence of the frequency with which workers receive real-time actionable feedback on their sitting behaviour and emerging mental fatigue. Literature shows that individuals who want to improve aspects of their behaviour request to receive more often feedback (Kluger & Adler, 1993), and that a higher frequency results in an accumulation of effects of feedback (Lurie & Swaminathan, 2009). Therefore, we aim to examine whether increased self-controlled feedback frequency has a moderating effect on the effectiveness of real-time actionable feedback on worker sitting behaviour and break-taking behaviour.

This research aims to make various contributions to the research literature on the role of feedback in self-management of health-related behaviour in the workplace. First, using insights from feedback intervention theory, we investigate the effectiveness of real-time actionable feedback delivered by a smart chair on employee self-regulation of sitting behaviour. Second, we investigate the effectiveness of real-time actionable feedback given to employees to take a break from typing to recover from early mental fatigue, thereby applying a recently developed technique that uses keystroke intervals to assess emerging mental fatigue.
Finally, our research provides practical implications for how real-time actionable feedback can be used in sensor and intervention technologies to enable workers to better regulate their health-related work behaviour.

Theoretical Background

Real-time actionable feedback

Feedback in general is a piece of evaluative information about previous behaviour (Anseel et al., 2009; Sargeant et al., 2009), often including an external or personal norm that is relevant for this behaviour. The effectiveness of feedback is affected by many factors related to the feedback itself, the ways it is provided, and the receiver of the feedback. Two main feedback-related factors we focus on in the present research are the timing of feedback, and the actionability of feedback. Regarding the timing of feedback, feedback intervention theory states that feedback is more effective in adapting behaviour if there is a shorter time between displayed behaviour and receiving feedback on that behaviour (Kluger & DeNisi, 1996). The reason for this is that real-time feedback can direct attention to immediate causes, motives and conditions of the current behaviour, allowing direct targeted adjustments to be made. Recent studies support this claim of increased effectiveness of real-time feedback (Houde et al., 2013; Luke & Alavosius, 2011). Effects of real-time feedback have been predominantly found in experimental studies (Kulik & Kulik, 1988; Webb, Stock, & McCarthy, 1994), and in a few field studies where organizational behaviour such as quality control (Mason & Redmon, 1993)and training of teaching skills was targeted (Reid & Parsons, 1996). Most research in the work environment, however, examines feedback on behaviour that is given in a retrospective manner, for instance, by giving feedback on a complex task only after it has been fully completed (Alder, 2007). As contemporary smart devices with built-in sensor technology are capable and intended to provide immediate feedback on behaviour, we need additional research to examine the effectiveness of real-time feedback provided by those devices. We aim to close this research gap by investigating whether real-time feedback can help workers in self-regulating health-regulated behaviour in the workplace. Furthermore, as soon as feedback is given real-time, the worker should be enabled to easily change the behaviour when necessary, so the feedback should be actionable. Actionable feedback is feedback that is timely, individualized, non-punitive, and customizable (Hysong et al., 2006). The timely and customizable characteristics give workers clear information and directions on how to act in order to improve behaviour (Larouche et al., 2018). The non-punitive nature prevents workers from experiencing negative emotions in response to the feedback, thereby giving room for learning and self-improvement (Cannon & Witherspoon, 2005). Current real-time feedback systems in the workplace often do not include actionable feedback, and only show how a worker negatively deviates from standards or norms (Roossien et al., 2017) without giving advice on how to effectively adjust that behaviour. Research suggests that feedback providing actionable information is highly effective in changing behaviour even when it is not given real-time (Larouche et al., 2018). Therefore, in this study, we combine the real-time feedback with actionable information to optimize the feedback effects on worker behaviour.

Sitting behaviour

Prolonged sitting is very common behaviour for office workers. In literature, recommendations on the maximum duration of sitting bouts vary from 20 to 55 minutes (Goossens et al., 2012; Netten et al., 2013). These recommended norms, however, are often exceeded (Evans et al., 2012) as office workers sit on average 5.4 hours per working day behind a desk (Roossien et al., 2017) and 7.1 hours per working day in total, i.e. including sitting during lunch and meetings. More than 21% of working days is spent in sitting events longer than 55 minutes (Netten et al., 2013). This prolonged sitting causes a wide range of illnesses, including musculoskeletal problems (Mathiassen, 2006; Wilmot et al., 2012), cardiovascular disease (Wilmot et al., 2012) and diabetes type 2(Wilmot et al., 2012).

These diseases can be prevented by using interventions that alter the sitting behaviour of office workers. Interventions examined in previous research include advice or counselling on physical activity (Marshall, Leslie, Bauman, Marcus, & Owen, 2003; Opdenacker & Boen, 2008; Østerås & Hammer, 2006), fitness testing (Aittasalo, Miilunpalo, & Suni, 2004), and e-mail messaging about healthy eating and active living (Plotnikoff, McCargar, Wilson, & Loucaides, 2005). These interventions showed no significant alteration of sitting behaviour. A review of workplace health promotion interventions from Malik et al. (2014) recommends including the use of sensor technology to objectively monitor sitting behaviour based on which specific feedback on actual durations of sitting bouts can be given instead of using general information and behavioural guidelines as input for the feedback. The application of these technologies indeed caught on, and especially activity monitors that monitor daily exercise in various ways were used on a large scale to monitor sitting behaviour and physical activity (Donath, Faude, Schefer, Roth, & Zahner, 2015; Evans et al., 2012; Neuhaus et al., 2012). These interventions, however, only used retrospective feedback, instead of also generating real-time actionable feedback messages.

A few recent studies used smart chairs to examine real-time feedback on sitting behaviour (Goossens et al., 2012; Roossien et al., 2017), sometimes combined with activity monitors. These interventions, however, sorted little to no effect. Possible explanations included a lack of actionable information (Goossens et al., 2012; Roossien et al., 2017), because workers received a tactile feedback message (the chair buzzed), but had to press a button on a label attached to the chair to get more information about what was wrong. If they pressed the button, they were still only shown an orange light indicating where on the chair the abnormal sitting behaviour occurred, but no advice was given on what to do (i.e. change leg position, stand up, sit up straight). Due to this lack of actionable feedback, the real-time feedback may not have been effective.

Real-time feedback is given when current behaviour is deviating from the norm for that behaviour. In case of sitting behaviour in the present study, real-time feedback gives information on the duration of a current sitting event. Such real-time feedback that is specified to the actual current sitting behaviour of the individual is suggested to be more effective in changing that behaviour than more general feedback (Huang et al., 2019). Furthermore, feedback is more likely to be effective when it is actionable (Bond et al., 2014; He & Agu, 2014). For example, actionable feedback messages concerning sitting behaviour are "Stand up" and "Walk for 2 minutes" (Larouche et al., 2018). We therefore propose that real-time, actionable feedback on prolonged sitting behaviour may enable office workers to reduce the duration of sitting events.

More specifically, we expect that the effects of real-time actionable feedback on sitting behaviour of office workers are twofold. First, real-time actionable feedback on a prolonged sitting event is likely to prompt workers to stand up from their chair within a relatively short time frame (e.g., 15 minutes) (Lechermeier & Fassnacht, 2018). Distinct yet related to this direct feedback effect on standing up behaviour, the feedback may make workers more aware of their prolonged sitting behaviour and motivate them to shorten the duration of the sitting event. To capture both feedback effects, we accordingly hypothesize:

1A. Real-time actionable feedback (versus no feedback) on prolonged sitting prompts office workers to stand up from their chair earlier.

1B: Real-time actionable feedback (versus no feedback) on prolonged sitting decreases the duration of sitting events of office workers.

We investigated the effects of real-time, actionable feedback on sitting behaviour in a field experiment of 6 weeks (see method). We therefore also tested whether feedback on sitting behaviour produces a learning effect over time. It is plausible that, over time, participants will not only become more and more aware of their prolonged sitting behaviour through repetitive feedback, but also learn to limit long sitting bouts. Therefore, we hypothesize:

1C: Time has a negative effect on duration of sitting events, such that as time progresses during the experiment, the duration of the sitting events decreases.

Mental fatigue

Mental fatigue is a state of tiredness which is tied to multiple work-related problems, such as loss of efficiency (Boksem & Tops, 2008), distraction (Boksem, Meijman, & Lorist, 2005), and difficulties in planning and adapting activities (Van der Linden & Eling, 2006; Van der Linden, Frese, & Sonnentag, 2003). Mental fatigue may also impact health, leading to prolonged fatigue, deteriorated sleep quality, psychosomatic complaints, and emotional exhaustion (Sluiter, De Croon, Meijman, & Frings-Dresen, 2003)

Mental fatigue is a reason for changing fatigue-related behaviour. Fatigue makes that the effort to concentrate on work no longer pays off, because the work slows down or the results are of lower quality (Boksem & Tops, 2008). Previous studies on mental fatigue reduction have shown that taking small breaks during the day allows workers to recover from mental fatigue and stay fit during working days (Kim, Park, & Niu, 2017) However, research suggests that interventions to stimulate breaks at predetermined times show no effect (Trougakos et al., 2014), because workers prefer to autonomously self-regulate breaks from work, so without a timer or manager telling at what time exactly a break should be taken. Self-regulation of break-taking behaviour is complicated, however, because workers tend not to notice when they get fatigued until they are extremely fatigued (Zhang et al., 2011). When they notice that they are extremely fatigued, their need for recovery time is very high, whereas this extended time is not always available, causing a lack of recovery during the working day (Trougakos & Hideg, 2009). Lack of recovery from mental fatigue is associated with productivity loss (Ricci, Chee, Lorandeau, & Berger, 2007) and loss of general health (Sluiter et al., 2003). Therefore, real-time feedback on emerging mental fatigue could help workers take a timely break, thereby minimizing the development and consequences of severe mental fatigue.

Real-time feedback on mental fatigue in the office environment, however, is hard to give, because there is a lack of methods for measuring emerging mental fatigue that are useable in office work. Known methods are either retrospective, so not real-time, or very invasive, making it impossible to use them on a regular basis in the work environment.[1] Recent developments using keystroke intervals in typing behaviour as a proxy for mental fatigue have opened up the possibility to measure emerging mental fatigue of office workers in a real-time, non-invasive way (de Jong et al., 2018; Pimenta et al., 2014). This measurement method allows users to receive real-time feedback that enables them to self-regulate their fatigue-related behaviour. In this approach, the interval between keystrokes is used to determine the mental fatigue of office workers. Using this method, real-time actionable feedback can be given, allowing workers to consider this feedback information when deciding to take a break. Thus, such real-time feedback allows autonomous self-regulation of break-taking behaviour, which is likely to help reduce mental fatigue (Trougakos et al., 2014).

We expect that the effects of real-time actionable feedback on mental fatigue of office workers are threefold. First, real-time actionable feedback on mental fatigue is likely to prompt workers to take a break within a relatively short time frame (e.g., 15 minutes) (Lechermeier & Fassnacht, 2018). Besides this direct feedback effect on break-taking behaviour, the feedback may make workers more aware of their emerging fatigue and motivate them to shorten the duration of typing events. In addition, we expect that mental fatigue feedback will produce a learning effect over time in the six-week experiment we conducted. Over time, participants are likely to take a break more quickly in response to the feedback they receive, thereby reducing the duration of typing events.

To capture these three feedback effects, we accordingly hypothesize:

[1] Known methods for measuring mental fatigue are a psychomotor vigilance task (PVT) at the end of the day (Riethmeister, Bültmann, Gordijn, Brouwer, & de Boer, 2018), questionnaires (Sluiter et al., 2005, 2003), or an Electroencephalogram (EEG) (Liu et al., 2018; Wascher, Heppner, & Hoffmann, 2014), requiring the subjects to use an EEG device mounted on their head for the time of the study.

2A: Real-time actionable feedback (versus no feedback) on mental fatigue prompt workers to take a break from typing earlier.

2B: Real-time actionable feedback (versus no feedback) on mental fatigue decreases the duration of typing events of office workers.

2C: Time has a negative effect on duration of typing events, such that as time progresses during the experiment, the duration of typing events decreases.

The moderating effect of Feedback frequency

Feedback frequency, defined as the number of times a feedback intervention was provided (Kluger & DeNisi, 1996), is known as one of the drivers of feedback effectiveness. Higher feedback frequency improves the learning of new behaviour (Salmoni, Schmidt, & Walter, 1984). This learning effect of feedback frequency is further strengthened when feedback receivers can self-control feedback frequency (Chiviacowsky & Wulf, 2002). Individuals who are able to utilize the feedback for improving their behaviour, get motivated to ask for more feedback, which further increases their behavioural adjustments and thus the effect of the feedback (Chiviacowsky & Wulf, 2002).

Earlier studies on feedback frequency in the work environment show an inverted U-shaped effect for externally imposed feedback frequency, so the increase of frequency improves the outcomes, up to a tipping point, after which the outcomes worsen with every increase of feedback frequency (Lam et al., 2011). This happens because too frequent feedback overwhelms the cognitive capacity of the receivers, thereby invalidating them to improve their behaviour (Lam et al., 2011). For self-controlled frequencies, however, the effect of frequency has been found to be linear (Wulf, 2007), because participants will only ask for more feedback if they feel able to process the feedback (Wulf, 2007), so they will not become overwhelmed. However, this frequency effect has not yet been examined for real-time actionable feedback on health-related work behaviours in the work environment (Hermsen et al., 2016). Therefore, we aim to give more insight in this lacuna by examining how self-controlled feedback frequency may moderate the effects of real-time actionable feedback on health-related work behaviour among office workers

Accordingly, it is expected that higher feedback frequency strengthens the effects of real-time actionable feedback on office workers' sitting behaviour and break-taking behaviour.

This moderating effect is hypothesized for all 6 sub-hypotheses regarding the effect of real-time actionable feedback messages on sitting behaviour and break-taking behaviour of office workers. The moderated hypotheses for 1A and 2A are called 3A and 4A. The moderated hypotheses for 1B and 2B are called 3B and 4B. The moderated hypotheses for 1C and 2C are called 3C and 4C.

Methods

Experimental field study and procedure

To test the study hypotheses, we have conducted a 6-week experimental field study among university staff. In this field study, the participants received multiple sensor tools that obtained real-time data on their sitting behaviour and mental fatigue developed during typewriting, and sent it to a data platform. Dependent on the experimental condition regarding feedback frequency (see description of manipulation below), participants may or may not receive a feedback message by SMS when their sitting or typing behaviour exceeded predetermined standards.

Setting

The organization in which the experimental field study took place is a medium-sized division of a large university in the Netherlands. The health and safety officer of this division had a strong focus on preventing illnesses among employees and gave permission for the field study to be conducted. The experimental protocol for the study was approved by the designated research ethics committee of the cooperating university.

Participants

Participants were recruited by the health and safety coordinator of the institution. Participants were eligible to participate if they had an employment contract of at least 0.8 FTE (31,4 hours per week) and were not suffering from long-term illnesses or having adjusted tasks as part of a re-integration trajectory at the time of the experiment. A total of 22 office workers started the experiment (see Figure 1), of which two dropped out due to health issues and family circumstances. Twenty participants completed participation, of which two had data absence and were excluded from analyses. The remaining 18 participants (six were female) had an average age of 43 (SD_{age} =11,1) and an average employment duration of 14 years ($SD_{employment}$ = 9). Most participants (83%) had a university degree, while 17% had a vocational degree. Analyses of sitting behaviour included data of 16 participants, and the analyses of mental fatigue included data of 12 participants (see Figure 1 for a participant flow chart). The spread of employees across the job spectrum was satisfactory, including both junior and senior educational and scientific staff, as well as support staff.

Sensor tools and feedback

Measuring of sitting events

Employees were using an Axia Smart Chair (BMA/SBSeating, Zwolle, the Netherlands) that registered their sitting behaviour. If participants were sitting for 55 minutes in a row, and had not yet received the maximum number of feedback messages (see below description of manipulation of feedback frequency), a feedback message was sent containing the observation that they had been sitting for a long period of time and the advice to stand up and take a short stroll.

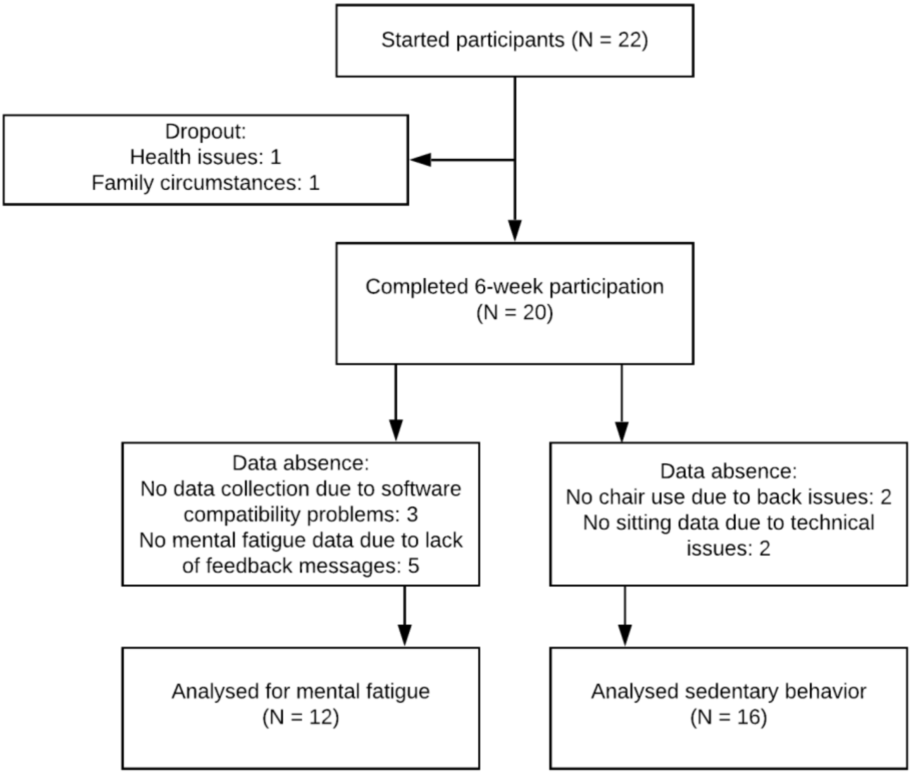


Figure 1: Participant flow chart

Measuring of mental fatigue in typewriting

Participants used a keylogger in a QWERTY keyboard to monitor their interkey intervals (aXtion, Groningen, the Netherlands) based on which their level of mental fatigue was measured (de Jong, Bonvanie, Jolij, & Lorist, 2020). The interkey interval was calculated using a moving average of all keystrokes over a 15-minute window and registered in the research database every minute. The average interkey interval between 9AM and 10AM was used as benchmark, under the assumption that during this hour, participants would not yet be fatigued. If there was no activity between 9AM and 10AM, the last known benchmark was used. When participants' interkey interval during the working day became 10% or more slower than the benchmark, and participants had not yet received their maximum number of feedback messages (see below description of manipulation of feedback frequency), they received a feedback message saying that their typing behaviour shows that they seem to get fatigued, and therefore they are advised to take a break.

Independent variables

Feedback frequency: the participants were assigned to one of the three feedback frequency conditions (low, medium or high feedback frequency) randomly. However, right from the start of the experiment, participants were able to self-control feedback frequency by altering the frequency at which they received feedback through a web-interface. That is, feedback frequency could be set to low (minimum 1 and maximum 3 text messages per day), medium (4-7 messages) or high (8-12 messages) levels. Of the 20 participants who completed participation, 12 decided to change the frequency with which they received feedback, six of which changed more than once. During the experiment, all frequencies were used for different periods by multiple participants. At the end of the 6-week experimental period, 1 participant received feedback on high frequency, 9 received medium frequency feedback, and 10 received low frequency feedback.

To ensure that participants who did not exceed the predetermined standards for sitting behaviour and mental fatigue received at least the minimum number of feedback messages of their chosen frequency, default messages were sent. Default messages said “No deviations from the norms have been registered in the last time period. Keep paying attention to your work behaviour”. Depending on the chosen frequency, a check was performed 1 to 8 times a day to see whether in the period before the check a feedback message was sent. If not, the default message was sent. The times at which the default message check was executed are shown in Figure 2. As soon as the maximum number of messages was reached, both feedback messages and default messages were stopped. On average, participants received 2,13 default messages per experiment day.

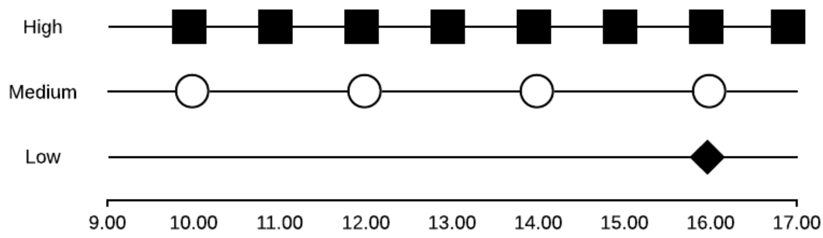


Figure 2: Times at which a check was performed to see whether a default message must be sent

All participants received an e-mail once a day with an overview of their sitting behaviour and mental fatigue during the day.

Feedback message (yes or no): indicates whether or not the participant received a real-time, actionable feedback message in response to a prolonged sitting event with a duration longer than 55 minutes or in response to emerging mental fatigue developed during typing.

TimeStamp: numeric variable that contains the experiment day (1-46) and representation of the hour at the end of the sitting or typing event. This variable was created to test hypothesis 1C and 2C predicting a learning effect of feedback on sitting behaviour and break-taking behaviour over time.

Measures

Two separate datasets were used, one with the data regarding sitting events and one with data regarding typing events. These data were nested within participants, with sitting and typing events being the unit of analysis. A sitting event started when the participant sat down for at least 55 minutes on the smart chair and ended when the participant stood up. A typing event started when the measurement of interkey intervals indicated that a participant became tired and stopped when the participant took a break of at least 15 minutes.

Dependent variables

Standing up (yes or no): indicates whether or not participants stood up from their chair within 15 minutes after exceeding the norm of sitting longer than 55 minutes continuously.

Taking a break (yes or no): indicates whether or not participants took a break within 15 minutes after their keystroke interval became 10%, or more, slower than their benchmark, which was used as a proxy for mental fatigue.

Duration of sitting event: the duration in minutes of a sitting event exceeding the 55 minutes norm.

Duration of typing event: the duration in minutes of a typing event in which mental fatigue emerged.

Statistical analyses

All measures are reported for sitting and typing events that exceed pre-set norms of sitting longer than 55 minutes (sitting event) or 10% slower keystroke interval in typewriting (typing event); these sitting and typing events are denoted by variable **e**. Sitting and typing events are produced by individual subjects **s** (**s**=1..18) and at a certain point in time as denoted by timestamp. Timestamp is defined by the experimental day (1-46) on which events occurred before the decimal point and the elapsed time of the day in percentages when events occurred after the decimal point (**timestamp**=1,00..46,99). For each sitting or typing event, there is a function **s(e)** that refers to the subject of the event, and a function **timestamp(e)** indicating the timestamp at which the event occurred. During a sitting or typing event either a feedback message is generated to advice the subject to stand up from the chair or take a break from typing, or not. This is represented by Boolean function **feedback(e)**.

Feedback effects on standing up and taking a break

To test hypothesis 1A and 2A, we examined whether feedback(e) (yes or no) has an effect on subjects' direct action, that is whether or not they stand up (standingup(e)) from the chair (H1A) or take a break (break(e)) from typing (H2A) within 15 minutes. Thus, **standingup(e)** and **break(e)** are a Boolean function with value true if **dur(e)** <15, otherwise it is false. Given that **standingup(e)** and **break(e)** are a binary variable, we conducted logistic regression analysis using xtlogit in Stata (StataCorp, 2019). Given the nested data structure, the xtset command was used to take into account that standing up and taking a break were nested within subjects. The logistic regression equation is

$$log\ \left(\frac{p}{1}-p\right)= M\ +\ a * feedback(e)\ +\ \Sigma(bs\ *\ s(e))\ +\ \varepsilon$$

where log (p/1-p) is the odd ratio for standing up (H1A) or taking a break (H2A), M is the mean of the binomial distribution of standing up or taking a break, $a * feedback(e)$ is the independent variable feedback(e) and its coefficient a (fixed effect at sitting or typing event level), $\Sigma(bs\ *\ s(e))$ is the random variance at the subject level, and ε is the random error at the sitting or typing event level.

To test hypothesis 3A and 4A, we examined whether feedback frequency moderated the effects of feedback(e) on standing up (H3A) or taking a break (H4A). We conducted a logistic regression analysis for the binary dependent variable of standing up or taking a break with the following equation:

$$\begin{aligned}\mathrm{log}\left(\frac{\mathrm{p}}{1}-\mathrm{p}\right)= \mathrm{M}\ +\ \mathrm{a1}*\mathrm{feedback(e)}+\ \mathrm{a2}*\mathrm{freq}\ +\ \mathrm{a3}*\mathrm{feedback(e)}\\ *\ \mathrm{freq}\ +\ \Sigma\big(\mathrm{bs}\ *\ \mathrm{s(e)}\big)+\ \varepsilon\end{aligned}$$

where $log\ (p/1-p)$ is the odd ratio for standing up (H3A) or taking a break (H4A), M is the mean of the binomial distribution of standing up or taking a break, $a1 * feedback(e)$ is the independent variable feedback(e) and its coefficient a_1, $a2 * freq$ is the independent variable feedback frequency(e) and its coefficient a2, $a3 * feedback(e) * freq$ is the interaction between feedback(e) and feedback frequency(e) and its coefficient a3, $\Sigma(bs * s(e))$ is the random variance at the subject level, and ε is the random error at the sitting or typing event level.

Effects on duration of sitting and typing events

To test hypothesis 1B and 2B, we examined the effect of feedback(e) on the total duration of sitting events (H1B) or typing events (H2B), notated as **dur(e**). A multilevel regression analysis was conducted using the xtreg command in Stata. The xtset command was used to account for the nested structure of the data (sitting or typing events occur within individual subjects). The regression equation is

$$dur(e) = D + a * feedback(e) + \Sigma(ds * s(e)) + \varepsilon$$

where $dur(e)$ is the dependent variable duration of the sitting (H1B) or typing (H2B) event, D is the overall mean of the duration of sitting or typing events (i.e. $dur(e)$), $a * feedback(e)$ is the independent variable feedback(e) and its coefficient a, $\Sigma(ds * s(e))$ is the random variance for the subject, and ε is the random error at the sitting or typing event level.

To test hypothesis 3B and 4B, we used a multilevel regression analysis for the dependent variable dur(e) with the equation

$$dur(e) = D + a1 * feedback(e) + a2 * freq + a3 * feedback(e) * freq + \Sigma(bp * s(e)) + \varepsilon$$

where $dur(e)$ is the dependent variable duration of the sitting (H3B) or typing (H4B) event and D is the overall mean of the duration of sitting or typing events (i.e. $dur(e)$), while the remaining terms are equal to those in the previous equation for testing H2a and H2B

Effects over the 6-week experimental period

In the last analyses, we have tested whether time (i.e. timestamp) influences the duration of sitting or typing events (i.e. dur(e)). We also explored whether feedback frequency (i.e. freq) moderated such time effects. Specifically, we conducted two multilevel regression analyses for testing the effect of time. The first analysis tests hypotheses 1C for the duration of sitting events and 2C for the duration of typing events, and does not include feedback frequency and is using the following equation:

$$dur(e) = D + a1 * timestamp(e) + \varepsilon$$

The second analysis tests whether feedback frequency moderates the time effects on the duration of sitting events (H3C) and the duration of typing events (H4C) using the equation

$$dur(e) = D + a1 * timestamp(e) + a2 * freq(e) + a3 * timestamp(e) * freq(e) + \Sigma(d's * s(e)) + \varepsilon$$

Results

Data overview

Table 1 shows an overview of relevant descriptive statistics for the study variables for both the sitting and typing events. Only the sitting and typing events for which the pre-set norm was exceeded are included in the data set.

Due to errors in the feedback settings, several participants received a message about their prolonged sitting (> 55 minutes) too late. Unfortunately, these events with delayed feedback could not be included in the analyses of standing up and duration of sitting events. This explains the low number of 19 sitting events where a real-time, actionable feedback was sent. As a result, the three feedback frequency conditions contained too few events and the available events were not evenly distributed across the conditions to test whether feedback frequency would moderate the effects of real-time actionable feedback. Therefore, we were unable to test hypotheses 3A and 3B. These limitations are further addressed in the Discussion section.

	Sitting events	Typing events
Number of events	245	1065
Number of subjects	16	12
Average number of events per subject (min – max)	15,3 (1 – 34)	88,7 (6 – 128)
Number of events where a relevant feedback message was sent	19	93
Average number of events with feedback, per subject	1,2	7,8
Average duration of event (minutes)	65,74	53,71
Average duration of event where a relevant text was sent (minutes)	39,05	43,11

Table 1: Data overview

Hypothesis testing

Feedback effects on standing up and taking a break

An overview of the results is given in table 2.

Standing up from the chair

To test hypothesis 1A, we examined whether receiving a feedback message after sitting for 55 minutes, compared to not receiving feedback, resulted in more immediate standing-up behaviour (Standing up). We found no significant effect of feedback on standing up (coef = -0,499, p = 0,460, see table 2, H1A), indicating that real-time actionable feedback did not lead to immediate standing-up behaviour. Thus, hypothesis 1A was not supported.

Taking a break from typing

To test hypothesis 2A, we examined whether receiving a feedback message, compared to not receiving feedback, after exceeding the norm of 10% slower interkey interval, resulted in more direct break-taking behaviour (Break). We found a significant effect (coef = 0,580, p = 0,036), indicating that a real-time actionable feedback message indeed leads to taking a break from typing within 15 minutes more often (see table 2, H2A). Hypothesis 4A predicting that feedback frequency would moderate the effect of feedback on direct break-taking behaviour could not be confirmed (coef = -0,197, p = 0.287, see table 2, H4A).

	(H1A) Standing up	(H2A) Break	(H4A) Break
Feedback	-0.499	0.580**	-0.352
	(0.676)	(0.276)	(0.682)
frequency			-0.197
			(0.185)
feedback*frequency			0.618
			(0.405)
_cons	-1.395***	-1.417***	-1.127***
	(0.228)	(0.106)	(0.290)
N	245	732	732
Pseudo R^2	.z	.z	.z
Standard errors are in parenthesis			
*** p<0.01, ** p<0.05			

Table 2: Regression results for standing up and taking a break

Effects on duration of sitting and typing events

An overview of the results is given in table 3.

Duration of sitting events

To test hypothesis 1B, we examined whether receiving a feedback message, compared to not receiving feedback lowered the duration of sitting events (dur(e) sitting). We found no significant effect of feedback(e) on duration of sitting events (coef = -10,92, p = 0,483, see table 3, H1B), indicating that feedback messages do not lead to shorter sitting events. Therefore, we cannot confirm hypothesis 1B predicting that actionable feedback decreases the duration of sitting events.

Duration of typing events

To test hypothesis 2B we examined whether receiving a feedback message, compared to no feedback message, lowered the duration of typing events. We found that the duration is significantly affected by receiving a feedback message (coef = -11.773, p = 0.032, one-tailed), thereby supporting our hypothesis 2B (see table 3, H2B). We found no support for Hypothesis 4B predicting that feedback frequency would moderate the effect of feedback on the duration of typing events (coef 3.192, p = 0.353, see table 3, H4B)

	(H1B) Dur(e) sitting	(2HB) Dur(e) typing	(H4B) Dur(e) typing
Feedback	-10.916	-11.773**[a]	-9.829
	(15.545)	(6.376)	(15.522)
Frequency			3.192
			(3.436)
feedback*frequency			-1.322
			(9.484)
_cons	128.547***	54.883***	50.146***
	(9.271)	(2.013)	(5.484)
N	245	732	732
Pseudo R^2	.z	.z	.z
Standard errors are in parenthesis			
*** p<0.01, ** p<0.05, * p<0.1, [a] one-tailed test			

Table 3: Regression results for event-level behaviour (duration of sitting and typing events)

Time effects over the 6-week experimental period

An overview of the results regarding the effects of time on the duration of sitting events and typing events over the course of the 6-week experimental period is given in table 4.

Duration of sitting events

We examined whether time (i.e. timestamp) lowered the duration of sitting events during the experimental period of 6 weeks (hypothesis 1C). This time effect was significant (coef = -0,711, p = 0,010, see table 4, H1C), indicating that as time progressed during the experiment, the duration of the sitting events decreased. We then explored whether this time effect was moderated by feedback frequency (freq). Feedback frequency had no significant moderation effect in the relationship between timestamp and duration of sitting events (see table 4, H3C).

Duration of typing events

Lastly, we examined whether receiving feedback on mental fatigue developed during typing behaviour lowered the duration of a typing event over the 6-week experimental period. This time effect was not significant (coef = 0.069, p = 0.614, see table 4, H2C), so hypothesis 2C was not supported. Hypothesis 4C, stating that the frequency of feedback strengthens the decrease of duration as time progressed during the experiment, was also not supported (coef =5.709, p = 0.322, see table 4, H4C).

	(H1C) dur(e) sitting	(H3C) dur(e) sitting	(H2C) dur(e) typing	(H4C) dur(e) typing
Timestamp	-0.711***	0.358	0.069	-0.556
	(0.277)	(0.931)	(0.137)	(0.369)
Frequency		20.409		-5.709
		(19.723)		(5.765)
Timestamp*frequency		-0.969		0.428*
		(0.807)		(0.228)
_cons	148.803***	127.093***	51.953***	60.611***
	(14.122)	(26.273)	(3.969)	(9.907)
N	245	245	732	732
Pseudo R^2	.z	.z	.z	.z
Standard errors are in parenthesis				
*** p<0.01, ** p<0.05, * p<0.1				

Table 4: Regression results over the 6-week experimental period (duration of sitting and typing events)

Assumption testing

Regarding mental fatigue, the underlying assumption was that taking a break timely would enable workers to recover from their mental fatigue. To test this assumption, we have examined whether the average interkey interval after a 15 – 45-minute break was lower than the interkey interval at the moment the worker started the break. We found no significant difference between the interkey interval just before and immediately after breaks. Therefore, we cannot confirm the assumption that breaks decreasing the mental fatigue of office workers. We come back to this finding in the Discussion section.

Discussion

Recap of the results

Table 5 presents an overview of all hypotheses that are tested, including their number and outcome. The presented results show that receiving real-time actionable feedback messages influences employees in taking breaks from typing, whereas no significant effects were found for sitting behaviour. That is, real-time actionable feedback on mental fatigue developed during typing prompted employees to take a break within 15 minutes and to reduce the duration of typing events. In addition, we also found a learning effect for sitting behaviour. Over time in the experimental period, we see that participants significantly shorten the duration of the sitting events, confirming the expected learning effects.

The results did not support the hypotheses stating that the relation between real-time actionable feedback and sitting and typing behaviour of office workers would be strengthened by a higher feedback frequency. Also, the assumption that a break decreases the mental fatigue of office workers cannot be confirmed using our data.

	Nr.	Main effect	Nr.	Moderating effect of feedback frequency
Direct effect				
Sitting	1A	Not supported	3A	Unable to test
Typing	2A	Supported	4A	Not supported
Event-level effect				
Sitting	1B	Not supported	3B	Unable to test
Typing	2B	Supported	4B	Not supported
6-week experimental period				
Sitting	1C	Supported	3C	Not supported
Typing	2C	Not supported	4C	Not supported

Table 5: Overview of the outcomes of all analyses

Implications for theory

The outcomes of this study show that real-time actionable feedback messages can help employees self-regulate their health-related work behaviour. This confirms two major principles from Feedback Intervention Theory suggesting that feedback is more effective when it is real-time and actionable. However, the feedback effects are different for sitting and typing behaviour, which we will look further into.

There are two main lines of thought that could explain the different outcomes for sitting and typing behaviour. First, there is a relevant difference between novelty and expectedness of information provided in feedback messages about sitting and typing events. The feedback on sitting events contains information that the employees are usually aware of: the norm of prolonged sedentary behaviour (i.e. sitting for more than 55 minutes) was known to the participants in this study, and they could monitor the duration of their sitting bouts themselves. The feedback on mental fatigue developed during typing, however, is different from that: as Zhang (2011) shows, people are unaware of their mental fatigue in an early stage. Therefore, the feedback information about their emerging mental fatigue was likely to be unexpected information to the participants. In the light of this difference in novelty and unexpectedness of feedback information, the different outcomes for sitting and typing events seem to confirm the idea of West (2000) that new, unexpected information induces a reflection process that can facilitate behavioural adjustment.

The second possible explanation for the different feedback effects for sitting and typing events, is the difference between the effect horizon of sitting behaviour and emerging mental fatigue while typing. In case of prolonged sitting behaviour, a feedback message was sent indicating that the norm regarding healthy sitting behaviour had been exceeded and including the advice to stand up from the chair. Such prolonged sitting events, however, do not affect health and performance in the immediate short run, but is most relevant for long-term health, i.e. the prevention of musculoskeletal or cardiovascular problems. The feedback on mental fatigue developed during typing, however, makes short-term effects salient: it explicitly indicated that the participants' current typing performance was decreasing due to fatigue. Therefore, acting upon a feedback on typing events did not only affect long-term health outcomes of mental fatigue, but also immediate performance of the worker. Therefore, the incentive is a lot more tangible, which could explain why people did tend to take a break from typing immediately in response to a feedback message, whereas feedback had no effect on their sitting behaviour.

The present results did not confirm our assumption that taking breaks from typing would reduce mental fatigue of workers. This non-effect contradicts findings of Kim, Park, and Niu (2017) demonstrating that breaks reduce the mental fatigue of office workers. There are two issues that may have caused the differences in outcomes between our research and that by Kim et al. (2017).

Firstly, we have used in our study breaks varying from 15-45 minutes, whereas Kim et al. (2017) focused on examining the effects of micro breaks (i.e. breaks to have a drink, to chat with a colleague, or to stretch or gaze out the window). The breaks that Kim et al describe are all breaks that focus on relaxation to recover from mental fatigue, whereas the breaks in the present research are periods where participants may have stopped typing but have not necessarily switched to relaxation activities. A participant can, for instance, read a paper, have a meeting, or have a discussion with a colleague in this time. Such activities might not be suitable for reducing mental fatigue. In this regard, Trougakos et al. (2014)showed that contact with colleagues can actually make mental fatigue even worse. Therefore, more research is needed into the actual activities during work breaks to examine how real-time actionable feedback on mental fatigue can help employees to recover from early-stage mental fatigue.

Secondly, our assessment of mental fatigue was based on objective measures of participants' interkey interval when typing, and the preand post-break measurements of those interkey intervals were compared to test the effect of breaks on mental fatigue reduction. Kim et al. used questionnaires to measure end-of-work negative affective states of workers, of which fatigue was one. These measures are subjective and generally assessed at the end of a working day, making it problematic to compare their microbreak effects with the 15-45-minute breaks used in the present study. Therefore, we would recommend to conduct further research on how different types of breaks assessed with different methods influence recovery from mental fatigue.

Practical implications

Our study shows that the use of real-time actionable feedback messages impacts health-related behaviours of office workers. A practical implication of our results is that workers who are probably unaware of their emerging mental fatigue developed during typing on a computer can immediately benefit from feedback messages saying that they get fatigued and recommending taking a break from typing. Furthermore, our results suggest that workers receiving feedback on their prolonged sitting behaviour do not change their behaviour immediately, but they do learn over time and reduce the duration of their sitting events. As such, these short-term feedback effects on break-taking behaviour and long-term feedback effects on sitting behaviour are promising and beneficial for worker health. Remaining questions are how to stimulate workers to alter prolonged sitting behaviour in the short run, and what kind of breaks are best to take in order to decrease mental fatigue.

Employers, however, should be careful in implementing technologies that provide employees with real-time actionable feedback messages for several reasons. Firstly, we show that feedback may have different effects on different types of behaviour, and different feedback effects can occur among different groups of workers performing different types of tasks in different work environment. Secondly, a parallel study (Bonvanie, Broekhuis, Janssen, Maeckelberghe, & Wortmann,

2020) showed that workers who are in poorer health at the start of the monitoring phase feel less autonomous in altering their behaviour while being monitored. This felt lack of autonomy may lead to an increase of negative feelings towards the employer and job. Thus, providing employees with self-management devices meant to monitor and self-regulate health-related work behaviour might have the anticipated positive health effects for certain groups of employees, while other groups of workers suffer from unforeseen negative health effects

Limitations

The first limitation was shortly addressed in the results section, being the low number of sitting events that we could include in the analyses to test the hypotheses. This low number of events was due to an incorrect setting in the generation of feedback, as a result of which feedback messages were sent to participants too late in response to their sitting events, which unfortunately was only noticed in the stored data after the end of the experimental period.

In the original study design, we also wanted to test whether self-controlled (versus externally imposed) feedback frequency would have linear behavioural effects rather than U-shaped curvilinear effects as reported by Lam (2011). In order to do so, a yoked control group was set up as a second cohort in this study. Unfortunately, technical errors in the transmission of feedback messages caused the time between follow-up messages to be different between the two cohorts. This made it impossible to compare both cohorts, so the second cohort was excluded from analysis.

The typing tool used a daily, static benchmark which was always measured in the same timeslot, viz. the first hour of the working day. However, the relevance of this benchmark might differ for workers who executed different computer tasks (with very different ways of typing) during the benchmark time window and the rest of the day. This static benchmark could have, for instance, affected the outcomes when during the benchmarking time window e-mails were answered and afterwards analyses were programmed. In future projects were similar tools are applied, we would recommend to use either a self-learning system that can detect the type of activity, or a function that the participant can use to disable feedback for a set amount of time, in order to prevent receiving multiple feedback messages when the participant already knows that the messages are being sent due to the difference in task.

The data from the smart chair was not confirmed using an activity monitor. Therefore, it could be that workers sat for longer periods of time on another chair, for instance in a meeting or when working from home, yet still they received messages that no deviations from the norm were found. These events were not registered, and were not included in the analyses, so the outcomes might deviate from reality due to this lack of insight in the full sitting behaviour of the participants.

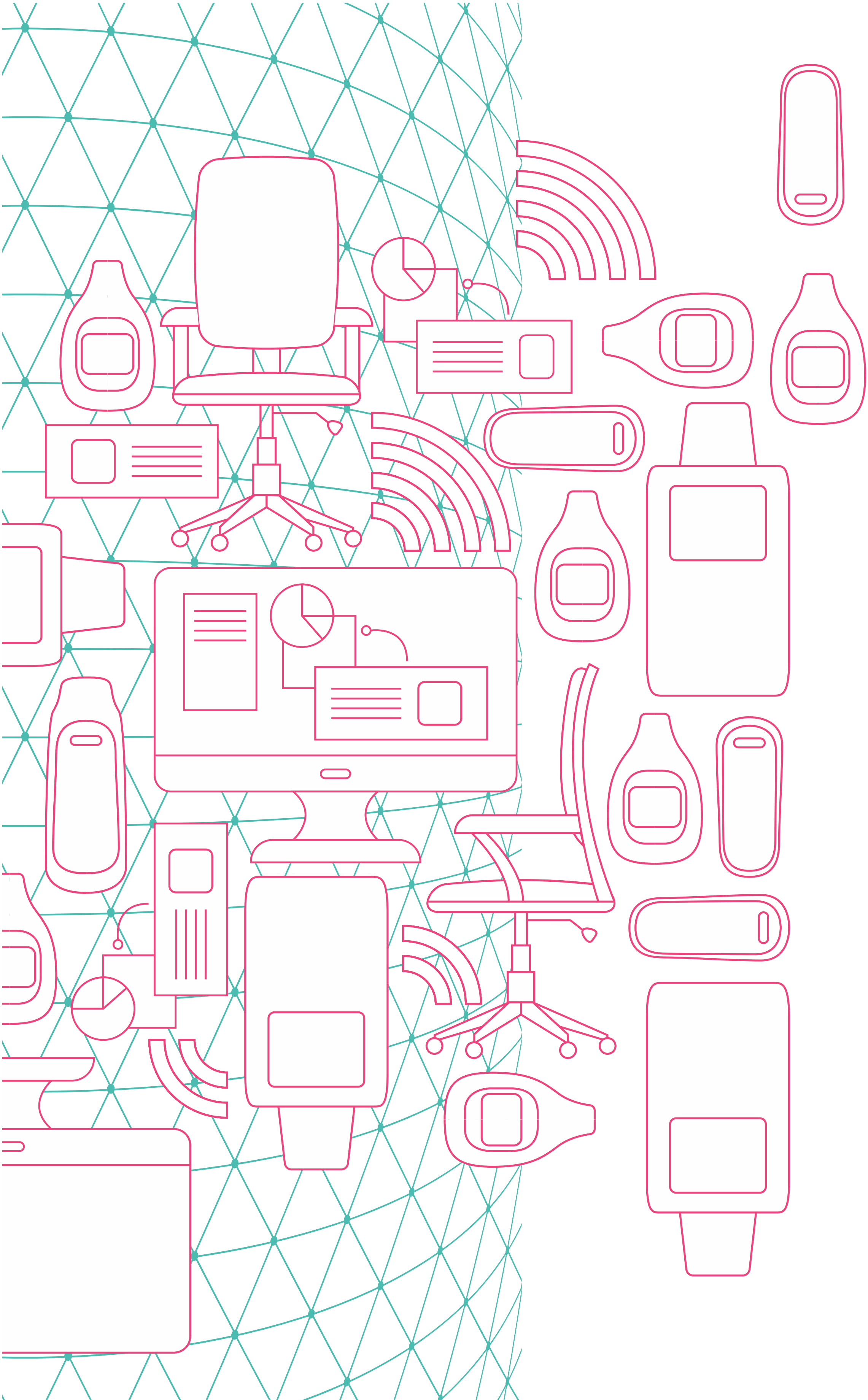
Areas for future research

Previous studies show that the combination of actionable messages regarding sitting behaviour and practical tools such as sit-stand desks decreases the amount of long sitting events for workers, even though these messages were not real-time related to actual current behaviour (Larouche et al., 2018). We recommend further research to examine the effectiveness of combinations of real-time actionable feedback messages with practical tools such as sit-stand desks that enable workers to switch between sitting and standing.

From a workplace health promotion point of view, the long-term health of workers is the main goal of implementing sensor technologies in the workplace. Despite the fact that many workers know that their behaviour may harm their health in the long term, they still do not always seem to change this behaviour when they receive notifications. We have argued that employees are more likely to respond to feedback messages that make them aware of the immediate harmful performance effects of certain behaviours, such as mental fatigue that occurs during typing behaviour, in addition to long-term effects. More research, however, is needed on how feedback messages can be combined with information obtained from other sources to effectively facilitate healthy work behaviour in the workplace.

Future research may focus on examining how the effects of feedback provided by sensor technology devices can be strengthened by feedback information obtained from colleagues and leaders. Especially in case of felt trade-offs between short-term performance effects (e.g., meeting deadlines) and long-term health effects (e.g., mental and physical wellbeing) of certain work behaviours, the feedback given by leaders and colleagues is likely to impact the choices made by the worker. If leaders and colleagues consistently value deadlines over health, this is likely to affect the experienced pressure for a worker to do the same, which could cancel out the efforts of employers to facilitate worker self-regulation of healthy work behaviour through self-management sensor technologies.

Research can also examine how objective data obtained from sensor and intervention technologies can be used to design ergonomic workplaces and healthy work routines for workers, including those who mainly have to do their work while sitting. By using sensor and intervention technologies, workers may be stimulated to use sit-stand desks when doing sedentary work for a longer period of time, or they could be triggered to use meeting rooms that facilitate stand-up meetings. Other ways to prevent prolonged sitting behaviour of office workers may include strategic positioning of necessary office equipment, such as printers and coffee machines, in order for workers to walk more during the day.



3

Health Self-Management Applications in the Work Environment

The Effects on Employee Autonomy[2]

[2] This chapter is published as: Bonvanie, A., Broekhuis, H., Maeckelberghe, E., Janssen, O. & Wortmann, J.C. (2020). Health Self-Management Applications in the Work Environment: the Effects on Employee Autonomy. *Frontiers in Digital Health*, 9:2.

Abstract

Organizations increasingly use Health Self-Management Applications (HSMAs) that provide feedback information on health-related behaviours to their employees so that they can self-regulate a healthy lifestyle. Building upon Self-Determination Theory, this paper empirically investigates the basic assumption of HSMAs that their self-management feature provides employees with autonomy to self-regulate their health-related behaviour. The two-phase experimental study contained a four-week HSMA intervention in a healthcare work environment with a feedback factor (performance *vs* developmental) and pretest and posttest measurements of participants' perceived autonomy. Following the experiment, interviews were conducted with users to gain an in-depth understanding of the moderating roles of feedback and BMI (a proxy for health) in the effects of HSMA on perceived autonomy. Findings reveal that the use of an HSMA does not significantly increase perceived autonomy, and may even reduce it under certain conditions. Providing additional developmental feedback generated more positive results than performance feedback alone. Employees with higher BMI perceived a greater loss of autonomy than employees with lower BMI. The reason for this is that higher-BMI employees felt external norms and standards for healthy behaviour as more salient and experienced more negative emotions when those norms are not met, thereby making them more aware of their limitations in the pursuit of health goals.

Introduction

To increase overall productivity and decrease workforce costs, organizations are increasingly embracing workplace health promotion programs as a critical strategy for improving employee health and work outcomes (De Jongh & Mcdougal, 2014; Hendriksen, Snoijer, de Kok, van Vilsteren, & Hofstetter, 2016). These programs tend to focus on individual health factors, such as diet and physical exercise, and represent a broad range of disease prevention and health promotion methods such as health checks (Damman et al., 2015), gym subscriptions (De Jongh & Mcdougal, 2014), physical activity (e.g., (Blake & Batt, 2015; Husain & Spence, 2015; Malik et al., 2014), and vitality training (Hendriksen et al., 2016). A common denominator in health promotion programs is an increasing reliance on health self-management applications (HSMAs) that provide individual users with key metrics about their bodily functioning and personal health-related behaviours (Grady & Gough, 2014; Schopp, Clark, Lamberson, Uhr, & Minor, 2017). For example, wearable activity trackers are used to inform users about the number of steps they take, the number of stairs they climb, and the intensity levels of their physical activities on a daily basis (e.g., (Blake & Batt, 2015).

A core assumption underlying the use and usefulness of such HSMAs is that their self-management feature provides employees with autonomy and control to self-regulate their health-related behaviour. Specifically, derived from Self-Determination Theory (SDT) (Ryan and Deci 2000; Ryan and Deci 2006), the notion is that the use of HSMAs promotes a sense of autonomy through which employees become intrinsically and deeply engaged in self-regulating their behaviour. Critical elements for behavioural change and health improvements are monitoring, goal setting, and action planning (Grady & Gough, 2014; Hendriksen et al., 2016; Schopp et al., 2017; Silva et al., 2010). However, although a substantial body of research has shown the potential of HSMAs in promoting employee health (Blake & Batt, 2015; Samaras et al., 2001), no empirical studies have examined and proven the basic assumption that HSMAs increase employees' perceptions of autonomy in the self-regulation of their health-related behaviour. Indeed, on the contrary, some scholars even suggest a loss of perceived autonomy resulting from self-monitoring technologies (Alder, 1998; Alder & Ambrose, 2005; Brey, 1999; Leclercq-Vandelannoitte, 2017; Martin & Freeman, 2003). As such, the literature on HSMAs and employee autonomy is inconclusive with several gaps addressed by this research.

First, employers providing HSMAs may impact the relative freedom employees experience in the use of such HSMAs and the self-regulation of their health-related behaviour. At first sight, the provision of HSMAs might suggest honourable intentions. Counter-effects however might emerge that affect employees' sense of autonomy in self-regulating their health-related behaviour. The use of worksite HSMAs makes the norms and standards for healthy behaviour that are usually latent yet imposed by external entities (e.g., health agencies, employers) salient (Campbell, Eyal, Musiimenta, & Haberer, 2016; Owens & Cribb, 2017). SDT suggests that if this happens, employees may feel that the locus of control over their health-related behaviour shifts from internal to external. This potentially decreases their perceived autonomy. Therefore, our first research goal is to investigate the effects of employer-provided HSMAs on employees' perceptions of autonomy regarding the self-regulation of health-related behaviour.

Second, HSMAs provide users with feedback information on specific aspects of their bodily functioning and health-related behaviour. This information is assumed to facilitate the autonomous self-regulation of healthier behaviour. This feedback usually focuses on discrepancies between one's actual health-related behaviours and standards set for those behaviours, which can be termed as 'performance feedback' (Li et al., 2011). However, one form of feedback that has hardly been used and examined in the HSMA context is 'developmental feedback'. Developmental feedback includes information that facilitates recipients to learn, develop, and make adaptive behavioural changes (Li et al., 2011). SDT suggests that developmental feedback may boost autonomy and intrinsic motivation for learning and improvement, whereas the evaluative and controlling information provided by performance feedback may inhibit feelings of autonomy (Ryan & Deci, 2000). Therefore, our second research goal is to investigate the potentially moderating role of feedback focus (performance versus developmental) in HSMAs' effects on perceived autonomy.

Third, individual differences, such as initial health condition may influence how employees respond to HSMAs in terms of perceived autonomy in self-regulating their behaviour. Previous research showed that employees with poorer self-rated health respond more negatively to health checks with feedback than do healthier respondents (Damman et al., 2015). Less healthy employees reported experiencing less control over their health-related behaviour and feared that health measures imposed by their employer would invade their privacy and interfere with their sense of personal autonomy (Damman et al., 2015). Therefore, our third research goal is to examine whether an employee's state of health influences HSMAs' effects on perceived autonomy.

Fourth, health metrics provided by HSMAs such as activity trackers capture daily activities that are carried out both within and beyond the workplace. Further, the standards set for physical activity (e.g., 10,000 steps a day) are usually not limited to the workplace. They are flexible standards for self-regulation of employees' health-related behaviour during both work and private time. Although HSMAs thus appear to blur the lines between work and private time, employees may establish different autonomy feelings in the self-regulation of their health-related behaviour in the workplace and at home. Employees may feel that HSMAs provided by their employer invade their private time and thus especially interfere with their sense of autonomy at home. Hence, to address these potentially different autonomy effects of HSMAs across work and private domains, we include measures of both work health autonomy and home health autonomy. Thus, our fourth research goal is to explore whether the effects of HSMAs that focus of feedback and health status are different for employees' perceptions of health autonomy at work and at home.

This study contributes to the HSMA research literature by using insights from SDT and feedback literature to examine the basic assumption underlying the use of HSMAs: that their self-management function promotes employees' perceptions of autonomy in self-regulating their health-related behaviour. Our research shows that the type of feedback (performance versus developmental) that employees obtain from HSMAs, in conjunction with their health condition, affects their perceived autonomy. Also, the effects of feedback and health condition on health autonomy perceptions are different at work and at home. These findings lead to guidelines for the effective use of HSMAs in different settings (work and at home) and for employees with different health conditions.

Theoretical Framework

An overview of relevant findings from previous studies is provided here, leading to the development of three hypotheses about the effects of HSMAs on perceived autonomy, and how feedback focus and health moderate these effects. We then argue that autonomy should be considered both at work and in private time, leading to an explorative question about the effects of HSMAs for both work health autonomy and home health autonomy.

HSMAs and perceived autonomy in the self-regulation of health-related behaviour

In the present research, we focus on the use of HSMAs, specifically the Fitbit One activity tracker. HSMAs provide users with feedback information on bodily functioning and health-relevant behaviours such as heart rate, steps taken, stairs climbed, and intensity of physical activity. Such devices are used in various domains, ranging from clinical settings for disease management (Campbell et al., 2016) to occupational settings for disease prevention and health promotion (Hendriksen et al., 2016; Malik et al., 2014).

Reviews evaluating the effectiveness of different methods for promoting physical activity reveal that activity trackers can be very effective in increasing the number of steps participants take (Bravata et al., 2007; Malik et al., 2014). This increase in activity however does not by definition imply an increase in perceived autonomy of users. On the contrary, Owens and Cribb (2017) argue that HSMAs do not inherently increase autonomy, and are even likely to decrease it, because externally imposed norms and values are likely to undermine genuinely autonomous deliberation by users. To date, research has not systematically and empirically examined how HSMAs influence employees' perceived autonomy in self-regulating their health-related behaviour. Therefore, we aim to address this gap in the research literature.

SDT (Ryan & Deci, 2000, 2006) is seen as a promising framework for the study of autonomy in the self-regulation of health-related behaviour. This theory contends that the quality of human motivation for regulating behaviour varies along a continuum from autonomous motivation to externally controlled motivation. Individuals are autonomously motivated if they experience an internal locus of causality and self-determination in the self-regulation of goal pursuits. In contrast, controlled motivation is present when individuals experience an external locus of causality in goal pursuits, which occurs when their goal-directed behaviour is controlled and regulated by externally imposed norms, standards, or sanctions. Research has shown that an increase in perceived autonomy promotes effective cognitive, affective, and behavioural self-regulation of health-related behaviour (Chatzisarantis & Hagger, 2009; Fortier et al., 2007; Rose et al., 2005; Silva et al., 2010; Williams et al., 2002, 2004).

The first goal of this study is to examine the effect of a workplace HSMA intervention on employees' perceptions of autonomy in self-regulating their health-related behaviour. Specifically, using an experimental field study in a company in the healthcare industry, we examine whether the use of an activity tracker (Fitbit One) provided by the employer increases or decreases the sense of autonomy that employees experience in regulating their health-related behaviour. Here, we build two competing hypotheses regarding the effects of HSMAs on autonomy.

Using HSMAs enables employees to self-monitor their personal fitness metrics, and to become aware of the extent of their physical activity. This self-awareness facilitates users to reflect on their personal health situation and then to focus on goal setting, action planning, and actual engagement in physical activities to improve their health (Bravata et al., 2007). This reliance on self-regulation makes employees responsible for their own health and enables them to independently self-manage their health-related behaviour. SDT argues that self-responsibility and self-direction facilitate a more self-determined form of motivational regulation of behaviour (de Korte, Huysmans, de Jong, van de Ven, & Ruijsendaal, 2012b). Therefore, the first part of our competing hypothesis predicts that HSMAs have a positive effect on employees' perceptions of autonomy in self-regulating their health-related behaviour (*Hypothesis 1a*).
However, even though HSMAs aim to facilitate autonomy in self-regulating health-related behaviour, HSMAs might also interfere with the development of autonomous self-regulation. First, employer-provided HSMAs have been found not to be value-free (Martin & Freeman, 2003), and may impose norms and standards, or expectations, for health-related behaviours. Specifically, by expecting employees to use HSMAs such as activity trackers, employers not only highlight health values but also impose guidelines, norms, or standards for physical activity (e.g., 10,000 steps a day), even if these are not explicit. As a result, employees may feel that the HSMAs interfere with their personal autonomy and free choice to behave in ways that the employer sees as undesirable, unfit, and unhealthy (Campbell et al., 2016). They may perceive the use of HSMAs as a form of surveillance and control, leaving them no real choice, even if the employee is the only person with access to the data.

Second, HSMAs, such as activity trackers, focus on self-regulating health-related behaviours not only in the workplace but also in private life. For example, goals set for physical activity (such as 10,000 steps a day) are formulated as fluid goals that transgress and blur the border between work and private spheres (Braukmann, Schmitt, Ďuranová, & Ohly, 2018; Leclercq-Vandelannoitte, 2017). With this continuous exposure to HSMAs, both in work and in private time, employees may experience the HSMAs as invading their privacy and decreasing their personal autonomy (Leclercq-Vandelannoitte, 2017). Accordingly, based on these two arguments that HSMAs may constrain free-choice behaviour and interfere with privacy, the second part of our competing hypothesis argues that HSMAs have a negative effect on employees' perceptions of autonomy in self-regulating their health-related behaviour (*Hypothesis 1b*).

The moderating role of focus of feedback

The essence of HSMAs is to provide feedback information on health-related behaviour so that users can adjust their behaviour to meet desired standards. HSMAs usually deliver performance-oriented feedback, which can be defined as information concerning discrepancies between one's actual performance (e.g., 6000 steps per day) and the performance standard (e.g., 10,000 steps per day) (Kluger & DeNisi, 1996). Such information focuses on past performance, while its valence is critical in determining one's current and future behaviour in regulating progress towards a standard (Li et al., 2011). Another type of feedback is developmental feedback, defined as helpful or valuable information that enables the recipient to learn, develop, and make improvements (Zhou, 2003). As such, this type of feedback focuses on the future rather than the past, with the feedback providing the recipient with developmental information that is helpful in improving certain performance dimensions (Li et al., 2011).

We offer two arguments for why focus of feedback could moderate the effects of HSMAs on autonomy. First, using only performance feedback may tend to increase the salience of the potentially inhibitory effects of HSMAs on autonomy. This is because performance feedback highlights norms and standards for healthy behaviour that are construed and imposed by external entities (i.e., employer or health agencies) rather than freely determined by the feedback recipients themselves (Kluger & DeNisi, 1996). Due to this external imposition of health norms and standards, employees may perceive performance feedback as evaluative and controlling information intended to subtly force them to adapt their health-related behaviour in line with the externally imposed standards. Consequently, HSMAs that only use performance feedback are likely to induce an external rather than an internal locus of causality in employees for regulating their health-related behaviour.

Second, in contrast, the use of developmental feedback may tend to boost the salience of the potentially supportive effects of HSMAs on autonomy. This is because developmental feedback is informational in nature and fosters an orientation toward learning and development (Li et al., 2011). Specifically, developmental feedback provides meaningful information that enables employees to learn why the recommended health-oriented behaviour is important. Moreover, developmental feedback offers employees alternative options and ways to achieve behavioural change and health improvements. Since these options provide choice and self-direction, developmental feedback enables employees to experience themselves as autonomous initiators and regulators of health promotion actions (Chatzisarantis & Hagger, 2009; Silva et al., 2010). Accordingly, we hypothesize that the focus of the feedback moderates the effects of HSMAs on employees' perceptions of autonomy in self-regulating their health-related behaviour, such that the effects are more positive when employees receive developmental feedback in addition to mere performance feedback (*Hypothesis 2*).

The moderating role of health

Employees differ in their health status, and these individual differences seem to influence how they respond to workplace health promotion programs. Recent research shows that less healthy employees experience more difficulties in adhering to healthy lifestyle behaviours recommended by guidelines (Delahanty, Meigs, Hayden, Williamson, & Nathan, 2002; Puhl & Heuer, 2010). They feel that workplace health promotion programs invade their privacy and go against their personal autonomy (Damman et al., 2015). Given this finding, we examine how differences in individual health conditions moderate the effects of HSMAs on autonomy. Here, we use body mass index (BMI) as a holistic measure of health (Gutin, 2018). We use BMI as a proxy of health because of its high predictive validity across many health outcomes and widespread use in population and medical research, and because it is a convenient and simple measure of health that can be self-reported by individuals without requiring inputs from medical authorities (Gutin, 2018).

We discuss two reasons why BMI might moderate the effects of HSMAs on employees' perceptions of autonomy in self-regulating their health-related behaviour. First, HSMAs may encourage weight-based stereotypes that overweight individuals are lazy and unattractive, and lack self-discipline and willpower, thus assigning responsibility and blame to overweight individuals with unhealthy lifestyles (Have, van der Heide, Mackenbach, & de Beaufort, 2013; Puhl & Heuer, 2010). As a consequence, workplace health promotion measures may be seen as a violation of privacy and a painful interference with personal autonomy to live life on one's own terms (Have et al., 2013). Moreover, employees with a high BMI may see the use of HSMAs as an attempt by their employer to subtly press them to take action to reduce their weight, thereby harming their sense of self-determination and autonomy. In contrast, as thinness is seen as the healthy ideal (Gutin, 2018), employees with a healthy BMI will not feel stigmatized when an HSMA provides feedback information about suboptimal health-related behaviours. Not feeling stigmatized, and helped by the feedback from the HSMA, they are more prepared, than high BMI employees, to reduce the suboptimal behaviours identified and stay healthy.

Second, employees with high BMI often need to make more drastic lifestyle changes than employees with healthy BMI to meet the standards for healthy physical activity and weight that are made salient by HSMAs. Such changes are far more difficult to achieve for overweight individuals (Delahanty et al., 2002), leaving them with a much greater likelihood of failing to adhere to the recommended guidelines (Puhl & Heuer, 2010). Failure adds to the stigmatization and stereotyping of overweight individuals, increasing their vulnerability to psychological distress and the risk of backsliding into unhealthy lifestyle behaviours (Puhl & Heuer, 2010). Consequently, employees with high BMIs may feel they are less able to regulate and change their lifestyle behaviours to meet the HSMA standards and recommended guidelines. This decreases their sense of autonomy and self-regulation. In contrast, healthy employees with an optimal BMI often need to make far less difficult lifestyle changes to meet the recommended guidelines and standards. As such, their healthy BMI facilitates self-efficacy and self-control in regulating health-related behaviour, which reinforces perceptions of self-direction and autonomy. Based on the above reasoning, we hypothesize that BMI moderates the effects of HSMAs on employees' perceptions of autonomy in self-regulating their health-related behaviour, such that the effects are more strongly negative (or less strongly positive) for employees with higher BMIs than for employees with lower BMIs (*Hypothesis 3*).

Health autonomy at work and at home

HSMAs such as activity trackers provide users with physical activity metrics that are usually measured on a daily basis and capture activities carried out within and beyond the workplace. Further, the standards set for physical activity (e.g., 10,000 steps a day) are not specified exclusively for the workplace but are fluid goals for health-relevant behaviours in both work and private lives. Thus, besides their influence on autonomy and control of health-related behaviour in the workplace, HSMAs may also affect the sense of autonomy that employees experience in regulating their health-related behaviour at home. On the one hand, the fluidity of HSMAs may enhance perceived autonomy in both domains. The pursuit of health-related goals (e.g., 30 minutes of moderate intensity exercise each day) is not limited to the work domain but continues into private time. This fluidity in goal pursuits in work and private domains is comparable with tele-working that may facilitate flexibility to reach both work and family goals in the same time frame (Madsen, 2003). However, on the other hand, employees may experience the continuous exposure to the HSMA's demands as an interference with their self-determination in personal life. This might decrease their perceived autonomy in self-regulating their health-related behaviour. Accordingly, we examine the potentially different effects of HSMAs on perceived autonomy at work and at home. We do so by including measures of both Work Health Autonomy (WHA), defined as perceived autonomy to regulate health-related behaviour during working hours, and Home Health Autonomy (HHA), referring to perceived autonomy to regulate health-related behaviour during private time. Previous research on autonomy in the workplace does not lend itself to deriving theoretical argumentation for different HSMA effects on these two distinct types of health autonomy. Therefore, the distinct measures of work and home health autonomy are studied in an exploratory fashion, rather than attempting to develop and test theory-driven hypotheses. Thus, our exploratory research question is whether HSMAs, feedback focus, and BMI have different effects on employees' perceptions of work health autonomy and home health autonomy.

Methods

Design, sample, and procedure

To examine the effects of employer-provided HSMAs on employees' perception of autonomy in the self-regulation of their health-related behaviour, we executed a pretest-posttest randomized two-phase field experiment study in a company in the Netherlands. The study included a four-week HSMA intervention with a feedback factor (performance versus development feedback) and pretest (T1) and posttest (T2) measurements of participants' perceptions of autonomy.

After the experiment period, a series of interviews was conducted with employees with varying BMIs.

Setting: The company involved is a medium-sized hospital that had started an organization-wide workplace health promotion program to facilitate the health, well-being, and work-life balance of its employees. The company employs a variety of workers such as nursing and technical staff , specialists and support staff , and office workers with varying levels of mental and physical activities. As one-size-fits-all advices for health promotion may not match such a heterogenous workforce, the hospital management team decided to provide employees with measures through which employees could self-regulate their own unique health behaviour including an activity tracker (Fitbit One). However, before implementing this activity tracker throughout the hospital, the management team wanted to investigate its effects and asked us to conduct an experimental field study. The experimental protocol for the study was approved by the designated research ethics committee and sent to the ethics committee of the healthcare institute for information purposes.

Participants: Participants were recruited by sending e-mails and a newsletter to all employees in which they were informed about the experiment and offered the opportunity to participate. Employees who were interested in the use of HSMAs are likely to be overrepresented in the sample. However, given that workplace health promotion programs usually rely on voluntarily participation and that participation rates vary from 10% to 64% (with an average of 33%) (Robroek, van Lenthe, van Empelen, & Burdorf, 2009), we think that the sample in the present experimental field study is representative for the total population of employees that voluntary participate in health promotion programs. In total, 166 employees responded out of 1525 potential participants (11%). Of these, two were unable to participate due to lengthy absences during the experiment period. Of the remaining 164 employees, 30 were assigned to a pilot group that was used to test and improve the methodological, technical, and logistical features of our experiment. Eleven participants were interviewed after finishing the experiment. All participants in both the pilot group and the main experiment gave an informed consent.

Pilot: During the pilot, the technical feasibilities of the HSMAs and data-logging system were tested and evaluated, and modifications were made where necessary. Moreover, small alterations were made to improve the wording of some questionnaire items, and additional information was added to the information sheet for new participants, especially about the use of participants' research accounts for data gathering and preventing them from linking the HSMA to their own smartphone.

Main experiment: The 134 participants that were not involved in the pilot were randomly assigned to either the performance feedback condition (PFC; N= 68) or the developmental feedback condition (DFC; N= 66). These 134 participants were invited by email to complete an online questionnaire at the pretest measurement point, and 122 completed the questionnaire ($N_{PFC} = 62$, $N_{DFC} = 60$). The 122 participants that completed this pretest were provided with an HSMA. Of these 122, 20 dropped out, either because they did not use their HSMA or because they did not complete the post-experiment questionnaire distributed after the four-week intervention period (see Figure 3 for detailed participant flow chart). Consequently, the final sample included 102 participants ($N_{PFC} = 50$, $N_{DFC} = 52$). The retention rate of the participants therefore is 76,1%, which is higher than most e-health interventions in the workplace showing high to very high attrition rates (Eysenbach, 2005), with only 20% of studies reaching a retention rate of 75% or more (Norman et al., 2007). Of the remaining participants, 84% were female. The participants average age was 46 ($SD_{age} = 10$), and their average employment duration was 11.9 years ($SD_{employment} = 10.4$). Most participants (64%) had a higher education or university degree, while 25% had a vocational degree, and 11% had less formal education. The spread of employees across the job spectrum was considered satisfactory, including both administrative and medical personnel, ranging from management and medical specialists to nursing, administrative, and technical staff.

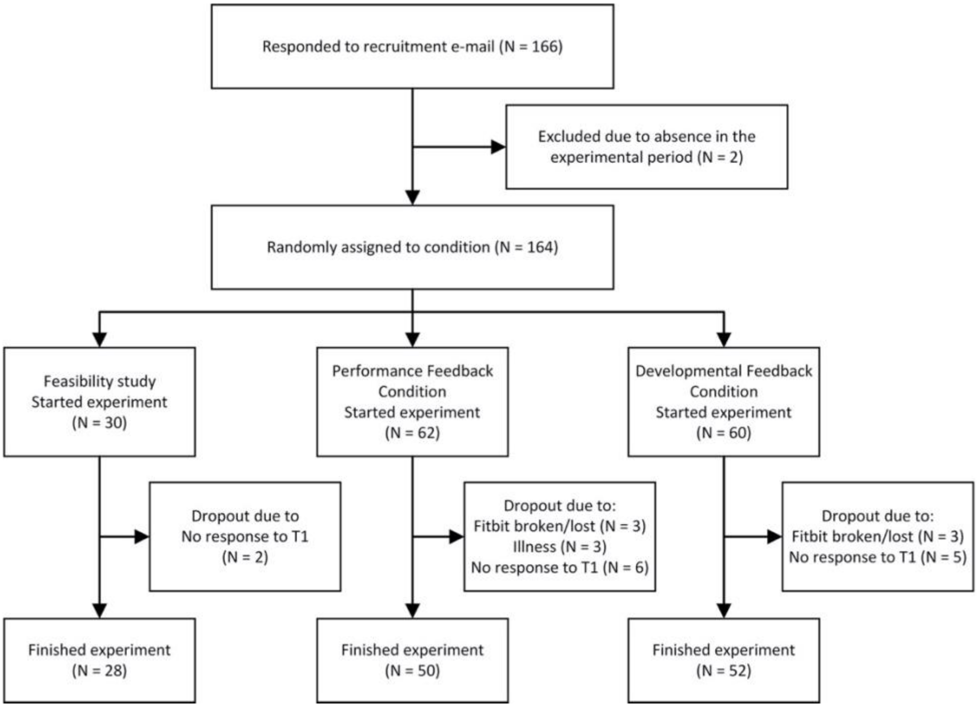


Figure 3: Participation flowchart

HSMA intervention and manipulation of feedback focus

Procedure: After completing the pre-test questionnaire, the participants were informed about the HSMA intervention following a standardized procedure. This involved a letter stating the goal of the study, the duration of the experiment (4 weeks), the expectations of the participants (to wear a Fitbit for the four weeks, complete a post-test questionnaire, and participate in a focus group or interview if asked to), the expected time-investment, and information on data confidentiality. Participants were not expected to use any smartphone or other applications connected to the device, and all data were collected and stored in accounts used only for research purposes. All participants were made aware that their employer did not have access to the data obtained using the activity tracker. The participants then received an activity tracker that measured their number of steps taken, stairs climbed, and minutes of light, moderate, and heavy activities during the day.

Manipulation of feedback focus: The screen of the activity tracker provided the participants with their personal activity metrics on a daily basis. In addition, they received an email once a week reporting their physical activity metrics in which the focus of the feedback was manipulated. Specifically, participants under the *performance feedback* condition received only performance feedback information showing factual metrics as assessed by the activity tracker for each of the past 7 days (e.g., October 18: 8000 steps, 14 stairs, 77 minutes light activity, 20 minutes moderate activity, and an estimated calorie use of say 2200 kCal) and the general norms for these measures (10,000 steps a day and a calorie intake of 2000 kCal for women, 2500 kCal for men). Participants under the *developmental feedback* condition in addition received development feedback, giving advice on how work-related activities could be altered in order to encourage a healthy behaviour pattern and lifestyle (see Appendix 1 for feedback examples). These developmental feedback mails included information on the intensity of daily activities, ways to increase their daily activity, tips and tricks to adjust and sustain exercise patterns, and information on food and nutrition. This feedback was based on advice from the Netherlands Nutrition Centre, the National Institute of Public Health and the Environment, and the Knowledge Centre for Sport & Physical Activity. The developmental feedback information in the e-mails was refreshed weekly, and built upon the information given in the previous week(s).

Measures

Autonomy. We adapted the three items of the Autonomy scale of the Job Diagnostic Survey (Hackman & Oldham, 1974) developed by Hackman and Oldham (1980) to assess participants' perceptions of work health autonomy (WHA) and home health autonomy (HHA). We pretested the suitability of the individual items of this adapted autonomy scale and solved small wording issues that led to confusion

with some of the participants. For WHA, one item from the initial Autonomy scale was applied to capture autonomy experiences for both the work as a whole and individual tasks, resulting in 4 items for WHA. Two example items are “I can independently decide how to take my health into account when executing my job” (WHA) and “In my private time, I’m free to decide whether I want to do something about my health and health-related behaviour” (HHA). We used a five-point Likert response scale ranging from 1 (strongly disagree) to 5 (strongly agree). See Table 6 for items and statistics of an exploratory factor analysis testing the discriminant validity of the two autonomy scales.
BMI. Participants reported their body weight and height. These self-reported values were used to calculate their Body Mass Index.

Control variables. We included the demographic variables of gender, age, organizational tenure, education, and previous experience with activity trackers (yes vs. no) as control variables as these variables could potentially influence participants’ perceptions of work and home health autonomy.

Statistical analyses

To examine the impact of the HSMA intervention (activity tracker) on perceptions of autonomy in self-regulating health-related behaviour during work and personal time, paired-sample *t* tests were conducted to test differences between pretest (T1) and posttest (T2) autonomy (Hypotheses 1a and 1b). This was done for WHA and HHA separately to investigate our explorative question. Having formulated competing hypotheses on the direction of the autonomy effects of HSMA, we used two-tailed tests using a significance level of .05. Further, multiple regression analyses were conducted to test the hypothesized effects of feedback focus and BMI on T2 autonomy in self-regulation of health-related behaviour, thereby including T1 autonomy as a covariate (Hypotheses 2 and 3). Specifically, the regression analyses consisted of two steps. The first step, in addition to the covariate of T1 autonomy, included dummies for feedback focus (performance = 0, developmental = 1) and BMI to test their effects on T2 autonomy. The second step included the cross-product term of feedback focus and BMI to explore their possible interaction effects on T2 autonomy. Our hypotheses had specified the direction of the moderating impacts of feedback focus and BMI on the autonomy effects of HSMA. Therefore, we used one-tailed tests with a significance level of .05. To facilitate interpretation and minimize multi-collinearity problems when testing interaction effects, we used cross-product terms of standardized predictors. Again, we ran separate regression analyses for work (WHA) and home health autonomy (HHA) to examine our explorative question.

Second stage of the study: interviews

To explore the mechanisms underlying the moderating effects of feedback and BMI that we identified (see Results section), additional qualitative data were gathered after completing the experimental period. The first author conducted interviews with 11 participants who were spread across the BMI spectrum. Two participants had BMI values lower than 20, two had BMI values between 20 – 25, three had BMI values between 25 – 30, two had BMI values between 30 and 35, and two had BMI values above 35. Interview requests were sent randomly to four participants in each BMI-category, and upon positive response an interview was scheduled. Seven interviewees were in the performance feedback condition, four interviewees were in the developmental feedback condition. The interviews were semi-structured, and protocol questions were focused on how interviewees had experienced and responded to the HSMA feedback in regulating their health-related behaviour in the workplace and in private time. The duration of the interviews was 25-45 minutes, and all the interviews were conducted during or immediately after working hours, unless the interviewee requested otherwise. All interviews were taped and transcribed, and a common codebook of 35 codes was generated by having two authors separately and iteratively code one interview, and then compare and align their codes. This codebook was validated by analysing two further interviews that were coded using this codebook by both these authors, resulting in an interrater reliability

(Holsti's coefficient) of .78 (Krippendorff, 2004). After this validation check, the codebook was used by the first author to code all 11 interviews. Following the coding of the interviews, network diagrams of co-occurring and consecutive codes were made for each interview separately and checked for consistency in interpretation by another author. The individual diagrams were clustered into sub-groups based on BMI score and feedback type to trace any patterns within and between sub-groups of interviewees. This allowed us to further analyse and clarify the roles of both BMI and feedback focus in the autonomy effects of HSMAs.

Results

Exploratory factor Analyses

In order to get some evidence for the discriminant validity of the autonomy scales that were created by adapting the Autonomy scale of the Job Diagnostic Survey, the items of the WHA (4 items) and HHA (3 items) scales were factor analysed using principal components extraction and oblique rotation. As can be seen in Table 6, two factors emerged with eigenvalues greater than 1, accounting for 70,35 percent of the variance. Each item "loaded" on its appropriate factor, with primary loadings exceeding 0,701 and cross-loadings lower than 0,094. The correlation between the two factors was insignificant.

Equivalence of experimental feedback groups

Prior to hypothesis testing, we conducted a one-way analysis of variance (ANOVA) to check the pretest equivalence of the variables across the two experimental feedback groups. That is, we tested whether the participants in the performance feedback group systematically differed from the participants in the developmental performance group with respect to their scores on the demographics of gender, age, organizational tenure, experience with HSMAs, education level, and BMI, and on the study variables of work health

Items	WHA	HHA
Work Health Autonomy		

In my work, I have the opportunity to plan my work activities such that they will benefit my health	**0,869**	-0,067
I can independently decide how I want to take my health into account in the execution of my work	**0,860**	-0,069
I can decide how to execute individual work tasks in the most healthy way	**0,843**	0,063
In my workplace, I have the freedom to take initiatives that benefit my health	**0,840**	0,076
Home Health Autonomy		
In my private time (outside of work), I feel totally free to decide whether or not I want to do something about exercise and health	0,094	**0,701**
I feel pressured by my employer to include exercise and health in the planning of my private activities (R)	-0,109	**0,854**
My employer restricts me in my freedom regarding how I deal with exercise and health in my private time (R)	0,002	**0,869**
Eigenvalues	2,939	1,986
Percentage Explained Variance	41,98	28,37
Cronbach's Alpha	0.871	0.730
Note: (R) indicates a reverse-worded item. Items belonging to a factor are marked **bold**		

Table 6: Results of Factor Analysis for WHA and HHA

	Sum of Squares	df	Mean Square	F	Sig.
Home Health Autonomy pre-test	0.007	1	0.007	0.019	0.890
Work Health Autonomy pre-test	0.109	1	0.109	0.127	0.722
HSMA Experience	0.094	1	0.094	0.374	0.542
Year of Birth	4.588	1	4.588	0.041	0.839
Education Level	0.189	1	0.189	0.164	0.686
BMI	23.313	1	23.313	1.904	0.171
Tenure	54.932	1	54.932	0.502	0.480
Gender	0.028	1	0.028	0.207	0.650

Table 7: ANOVA results

autonomy and home health autonomy at the pretest measurement point (T1). As can be seen in Table 7, the ANOVA results did not indicate significant differences for any of the variables, showing pretest equivalence of the variables across the two feedback groups.

Descriptive statistics

Table 3 presents means, standard deviations, and correlations for all the variables included. The correlations indicate that none of the control variables are significantly related to the autonomy variables, leading us to exclude them from our analyses to avoid biased parameter estimates (Becker, 2005).

Hypothesis Testing

Pretest-posttest differences in autonomy.

To test Hypothesis 1, we examined whether the use of the HSMA activity tracker influenced employees' perceptions of WHA and HHA. Specifically, we conducted paired-sample t tests to determine if there were significant differences between pretest and posttest means for the respective autonomy variables. Table 8 reports the pretest-posttest means, standard deviations, and t-values for both WHA and HHA. These are visualized in Figures 4 and 5. The difference between the pretest and posttest means is not statistically significant for WHA, whereas it is significant for HHA ($t = -3.184$, $p < .01$, see table 9) indicating that the use of HSMAs decreased employees' perceptions of autonomy in regulating their health-related behaviour in their private time. Thus, based on these results, Hypothesis 1a, predicting a positive effect of HSMAs on employees' perceptions of autonomy in self-regulating their health-related behaviour, was rejected, whereas Hypothesis 1b, predicting a negative effect of HSMAs on perceived autonomy, was confirmed for HHA but not for WHA.

	Mean	SD	HHA pre-test	HHA post-test	WHA pre-test	HHA post-test	Feedback type	BMI	HSMA experience	Type of job	Year of birth	Education level	Tenure
HHA pre-test	4.62	0.61	1										
HHA post-test	4.34	0.79	.351**	1									
WHA pre-test	3.44	0.92	0.031	-0.013	1								
WHA post-test	3.54	0.90	0.019	0.104	.635**	1							
Feedback type[1]	0.51	0.50	-0.014	0.009	-0.036	0.073	1						
BMI	24.48	3.51	-.277**	-.287**	0.060	-0.082	0.137	1					
HSMA experience[2]	0.45	0.50	0.119	-0.033	0.054	-0.058	0.061	0.153	1				
Type of job[3]	0.56	0.50	-0.118	-0.199	-0.081	0.037	0.094	0.037	0.042	1			
Year of birth	1971.55	10.46	-0.159	0.012	0.038	-0.053	-0.021	-0.014	0.123	.284**	1		
Education level[4]	4.70	1.07	0.039	0.093	0.072	-0.026	-0.040	-0.072	0.166	-0.019	0.202	1	
Tenure	11.88	10.43	-0.075	-0.031	-0.096	-0.002	0.071	0.034	-0.123	-0.078	-.558**	-.429**	1

*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)
1. 0 is performance feedback, 1 is development feedback
2. 0 is no previous experience, 1 is participant has used/uses an HSMA
3. 0 is mainly office work, 1 is physically active work
4. Range is 0 to 6, 0-1 reflects low education level, 6 is a university degree

Table 8: Means, standard deviations, and zero-order Pearson correlations for variables (N=102)

	Pretest		Posttest				
	Mean	SD	Mean	SD	t	df	p
Work Health Autonomy	3.43	.93	3.53	.90	1.226	97	.223
Home Health Autonomy	4.61	.61	4.35	.79	-3.184	98	.002

Table 9: Results of paired-sample t tests

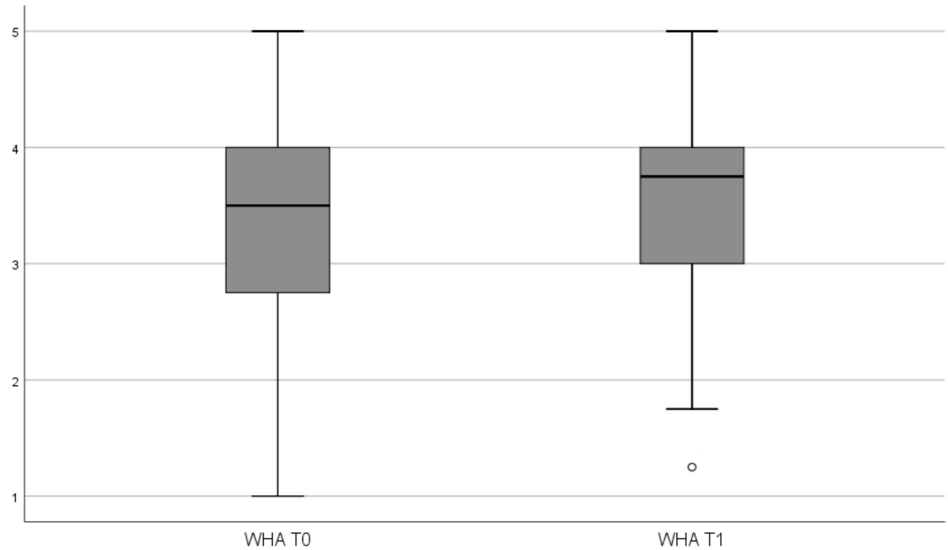


Figure 4: Results of paired sample t tests WHA

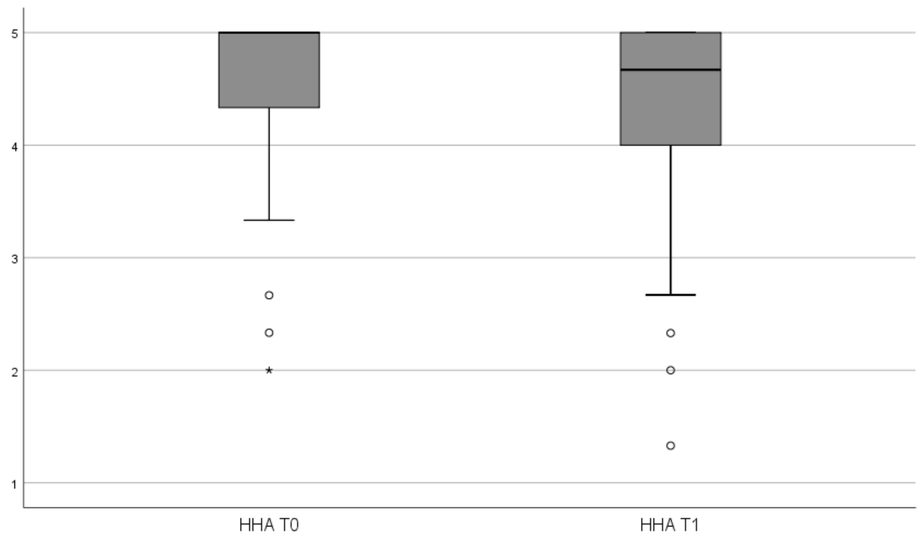


Figure 5: Results of paired sample t tests HHA

Effects of feedback focus and BMI.

Regression analyses, separately conducted for WHA and HHA at T2, showed that the feedback focus (performance versus developmental) had a marginally significant and positive effect on T2 WHA (b = .10, t=1.44, p < .10, one-tailed test). In line with Hypothesis 2, this finding indicates that the effect of HSMAs on WHA was more strongly positive when employees received developmental feedback than when they received only performance feedback. Feedback focus had no significant effect on T2 HHA (b = .03, t=.44, p >.05, one-tailed test), which contradicts Hypothesis 2. Table 10 reports these regression results under Model 1.

	T2 Work health autonomy				T2 Home health autonomy			
	Model 1		Model 2		Model 1		Model 2	
Predictor	b	t	b	t	b	t	b	T
Constant	3.54	51.77***	3.52	51.57***	4.34	59.99***	4.37	62.21***
Autonomy pretest	.57	8.22***	.58	8.43***	.23	2.98**	.23	3.15**
Feedback	.10	1.44†	.10	1.44†	.03	.44	.04	.50
BMI	-.12	-1.73*	-.10	-1.49†	-.17	-2.16*	-.19-	2.62**
Feedback * BMI			.12	1.75*			-.21	-3.00**
R^2	.42		.43		.16		.23	
Adjusted R^2	.40		.41		.13		.20	
F	23.29***		18.61***		6.18***		7.26***	

†p < .10,*p < .05, **p < .01, ***p < .001, one-tailed tests.

Table 10: Regression results for work health autonomy and home health autonomy

Furthermore, as can be seen in Table 10 under Model 1, BMI had significant negative effects on both T2 WHA (b = -.12, t=-1.73, p < .05, one-tailed test) and T2 HHA (b = -.17, t=-2.16, p < .05, one-tailed test). These results indicate that the effects of the HSMAs on both WHA and HHA were more strongly negative for employees with high BMI levels than for employees with low BMI levels, a finding fully in line with Hypothesis 3.

In addition, for exploratory reasons, we tested for interaction effects between feedback focus and BMI (see Table 10, Model 2). The interaction effect was significantly positive for WHA ($b = .12$, $t=1.75$, $p < .05$, one-tailed test) and significantly negative for HHA ($b = -.21$, $t=-3.00$, $p < .01$, one-tailed test). Additional simple slope tests (see Figure 6) indicate that BMI was significantly and negatively associated with T2 WHA ($b = -.23$, $t=-2.47$, $p < .05$) for participants who had received only performance feedback, but that BMI was unrelated to T2 WHA ($b = .02$, $t=.18$, ns) for employees who had also received developmental feedback. Thus, the effects of the HSMAs on WHA were more strongly negative for employees with high BMI levels who received performance feedback, whereas BMI did not moderate the effects of HSMAs on WHA when employees received only developmental feedback.

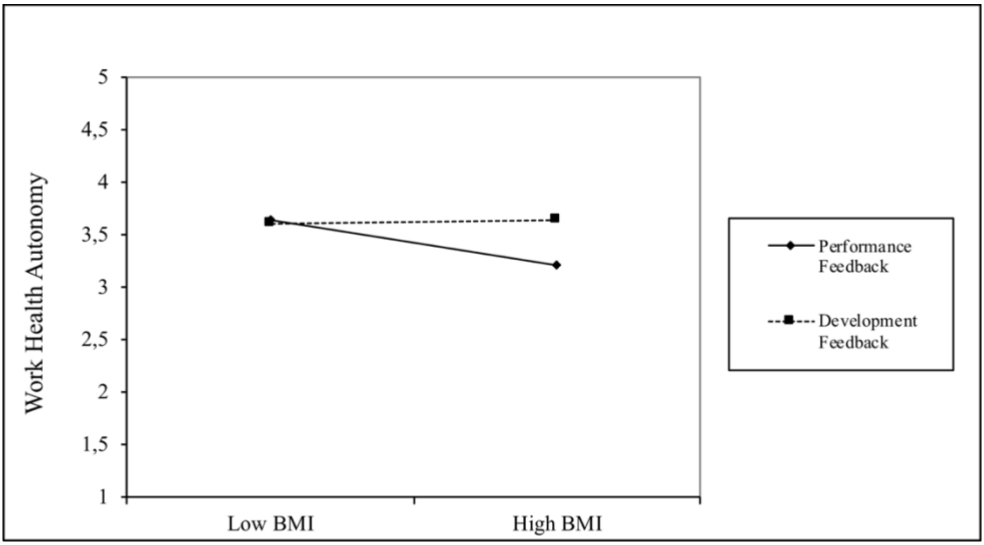


Figure 6: Pattern of interaction effect of BMI and feedback focus on T2 work health autonomy

In contrast, the interaction plot displayed in Figure 7 shows that BMI was unrelated to T2 HHA ($b = .02$, $t= .21$, ns) for participants who received only performance feedback, whereas BMI was significantly and negatively related to T2 HHA ($b =-.41$, $t=-3.73$, $p<.001$) for employees who received additional developmental feedback. As Figure 5 shows, with developmental feedback alone, the highest levels of HHA are to be found in low BMI employees, with the level of HHA decreasing strongly at higher BMI levels.

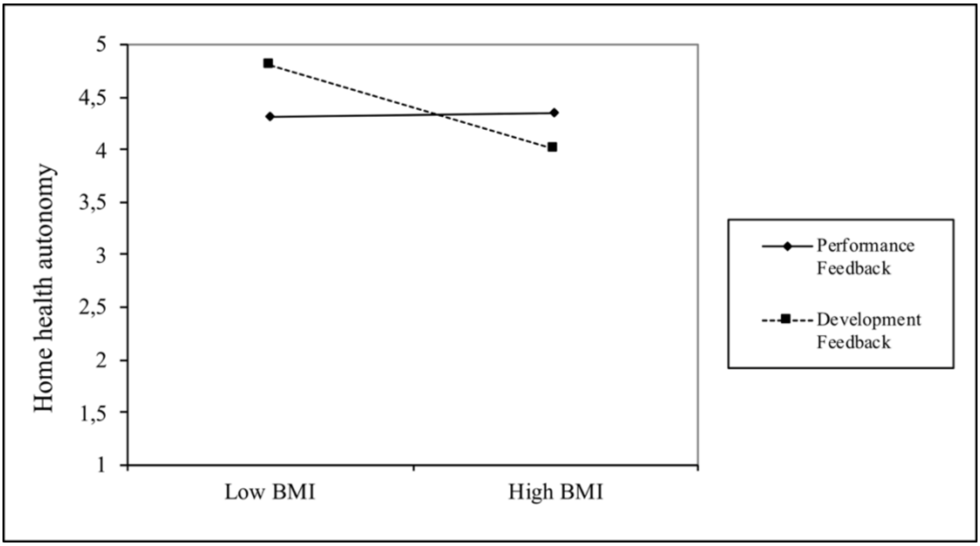


Figure 7: Pattern of interaction effect of BMI and feedback focus on T2 home health autonomy

Supplementary analysis of additional qualitative data

The qualitative interview research focused on understanding two of the main findings from the quantitative study:

1. Performance feedback group: the use of HSMAs resulted in a greater reduction in work health autonomy for employees with a higher BMI (see Figure 6)
2. Developmental feedback group: the use of HSMAs resulted in a greater reduction in home health autonomy for employees with a higher BMI (see Figure 7)

In order to identify the underlying mechanisms that cause these differences in perceptions of autonomy between employees with low and high BMIs, we asked the interviewees about their experienced autonomy both at work and at home, and the impact of the Fitbit and the received feedback on this autonomy. In this section, we present the effects that we uncovered and illustrate these with quotes from the interviewees.

BMI, performance feedback, and Work Health Autonomy

Employees with a high BMI experienced the standard norms highlighted in the performance feedback as very challenging and indicated that the use of the Fitbit made these norms more salient, whereas employees with a low BMI tended to interpret the performance feedback more loosely, and give it a positive spin:

> *I discussed it with a colleague who also participated in the Fitbit experiment, and it really depends on what patient rooms you are assigned to. Some are at the front of the department, and then you have to walk a lot more compared to rooms close to the counter. […] And then I thought, I only make this number of steps, I really have to walk some extra kilometers. (Q1: Medical personnel, performance feedback, high BMI)*
>
> *Yes, I often don't make the 10,000 steps, but that number is also something that was once made up. (Q2: Medical personnel, performance feedback, low BMI).*

Further, employees with a high BMI commented that the performance feedback made them very aware of the fact that they could not achieve the 10,000 steps norm. They found this very confronting, leading them to express more negative emotions and feelings about the performance feedback they received. As such, high BMI employees seem to experience the performance feedback as more of a burden:

> *Well, I thought I was quite active, and when I started [the experiment] I walked quite a lot […] But it was quite disappointing, how little you move or exercise at work. (Q3: Medical personnel, performance feedback, high BMI)*
>
> *I now [after the experiment, AB] have an app that registers everything. […] and then I think, ooh, did I only walk so little?*

> *That is not a lot for a day like that! And then I get embarrassed about it, this isn't good, especially because I worked the entire day. (Q4: Administrative personnel, performance feedback, high BMI)*

Third, employees with a high BMI relatively more often experienced obstacles to self-regulating and intensifying activity in the work situation. That is, they tended to see more obstacles such as scheduling or work pressure issues. Moreover, employees with a high BMI felt less need to compensate for this lack of opportunity to self-regulate at work in the home situation:

> *[…] No, because that is impossible. We don't have breaks, and no lunchbreak, so we pretty much work for eight hours straight. So, we can't go for a walk outside or something. (Q5: Administrative personnel, performance feedback, high BMI)*

> *We discussed it [among colleagues], that it would be great to have the opportunity to go for a walk during lunch, but now we only have time to quickly finish eating and then our break is over. (Q6: Medical personnel, performance feedback, high BMI)*

> *Because I have less spare time, I don't achieve it [the 10,000 steps]. And, as I said, sometimes [after work] I'm too tired, and then I start thinking that I would have to walk, no, I can't always make that. Time wise, or energy wise. (Q7: Medical personnel, performance feedback, high BMI)*

However, employees with a low BMI experienced more self-regulating options and less obstacles to move at work, and seemed to use the feedback from the HSMA to adapt their behaviour in the work environment:

> *I started taking the stairs. […] Otherwise I didn't really exercise more, but I took the stairs more often, because we're*

> *[at work] on the third floor and therefore climb three flights of stairs. (Q8: Medical personnel, performance feedback, low BMI)*

> *Yes, I really think a thing like that [HSMA] helps to exercise more. Because I have sometimes caught myself thinking, darn, I'm taking the elevator [at work] when I should have taken the stairs, and I know I won't reach my step goal today. You are more conscious of what you do, and sometimes do things that you wouldn't have done otherwise. (Q9: Medical personnel, performance feedback, low BMI)*

Moreover, and in contrast to employees with high BMIs, employees with low BMIs related a low performance feedback score to their overall movement, both at work and at home. They expressed the view that a low performance score encouraged them to self-regulate and also move more in the home situation, especially when the work situation lacked opportunities to increase the movement pattern:

> *Well, I was a bit lazy regarding exercising, and now I'm exercising at least once and often twice a week, really consciously. It is a bit dependent of my schedule, and you know, I'm taking the bike more often, and maybe taking longer walks with the dog to move more. (Q10: Medical personnel, performance feedback, low BMI)*

These differences in compensation behaviour between the work and home environment are especially interesting because both employees with high and low BMIs mention that they do regularly exercise in their private time:

> *I usually go to the gym 2 to 3 times a week, depending on my schedule. (Q11: medical personnel, performance feedback, high BMI)*

> *I run, about once a week, and once a week I go for a spinning class, and in the weekend when the weather is ok, I'm cycling a lot. (Q12: Administrative personnel, performance feedback, medium BMI)*

> *Well, we have a dog, so I walk multiple times a day. And I do Pilates, which is good for my body strength, but I can't really see it in my Fitbit (Q13: Medical personnel, performance feedback, low BMI)*

Even though their general exercise levels outside of work are comparable, the reasons to alter the amount of exercise are different.

BMI, developmental feedback, and Home Health Autonomy

In this section, we focus on employees with high BMIs who received developmental feedback, and we aim to shed light on why their perceived autonomy to self-regulate their health in their private time declined, while it remained stable in working hours.

First, employees with both high and low BMIs that received developmental feedback reported becoming aware of more opportunities to self-regulate their health-related behaviour in the workplace:

> *Yes, well, due to that Fitbit, I no longer go to the restaurant to have lunch or dinner, just to not be tempted anymore regarding food. (Q14: Administrative personnel, development feedback, high BMI)*

> *Yes, with that Fitbit, well, you see the steps, [...] and then I consciously thought, when colleagues were taking the elevator, no, I'll take the stairs. (Q15: Medical personnel, development feedback, medium BMI)*

However, employees with high BMIs report negative emotions linked to receiving feedback on their health-related behaviour:

> *I recall that at some point we received an e-mail including norm groups [regarding activity levels] [...] and then I really felt miserable, because I didn't fit in those groups. It was great for people who had high step counts, but for people with low step counts that wasn't nice at all. (Q16: Medical personnel, developmental feedback, high BMI)*

The advice they received as part of the developmental feedback was aimed at their work situation but, due to its general nature, it could also apply to their private situations, as reported by some employees noting that the 'health responsibility' was being shifted from work to home. However, whereas employees with low and medium BMIs commented on this work-home shift in more neutral terms, employees with high BMIs were more negative:

> *Well, when I had to get some groceries, I started to walk. And I'm taking the bicycle more often now, whenever I have to get something in our village. Before, I took the car, but I'm a lot more conscious about that now. (Q17: Medical personnel, development feedback, medium BMI)*

> *Well, [...] our whole company has to be healthy, and we all have to be good role models. [...] And then I start thinking: What's next? Do I have to lose 20 kilograms of weight, because otherwise I can't work here? Because I'm not a good role model? (Q18: Medical personnel, developmental feedback, high BMI)*

This negative labelling of the attention to self-regulation of health-related behaviour even in private time was projected onto the fitness opportunities that the employers provided after working hours: these are experienced as stigmatizing by employees with high BMIs. These employees indicate that they sometimes feel they are being watched and judged in their daily job, and feel as if the health programs offered by the employer after working hours are only fit for non-obese colleagues:

> *I know I can join a company fitness class, […] but I'm afraid to do so. Because, who does that? All those trained bodies! I'm not going to stand amidst them, I really won't. (Q19: Medical personnel, developmental feedback, high BMI)*

> *And then they are supporting 'the week of taking the stairs' […], but then, when I'm standing in front of the elevator, people tend to say "Oh, are you taking the elevator? We are taking the stairs!". That feels terrible. Really terrible. (Q20: Medical personnel, developmental feedback, high BMI)*

This supplementary analysis of additional data has provided some insight into the reasons why employees with high BMI respond differently to HSMA feedback than employees with lower BMI.

High BMI employees in the performance feedback group attach more salience to the provided norms and standards for healthy behaviour, and experience more negative emotions when not reaching the norm, than employees with low BMIs. Further, they report that they increasingly notice limitations that stop them increasing their daily exercise.

Under the developmental feedback conditions, we see that both low and high BMI employees see more opportunities to change their workplace behaviour, and both are aware that the responsibility for health at work to an extent shifts to the home environment. However, whereas employees with low BMIs comment about this shift in neutral terms, employees with high BMIs see this negatively. Further, the health promotion programs offered by the employer after working hours are frowned upon by those with high BMIs because they feel judged by these programs.

Discussion

Discussion of the results

This study provides several new insights regarding the use of HSMAs in the workplace and their influence on employees' autonomy to regulate their own health-related behaviour. We will first summarize the results of our study, after which we will discuss the theoretical and practical contributions. We also present some limitations and potential directions for future research.

This study shows that the use of HSMAs, such as the Fitbit, does not influence employees' perceived autonomy in self-regulating their health-related behaviour at the workplace, i.e. their work health autonomy (WHA), whereas it does reduce this perceived autonomy in the private situation, i.e. home health autonomy (HHA). Looking at the effects of the type of feedback that participants received, we found that adding developmental feedback to performance feedback marginally enhanced the experienced WHA, but had no impact on HHA. Finally, we looked at the impact of using BMI as a single proxy for health status on these results, and we found that the effects of HSMAs on both WHA and HHA were negatively affected by BMI. That is, employees with a higher BMI suffered a greater loss of perceived autonomy in self-managing their health. Further, employees with a low BMI who received performance feedback experienced a relatively smaller loss of WHA than those with higher BMIs, and also reported an increase in HHA. The combined effects of feedback focus and BMI showed that the addition of developmental feedback mitigates the negative effects of HSMAs on WHA for employees with high BMIs, but at the same time decreases the HHA for these employees.

To better understand the influence of feedback focus and BMI interaction effects, we conducted additional interviews with participants with various BMIs. It showed that employees with high BMIs experienced, for several reasons, relatively less autonomy in self-regulating their health-related behaviour in both the home and work situation. First, they tend to assign more salience to the general norms provided (i.e. walking 10,000 steps per day) than employees with lower BMIs. Employees with a low BMI experience the norm as a loose guideline, whereas people with a high BMI consider it as an important and strict norm that they are difficult to meet. When employees with high BMI then do not reach this norm, they experience negative emotions, and they express that they become increasingly aware of the limitations imposed by their surroundings that prevent them from reaching the norm. Further, employees with a low BMI consider healthy behaviour part of their lifestyle whether at work or at home, whereas employees with a high BMI strictly separate these environments. As such, employees with high BMIs seem to allocate the feelings associated with receiving feedback from the HSMA to only one environment at a time, either at work or at home.

The present research has several implications for an appropriate and effective use of HSMAs, especially for users that are deemed less healthy. This is particularly of concern since HSMA-based workplace health programs are often implemented to specifically target these high-risk groups. Our results do not confirm the general assumption underlying HSMAs that their use increases an individual's autonomy to self-regulate their health-related behaviour (Karapanos, Gouveia, Hassenzahl, & Forlizzi, 2016; Nelson, Verhagen, & Noordzij, 2016). Previous authors have suggested that while self-management tools may have the intention to 'liberate' users, these, paradoxically, may impose autonomy (Kendall, Ehrlich, Sunderland, Muenchberger, & Rushton, 2011). Using an HSMA as part of a workplace health promotion program tends to assume that users will feel autonomous and able to change behaviour in a direction that is reflected in predefined norms set by health professionals (Lowenberg, 1995). However, our empirical evidence indicates that users with a high BMI do not experience this elevated autonomy and are also likely to identify more issues that prevent them from optimally using the HSMAs. Our study is the first to observe this loss of perceived autonomy in an experimental setting, albeit that these findings are in line with findings reported by Puhl and Heuer (Puhl & Heuer, 2010) that obesity stigma impedes the effective use of public health interventions. The present results are also consistent with the felt fear for a loss of autonomy expressed by less healthy employees subject to preventive health measures by their employer (Damman et al., 2015).

Regarding feedback focus, our findings show that perceived autonomy is not automatically enhanced by providing developmental feedback (in addition to performance feedback usually provided by HSMAs), even though the literature suggests that its goal-setting and future-oriented nature should have positive effects on autonomy (Li et al., 2011; Zhou, 2003). Interestingly, we also found that performance feedback alone was sufficient to increase the HHA of employees with low BMIs (see Figure 4), meaning that under certain conditions performance feedback can in itself be autonomy-enhancing. If we relate this to our initial ideas on perceived employee autonomy regarding health self-regulation, we see that these employees do not seem to feel as if autonomy is being imposed upon them (Kendall et al., 2011), but rather that the direction in which the self-management information points them accords with their own beliefs, thereby increasing their capacity to autonomously change or continue their behaviour.

The interaction effects of feedback focus and BMI suggest that participants with high BMIs attribute more salience to the norms implied by the HSMAs (e.g., 10,000 steps per day) and have more negative feelings about not reaching these norms than those with lower BMIs. This is in line with previous research on weight stigma and lifestyle changes indicating that overweight individuals have more difficulties in pursuing and persevering with lifestyle changes, potentially leading to greater self-stigmatization (Delahanty et al., 2002; Puhl & Brownell, 2003). However, we saw that the addition of developmental feedback seems to mitigate the negative effects of HSMAs on WHA. This can be explained by the future-oriented and goal-setting nature of developmental feedback (Li et al., 2011; Zhou, 2003), with feedback messages including concrete advice on how to alter ones' health-related behaviour in the workplace, and tips on how to set and reach realistic goals through everyday actions.

These messages take away the experienced limitations in the workplace, because they actively offer a range of possibilities to exercise at work. Thereby, the negative emotions associated with the performance feedback are mitigated. Because this developmental feedback was focused on self-regulation of health behaviour in the workplace and the performance feedback still highlighted that the employee did not meet the norms, the negative emotions about failing to meet the norms seem to be shifted from the workplace to home resulting in lower levels of HHA. Accordingly, high-BMI employees do not communicate with colleagues about their personal health goals, and do not seem to compensate for a lack of exercise in the workplace by additional exercise in the home environment. The differential findings for WHA and HHA for employees with high BMI confirm our initial idea that, in the case of workplace health promotion programs, autonomy regarding health self-regulation cannot be viewed as a single construct, but reflects the distinct aspects of WHA and HHA.

Practical implications

Our study shows that the use of HSMAs that are provided by the employer may cause harm for employees with high BMI, and that these harms may be mitigated by changing the type of feedback. Because the BMI of employees is a given factor when implementing a work health promotion program using HSMAs, we suggest that the negative effects of HSMAs should mainly be mitigated by thoughtful and inclusive implementation of these programs. Our study shows that HSMA usage can decrease employees' perceived autonomy to self-regulate their health-related behaviour. In order to respect the autonomy of employees using HSMAs, the HSMA should not be a stand-alone tool but be embedded in a work health promotion program that enables employees to gradually change their behaviour according to their own beliefs and change capacity. In our study, we saw that providing users with developmental feedback in addition to performance feedback is a step in the right direction, but also lifestyle coaching and flexible goal-setting could be considered as ways to increase the experienced feasibility of lifestyle changes for less healthy employees (Delahanty et al., 2002; Hendriksen et al., 2016), thereby increasing the autonomy of employees to pursue their health goals.

We also observed an increase in experienced stigma, which our high BMI respondents described as occurring because they experience an imbalance between attention to physical versus mental health, and the use of general norms for healthy behaviour instead of personalized norms and goals. The literature suggests these pitfalls can be avoided in both the development phase of health promotion programs, by including value levers in the design process (Shilton, 2013), and the implementation phase, by using groups of employees and other stakeholders to address and evaluate (morally) relevant features and issues of the program (Have et al., 2013).
Our study shows that employees with low BMIs benefit from performance feedback, but not from the additional developmental feedback. Therefore, we are less hesitant in recommending HSMAs for this group of employees, even if these HSMAs do not offer flexible goal-setting or other ways to personalize the feedback. We do however believe that employees with low BMIs may still benefit from additional personal coaching or supervision in altering their health-related behaviours because a low BMI does not necessarily equate to a healthy lifestyle.

Limitations

Despite these relevant and interesting findings, this study has certain limitations that should be acknowledged. Given the nature of the HSMA, we have not been able to construct a control group that used the HSMA but did not receive feedback in addition to our two experimental groups. Since the HSMA gives continuous feedback, it is not possible to give some people a "placebo HSMA" since the lack of feedback would tell them immediately that they were in the placebo condition. Instead, we used a within-subjects design, comparing participants to their own pre-test characteristics. We have tried to limit the impact of the work environment as much as possible, by ensuring that work health promotion programs were not started, altered, or stopped during the experimental period.

The use of BMI as a proxy of health status in health research is much discussed (MacLean et al., 2009; Puhl & Heuer, 2010). For the present study, a relevant question is whether BMI sufficiently captures the differences in perceptions of health promotion interventions between individuals who consider themselves ‘healthy’ or ‘unhealthy’. Health promotion interventions may be experienced very differently by individuals who feel like they only need to maintain their current health versus individuals who face large behavioural changes in order to improve unhealthy conditions. A relevant question is whether BMI is a valid operationalization of these individual differences in health condition. We have adopted BMI as a suitable proxy of health because it has been proposed as a holistic measure of health, has high predictive validity across many health outcomes, is widely used in population and medical research, and can simply be self-reported by participants (Gutin, 2018). Moreover, BMI is a relevant health factor for the self-regulation of the specific health-related behaviours (i.e., steps taken, stairs climbed, intensity of physical activities) we focused on in the present study. We do however share the concerns about the quality of BMI as an operationalization of people’s health as discussed in literature (MacLean et al., 2009; Puhl & Heuer, 2010) and realize that its use is a limitation of the present research.

The HSMA that was used in the experiment showed the number of steps on the screen of the HSMA, thereby sending performance feedback by default. We therefore chose to send additional developmental feedback to the second experimental group, on top of the performance feedback that was similar to the feedback received by the first experimental group. This enabled us to evaluate the effects of additional developmental feedback. The effect of only receiving developmental feedback however has not been studied.

Regarding the given feedback and norms, the feedback was limited to the general norm of 10,000 steps per day (Johnman et al., 2017). Although this norm is widely known and accepted in society, it is not without its critics in academia, and arguments are made to introduce other norms, such as the Active 10 (Brannan et al., 2019). Our reason for using the 10,000 steps norm was that this norm is widely known throughout society, including to the vast majority of our study population, due to a large number of public health initiatives and the widespread availability of activity trackers.

Since the employees that participated in the experiment registered voluntarily, it is likely that these employees had an above-average interest in health and healthy behaviour, or in changing their own lifestyle. This selection bias is however comparable with the selection bias that occurs when this type of workplace health promotion program is introduced in a regular working environment, because these programs are offered on a voluntary basis. Therefore, we believe this selection bias has no significant impact on the outcomes.

Since the experiment took place in a health care institution, there is a possibility that our participants had an idiosyncratic view on employee health and public health that is different from that of employees in other occupations performed in other types of organizations. However, given that the spread across the BMI spectrum in our sample is quite comparable with that of the average population (Centraal Bureau voor de Statistiek & Rijksinstituut voor Volksgezondheid en Milieu, 2020), and the fact that 14% of the Dutch employees are employed in the health care industry (Centraal Bureau voor de Statistiek, 2020), we do not think that the participants included in our sample would differ much from the general population in their responses to HSMAs and autonomy experiences. Notwithstanding, future research is needed to examine the generalizability of the present results to other occupations and other types of organizations.

Areas for future research

The different effects of HSMA use on WHA and HHA for employees with high BMIs are hard to explain. The qualitative results suggest that employees with a high BMI make a clear distinction between their health-related behaviours at work and at home, whereas those with a lower BMI do not. Although we have not found other examples of this type of compartmentalization of health-related behaviour, we believe this finding offers interesting insights into the workings of BMI, health, and lifestyle changes in the work environment, and we would recommend additional high-quality evaluative studies to further explore and explain these mechanisms.

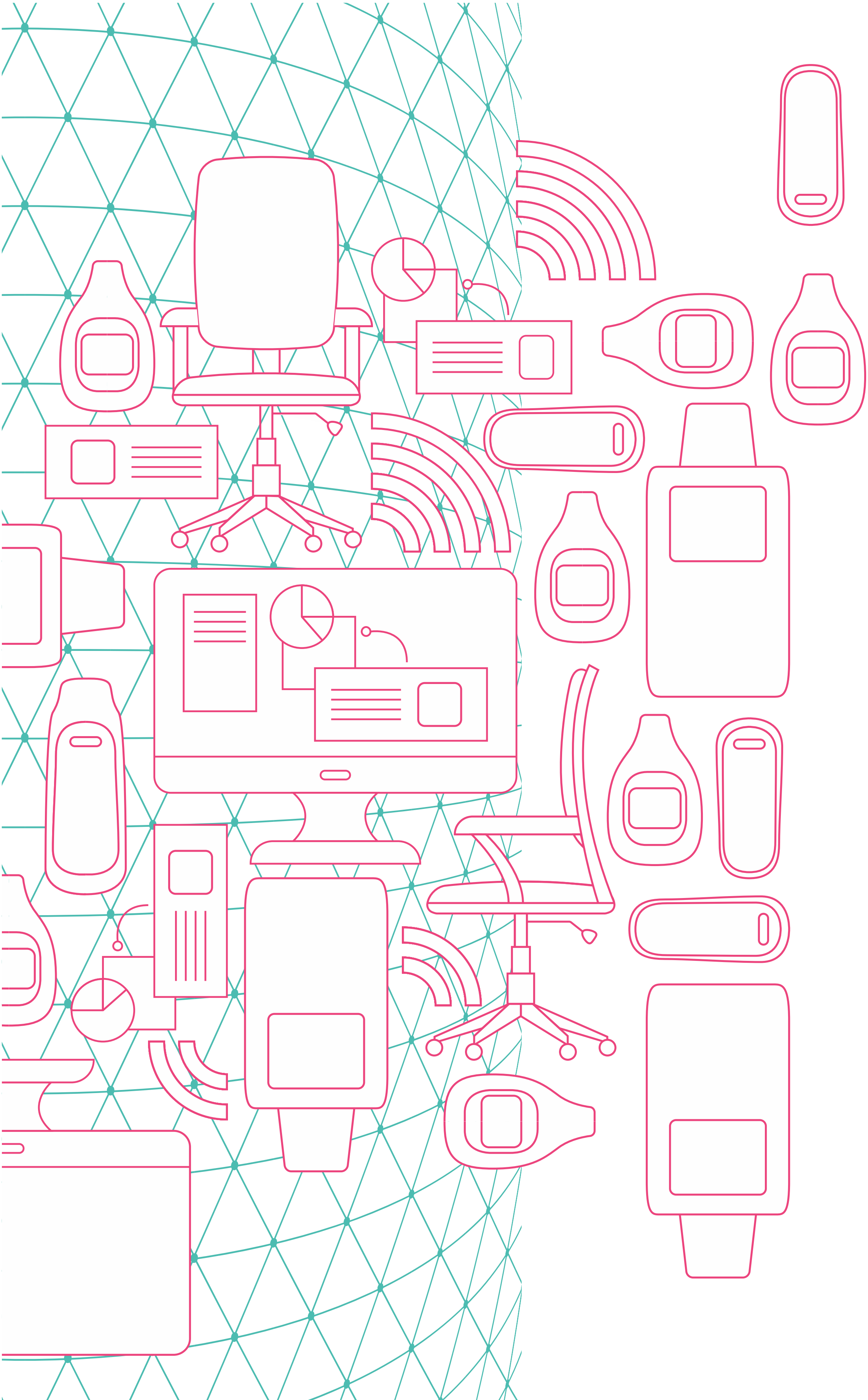
In order to increase the likelihood of success in the use of employer-provided HSMAs, studies should further explore the effects of different types of feedback on employees. Our study shows that adding developmental feedback generates different reactions regarding perceived employee autonomy than when only performance-related feedback is offered. Future experiments might remove performance feedback and only offer developmental feedback, and might use different feedback media such as text messages, personal feedback, or an app with additional information. In this context, attention must be paid to the use of motivational techniques that are currently used in HSMAs (such as challenges with other persons, or publishing your data on social media) and the effect of these motivational techniques on the autonomy and privacy of the users.

Conclusions

This article provides insights into the execution and outcomes of an experimental field study focused on the effects of HSMAs in the workplace. Using both quantitative data and information from a series of interviews, we have extended the understanding of employee autonomy regarding health self-regulation.

Generally, the use of HSMAs is viewed positively on the basis that they will enhance users' autonomy in self-regulating their behaviour.

However, our empirical study shows that this claim underlying the use of HSMAs at work is unjustified: the use of an HSMA does not significantly increase perceived autonomy, and even reduces it for less healthy employees. Nevertheless, the type of feedback usually given by HSMAs is not by definition harmful: the majority of the study population did not experience any negative effects from receiving only performance feedback. Developmental feedback can mitigate some of the negative effects shown among high-BMI participants, although it also transfers some of the negative effects to the home situation. These findings on the mitigation and transfer of the negative effects of HSMAs on the perceived autonomy of employees to self-regulate health-related behaviour show a need for caution by employers, and reveal a need for further research on the responsible implementation of HSMAs in the workplace.



4

Ethics in Design and Implementation of Sensor Technology Applications for Workplace Health Promotion

A Case Study[3]

[3] An adapted version of this chapter has been submitted to an international peer-reviewed journal by C.C. Roossien, A.M. Bonvanie, M. de Jong, & E.LM. Maeckelberghe

Abstract

Responsible research and innovation studies have established a firm framework for addressing ethical issues in designing and using new technologies. However, despite this comprehensive ethics framework there is still a lack of knowledge on how to overcome the divide in ethical approaches to designing and implementing innovative technologies, on how context-specific ways can be used to address critical ethical issues such as privacy and autonomy in responsible research and innovation, and how ethical responsibilities of the different stakeholders can be made manifest and used.

These three problems are a major challenge for the development and implementation of new technologies. The case study of SPRINT@Work describes how these problems were addressed in a multidisciplinary research project, thereby developing a context-sensitive ethics approach. Using this context-specific approach, we could specify and operationalize the critical principles of privacy and autonomy in the SPRINT@Work project, we bridged the gap between design and implementation of the technologies regarding values and their impact on intended and actual use, and make the responsibilities regarding use of the technologies more tangible.

Introduction

Responsible Research and Innovation (RRI) is a field of science that aims to highlight the socio-ethical issues in research and innovation practices (Asveld et al., 2017; B. J. Koops, Oosterlaken, Romijn, Swierstra, & van den Hoven, 2015; van de Poel & Verbeek, 2006; Van den Hoven, Lokhorst, & Van de Poel, 2012). In the past decade, new knowledge and guidelines have been developed that empower researchers to incorporate the researcher's ethical responsibility throughout the innovation process (Stahl, 2013; Stilgoe et al., 2013), focussing on anticipation of (un)foreseen ethical qualms, reflexivity on one's own role, inclusion of a diversity of perspectives, and responsiveness to societal needs.

Research into the design and implementation of work-related sensor technologies intended to promote self-regulation of healthy work behaviour, seems to be surrounded by ethical issues that require Responsible Research. Examples of sensor technologies that are applied in the workplace are accelerometers measuring bending and standing activity (Villumsen, Madeleine, Jørgensen, Holtermann, & Samani, 2017) and wearable sensors for measuring fatigue (Aryal, Ghahramani, & Becerik-Gerber, 2017). Additional intervention technologies, such as activity monitors are increasingly implemented to support workers to alter their behaviour in order to prevent or solve health problems (Huang et al., 2019; Jacobs et al., 2019). Two ethical issues that are critical in the design and implementation of such sensor technologies are privacy (Spook, Koolhaas, Bültmann, & Brouwer, 2019) and employee autonomy (Damman et al., 2015; Leclercq-Vandelannoitte, 2017). The purpose of the present case study is to explore how those critical ethical issues were addressed in a multidisciplinary research and innovation project on sensor technologies for three reasons. First, studies on sensor technologies tend to compartmentalize, by only looking at the development phase of sensor technologies (Aryal et al., 2017; Efstratiou et al., 2007; Motti & Caine, 2014; Saurabh, Rao, Amrutur, & Sundarrajan, 2014) or the implementation phase (Kortuem et al., 2007; Leclercq-

Vandelannoitte, 2017; Sole, Musu, Boi, Giusto, & Popescu, 2013). This is calling for research how an integrative ethics approach can solve this compartmentalization. Secondly, ethical issues in research and innovation projects are often generalized, without acknowledging specific contingencies (i.e., situational concerns) that may play a role in the work context, for instance due to the hierarchical relation between worker/user and employer/provider of the technology (Palm, 2009). Lastly, little is known about how to represent and utilize the ethical responsibilities of the different stakeholders in research and innovation projects (Leclercq-Vandelannoitte, 2017). Therefore, in this case study we want to investigate the distinct ethical responsibilities of developer, employer and employee and how these distinct responsibilities can be effectively addressed. In what follows, we first describe the current literature about RRI, the autonomy and privacy of workers, and the responsibilities regarding the use of health-related sensor and intervention technologies. Secondly, we explore the case of SPRINT@Work (Bonvanie et al., 2020; de Jong et al., 2018; Roossien, Heus, Reneman, & Verkerke, 2020) to show how a context-sensitive ethics can address these issues regarding sensor and intervention technologies in the workplace, and how this approach can help to overcome issues as generalization and compartmentalization and to identify the relevant responsibilities.

Theoretical background

Responsible research and innovation

Responsible research and innovation (RRI) is the interdisciplinary approach that tries to guide the debate about the societal impact of innovations Grunwald (2014). This chapter focuses on responsible design and implementation of technologies aimed at the workplace. Publications in this field struggle with three important problems: compartmentalization, generalisation, and vagueness about responsible use (Efstratiou et al., 2007; Kortuem et al., 2007; Leclercq-Vandelannoitte, 2017; Palm, 2009).

First, there is a compartmentalization of focus problem. Studies until now mostly focus on ethical issues in either the design of new sensor technologies (Aryal et al., 2017; Efstratiou et al., 2007; Motti & Caine, 2014; Saurabh et al., 2014) or the implementation of existing technologies (Kortuem et al., 2007; Leclercq-Vandelannoitte, 2017; Sole et al., 2013). The former one-sidedness does not incorporate questions about the tension between intended and actual use of the design. The latter one-sidedness takes technologies as a given and does not question the inherent values in the design. This situation does not do justice to reality: if design and implementation do not acknowledge each other's ethical concerns and intended values, the final use of the technology will not reflect the intentions of both sides. A broader view on the transition between design and implementation is called for (Jakobsen et al., 2019), in order to facilitate responsiveness between these phases of RRI.

A second problem is generalisation. A single issue is identified as core problem and addressed in a general way without attention for the specific context. There is, for example, extensive attention for privacy as this is seen as one of the major issues in the development and application of new technologies that collect large amounts of data of individuals (Al Ameen, Liu, & Kwak, 2012; Conger, Pratt, & Loch, 2013; Nissenbaum, 2010; Zhu, Gao, & Li, 2016). However, this attention is aimed at technologies that are used in the public space, and there is no specific analysis of privacy issues regarding the use of sensor technologies in the work environment designed for health promotion. Therefore, specific issues that concern privacy in the worker-employer relationship are not addressed. Nor is there any discussion about how privacy is embedded in the broader context of thinking about the effect of sensor technology on autonomy of people, or in this case specifically the autonomy of workers. Research suggests that workers experience (Leclercq-Vandelannoitte, 2017) and fear (Damman et al., 2015) losses of privacy and autonomy due to the use of (preventive) technology in the workplace. This lack of context-specific knowledge on both privacy and autonomy makes that these ethical issues currently are not addressed properly in the development of new technologies for the work environment. Therefore, further research needs to address and contextualize these autonomy and privacy issues in the design and implementation of sensor technology for the workplace.

Third, the topic of responsible use of sensor technologies in the workplace remains vague and unaddressed. Providing transparency about what is responsible use and who is responsible for responsible use are lacking. Leclercq-Vandelannoitte, for example, observes that in the use of ubiquitous technologies in the workplace, workers nor employers recognize who is responsible for, and what is the importance of, responsible use of these technologies (Leclercq-Vandelannoitte, 2017, p. 151). Furthermore, designers do not provide insight into what a responsible use of their design is. Identifying responsible use is notoriously difficult due to the interdependent design-use dynamics (Kiran, 2012). These dynamics entail that design and use continuously impact one another, because a certain function is often the reason for the design of a technology application, but then the adoption of the design can substantially change the function. An example is the innovation of Short Message Service (SMS): the SMS function was designed to enable mobile owners to receive messages about incoming voice mails and bills from the mobile company (Taylor & Vincent, 2006), but then developed into a main function for communication between individuals, thereby posing additional design demands, as well as responsibilities that were not deemed relevant for the original function. These interdependent design-use dynamics make it hard to predict how a technology will be used, and whether it will be used as intended. This, however, should not withhold designers from at least sketching the responsibilities inherent in their designs.

These three problems are a major challenge for the development and implementation of new technologies from an RRI perspective. The main questions are: How to prevent compartmentalization of focus regarding inherent values in the design and its implementation? How to prevent out of context generalisation of ethical issues? How to address and deal with inherent responsibilities of different stakeholders in the design and implementation of sensor technology in the workplace? In the case of SPRINT@Work (see Method), these questions were addressed with a context-sensitive ethics approach, i.e. taking the concrete setting seriously not only to further the application of ethical principles in that context, but also using the setting as a source of moral knowledge (Musschenga, 2005). In this way, we aim to explore the dynamics between developer and user in the design and implementation of sensor technology for the two critical ethical issues of privacy and autonomy, by testing our conceptualisation of the RRI ethical principles in the work environment, and further adjust them where deemed necessary.

Privacy of workers

An important question is what kind of intrusions are acceptable in a work environment? Employers are supposed to guarantee a safe working environment for their employees, and they should be reluctant when it comes to meddling with the private lives or private data of their employees. Interfering with employees' health behaviour, especially when it is connected to lifestyle, is considered to be dubious at best, since it targets individuals (both at work and at home) instead of organizational or collective problems, even if it is aimed at sustainable employability (van Berkel et al., 2014). To ensure that the privacy of the worker is guaranteed, sensor and intervention technologies should comply to several criteria. Firstly, according to the EU General Data Protection Regulation (GDPR), the worker should be able to access all personal data and outcomes of the sensor and intervention technology, without interference of others (GDPR). Secondly, the employer should not have access to the data and outcomes of an individual worker or be able to derive them from data reported at a higher group level (GDPR). Current regulations on data collection and individual privacy limit the possibilities of data sharing (GDPR), as the only legal basis for data processing is formulated in article 6(1)(d) of the GDPR, stating that the data processing has to be necessary to protect vital interests of the subject, so it has to be a life-or-death situation. Legally, data sharing at group level is only allowed if the data does not contain identifiable information, i.e. personal data traceable to individuals (GDPR). When it comes to sensor data that cross the border between work and private life, serious legal questions arise as soon as data privacy and health privacy are at play (Brassart Olsen, 2020). For workplace improvements, however, non-identifiable information on group level should be possible to share (Arora, 2019). Third, the worker should be able to communicate (parts of) the data to relevant actors (such as general practitioners or therapists) without the knowledge of the employer (Arora, 2019).

A needs assessment among workers with physically demanding work in SPRINT@Work identified a demand for sensor and intervention technologies (Spook et al., 2019). However, respondents expressed concerns about what would happen with the personal data retrieved by the sensors, fearing their privacy would be infringed, especially if employers would have access to the data. These apprehensions confirm the findings of other studies (Choi, Hwang, & Lee, 2017; Jacobs et al., 2019). The GDPR, as described above, offers an extensive legal framework protecting the rights and freedoms of the data subjects, including ensuring data minimization, informed consent, good practice via e.g. Data Protection Impact Assessment, and privacy by design (GDPR, 2016; Lodge & Crabtree, 2019; Mulligan, Koopman, & Doty, 2016). Workers, however, also declared that they incidentally would like to share their data with their employer to explore possibilities to improve the working conditions, if they could retain full ownership of the personal data (Spook et al., 2019).

Absolutizing a legal framework endangers narrowing the basic questions of why privacy is an important moral value. Data protection is of major importance to ensure privacy, but data protection does not capture a full understanding of the concept and function of privacy. Numerous scholars have warned against a reductionist conceptualisation of privacy as merely about the protection of the personal sphere and raised questions about possible conditions under which this can be overruled (Barocas et al., 2013; DeCew, 2015; Dwork, 2006; Mulligan et al., 2016; Nissenbaum, 2010; Solove, 2008). They have argued for a broader understanding of privacy as a value that receives its content by reflection on the practice and its context. Whereas a legal framework for privacy by its nature, becomes fixed, privacy as a value is shaped by the situation in which privacy is at stake. Nissenbaum succinctly summarized this as: "*what people care about is not simply restricting the flow of information, but ensuring it flows appropriately*" (Nissenbaum, 2010, p. 2).

Privacy as an essentially contested and malleable concept is dependent on, amongst other things, the context in which privacy is examined, and the social and technological circumstances that apply to that context. As the theoretical debate about privacy goes on, there is a need for a context-sensitive approach. Mulligan et. al have suggested an approach that can be summarized in four questions that need to be answered "*While dilemmas between privacy and publicity, or privacy and surveillance, or privacy and security persist, the question we more often face today concerns the plurality available to us amidst contests over privacy: "Which privacy? For what purpose? With what reason? As exemplified by what?*" (Mulligan et al., 2016, p. 15). This enables researchers and practitioners to pragmatically define the relevant characteristics of the applicable notion of privacy.

Employee Autonomy and Sensor Technology

A major challenge caused by a workforce that will have to continue working into relatively high age is to keep workers fit for work (Kenny, Yardley, Martineau, & Jay, 2008). "*Sustainable employability means that, throughout their working lives, workers can achieve tangible opportunities in the form of a set of capabilities. They also enjoy the necessary conditions that allow them to make a valuable contribution through their work, now and in the future, while safeguarding their health and welfare. This requires, on the one hand, a work context that facilitates this for them and on the other,* *the attitude and motivation to exploit these opportunities*" (van der Klink et al., 2016, p. 74). Maintaining and supporting the individual workability of workers largely depends on the ability of employees to adapt their work behaviour to changing circumstances. Employee autonomy in self-regulation of work behaviour is widely claimed to be crucial in this adaptation process (Ryan & Deci, 2006). Organizations are therefore introducing more and more smart devices on the work floor with which employees can regulate their own tasks and associated work behaviour, on the assumption that self-management devices ensure the autonomy employees need for their self-regulation.

Technological interventions can assist to maintain individual workability, for instance by developing technology that addresses the needs of aging workers in an objective manner , such as interventions to increase physical activity or ergonomically adapt workplaces (Truxillo, Cadiz, & Hammer, 2015), and workplace health interventions that create balance between workers' capacity and workload (Kenny et al., 2008). Sensor technologies, such as activity monitors or heartrate monitors, can monitor workload in an objective manner. Additional intervention technologies, such as smart chairs (Goossens et al., 2012; Roossien et al., 2017)are aimed at supporting workers to alter their behaviour in order to prevent or solve health problems effectively.

Workers are willing to adopt sensor technologies when they perceive them as useful (Choi et al., 2017; Jacobs et al., 2019), but their willingness also depends on how their concerns regarding data security and misuse of technologies are met (Jacobs et al., 2019). From a philosophical point of view, autonomy is a notoriously complex concept and caution is necessary for narrowing the notion of autonomy to an idea of self-determination. Autonomy is a normative idea that gives direction to actions that are governed by a responsible commitment to the norms with which one binds oneself . It can be about one's own willed ideals, but also a commitment to the norms and standards people encounter because of where they are, e.g. the work place, and take as their own normative standards (Kukla, 2005).

This concept of autonomy, coined by Kukla as conscientious autonomy, covers both the high moral values that give direction to peoples' lives, as well as those small practical commitments that give shape to ordinary lives. For instance, if someone values being healthy, the practical commitments could be to walk to work instead of taking the car, or taking the stairs instead of the elevator.

Responsibility in the work environment

The ultimate responsibility for safeguarding the working environment lies with the employers. Employers are responsible for the workability of their workers and need to actively prevent harm and accidents (Arbeidsomstandighedenwet, 1999; Palm, 2009). In the case of workers with hard physical labour, the employer is obligated to protect the workers' safety during work by conducting a periodic occupational health examination and monitor the safety of employees (Arbeidsomstandighedenwet, 1999). Despite the employers' limited access to the outcomes of this regular health check, this examination is a manner to protect the workers and take responsibility, because the occupational physician can have access to this data and warn the worker if something is wrong. The occupational physician is bound to confidentiality due to the nature of the profession. To protect the worker while using sensor and intervention technology in the work environment, all stakeholders need to take their responsibility for a proper use of those technologies (Johnson & Powers, 2005). Taking this responsibility regarding health in the workplace is considered important, but employers may have different views on this responsibility than workers (van Berkel et al., 2014). The responsibility of the employer to prevent harm in the workplace is a responsibility that is acknowledged by both worker and employer, but the responsibility to stay healthy and fit for the job is considered by many employers to be the worker's responsibility while workers feel that they are autonomous in how they want to live their lives (van Berkel et al., 2014). These disagreeing views see health as either a safety discourse, or a lifestyle discourse (Allender, Colquhoun, & Kelly, 2006), and the responsibilities of worker and employer regarding both these discourses need to be examined with the context-specific ethics in mind, in order to prevent ambivalence in the worker-employer relationship (van Berkel et al., 2014).

Method

This study is an instrumental case study description (Crowe et al., 2011) of SPRINT@Work, a project in which the aim was to develop sensor and intervention technologies for a sustainable workforce and to do so while including the perspective of implementation during design and vice versa. The case of SPRINT@Work addresses the difficulties in a real-life research setting of 'doing ethics'.

Focus of this research

The main ethical challenge in the project was how to achieve responsible development and implementation of sensor technologies aimed to enhance healthy behaviours in the workplace. Specifically, this challenge included the three problems of compartmentalization, generalisation, and vagueness about responsibilities and required an interdisciplinary research team to be addressed. First, we will describe the case and the ethical issue of workers' privacy and autonomy in this specific setting. Secondly, a context-specific conceptualisation of privacy and autonomy was required and developed in the project to show how and where privacy and autonomy questions in the health at work context differed from the questions posed in the general discussion on these values. These new conceptualisations are described and provide useful insights into how the relationship between worker and employer alters the relevance of privacy and autonomy, and how this is reflected in concerns about technologies in the workplace. Finally, the values of these conceptualizations will be discussed in the context of the three major problems - compartmentalization, generalisation, and vagueness about responsibilities - for the development and implementation of new technologies, and we will conclude with the lessons learned.

Setting

Project description

The project that is described in this paper is SPRINT@Work, an EU-funded interdisciplinary project, aimed at developing and evaluating sensor and intervention technologies that contribute to keeping the aging worker healthy and effectively employable (Bonvanie et al., 2020; de Jong et al., 2018; Roossien et al., 2020, 2017). The project team consisted of researchers and engineers from a variety of disciplines (cognitive neuroscience, information management, biomedical engineering and rehabilitation medicine, community and occupational medicine). Cognitive neuroscience and information management were both represented by one professor and one PhD candidate, biomedical engineering and rehabilitation medicine was represented by two professors and one PhD candidate, and community and occupational medicine was represented by two professors, one post-doctoral researcher and one PhD candidate. The four PhD candidates acted as executing researchers. By initiating both individual studies and collaborative research, the researchers aimed to develop innovative sensors and interventions that could make cognitive and physical performance objectively measurable, and that contribute to the employees' awareness of their own behaviour and its consequences for their health and employability.

Aim and data collection

The overall aim of SPRINT@Work was to provide individual workers with feedback, health self-management applications (HSMAs), to improve their mental and physical condition in order to keep them healthy at work and consequently promote long-lasting social participation. The team soon encountered two major overall questions: '*what kind of intrusion in the lives of employees is acceptable in a work environment?*' and '*what implications do sensor technologies have on the autonomous self-regulation of behaviour by workers?'*. The first question regards the privacy of workers, the second concerns employee autonomy. These two questions exemplify how design and implementation cannot be compartmentalized and generalized. Both questions also point at the need for a contextualized approach. The work environment is a setting that has its own rules and regulations and thus needs further specification about what privacy entails in this context. Finally, these questions also ask for reflection on *who is responsible for adequate responses to the ethical questions in both the design and the implementation phase*.

In several intervision sessions between the executing researchers, and later on the whole project team, the questions were addressed (a) whether the legal framework of privacy identifies sufficiently what is at stake in the specific context of the development and implementation of sensor technologies for sustainable employability, and (b) whether self-management devices aimed to promote self-regulation can be of assistance in enabling the autonomy of workers. The team developed a conceptual framework that contextualises data protection and privacy issues and the notion of employee autonomy into a framework of context-sensitive ethics that is helpful for both designing and implementing sensor technologies. This framework functioned as a benchmark for the researchers in SPRINT@Work, so they could continuously check whether their proposed design was in line with the context-specific ethics. During the project, this normative framework was continuously adapted using insights from the executed studies.

Context characteristics

In SPRINT@Work, the employer decided whether a study with HSMAs could be executed within the company. Workers then could voluntarily participate in the field studies where sensor and intervention technologies were used. This was articulated since the researchers adhere to the declaration of Helsinki on research involving human subjects (World Medical Association, 2013), stating that participants should voluntarily give an informed consent. This voluntary participation is similar to a non-research implementation of an HSMA in the work environment: employers are not allowed to oblige workers to use HSMAs, nor can they ask for data if the worker voluntarily uses an HSMA (Dutch Data Protection Agency, 2016). In the work environment however, the hierarchical relationship between worker and employer can make that workers do not feel as if they have this freedom. The workers' dependence on the employer for job security, career opportunities, and work pleasure makes the work environment a context that require a context-specific approach to addressing ethical issues that are inherently associated with de design and use of HSMAs.

Results

In the results section, we provide two examples of ethical issues that we have encountered during SPRINT@Work. With these examples, we show how protecting the privacy and autonomy of workers cannot be seen as stand-alone issues, but that there is an interplay between these values, the work context, and the responsibilities of worker and employer.

Privacy in SPRINT@Work

The case of firefighters

The regulations on privacy provided a framework but also provoked the question in SPRINT@Work whether legal requirements and regulations identify sufficiently what is at stake in the specific context of the development and implementation of sensor-technologies for sustainable employability. More specific, *what kind of intrusion in the lives of employees is acceptable in a work environment?*'

In one of the SPRINT@Work studies, some workers declared that they would like to share their data with their employer to explore possibilities to improve the working conditions, while retaining full ownership of the personal data (Spook et al., 2019). Specifically, it became clear that firefighters would strongly benefit from sharing personal data about health measures such as bodily temperature acquired from wearable sensor and intervention technologies when entering a fire. The firefighters themselves are not allowed to be distracted by immediate feedback about the obtained data, because they need to focus on the situation at hand. They neither have time nor opportunity to monitor the feedback and data from their own sensors (Roossien et al., 2020). However, if the captains could monitor the current body temperature of their workers on site using the real-time information from wearable sensor and intervention technologies, decline of the health and/or safety of the workers could be prevented. Legally, an employer cannot ask permission to access this personal data of the worker (GDPR, 2016), despite it is in the workers' advantage and safety. This points at an ambiguity in the data protection law regarding the protection of workers' privacy opposed to the responsibility of the employer to safeguard their health and safety: employers cannot, under any circumstance, use personal sensor data for protection of health and safety of the employee, even though they have the responsibility for protecting the workers from harm in the work environment. Ensuing question for the research team was to explore more in depth how privacy can be conceptualized in the specific context of sensor technologies at the work place, despite this ambiguity.

Context-specific approach of privacy

Following the pragmatic approach of Mulligan, we analysed this case of data sharing of firefighters. What would privacy provide the protected firefighters in this case? Control over personal information, i.e. the core temperature and heartrate of the firefighter, is the key target for protection. From the perspective of the GDPR as we explained earlier, this type of data can only be accessed under very strict circumstances and they must be handled by a health professional who is bound by professional confidentiality. In case of a fire no such health professional is available. The harm that supposedly would be prevented by privacy – access to personal information – might be superseded by prevention of a bigger harm: the information about the fire worker's temperature can prevent the fire worker from overexposure to heat. This example is illustrative of how information acquires ethical and normative significance not because it is about certain values, i.e. privacy, but because the context makes that it can be used for actions, in this case possible prevention of overheating. It is not about what information one has but about what one can do with that information. Manson et al call this an agency-based model of informing and communicating (Manson & ONeill, 2007). It is necessary to analyse what exactly the agent, in this case the firefighters' captain can do with the private information obtained. If overheating can be prevented, firefighters might want to have the option to share their sensor information with their captain, even though the captain is not bound by confidentiality as a health professional. The firefighters' permission to the captain to access this information is in this case based on the specific agency the captain has: protecting the firefighters from overheating. Another protection of the privacy of the firefighters could be that their captain should be bound by the confidentiality of his own profession.

The answer to the pragmatic questions Mulligan et al formulated 'Which privacy? For what purpose? With what reason? As exemplified by what?' is that in the case of the firefighters the privacy at stake is the ownership of personal data obtained by sensor technologies. The purpose of the privacy is to give the firefighters control over their own data, not to prevent the employer to use these personal data but also to give the firefighters the opportunity to share the data only in circumstances that they deem acceptable. This is exemplified by the agency-based model: in the ideal situation, the firefighter can opt to share data to protect himself from health hazards with a person, in this case the captain, who can act on these data for the specific purpose of preventing health hazards and who cannot use these data for any other purpose. The example of the firefighters shows that a narrow interpretation of privacy might result in diminishing their safety: if privacy is unidimensional, and the only choice would be whether or not to share the data with the employer, either the firefighter would have to accept greater risks during execution of the job because the data would be hidden (as it is in the GDPR), or the employer would have full access to all data, which could lead to misuse of data for other purposes.

Responsibilities of stakeholders

If we look at the example of the firefighters, we see that the experienced responsibility for health of the workers is taken seriously by the employer. The GDPR, however, prevents the employer from using personal data to protect firefighters from overheating in an emergency situation. In this case, the workers themselves cannot do anything: letting themselves get distracted from their task could cause immediate risks to themselves or their colleagues, so it is impossible to self-monitor their current health parameters. This gap between the desired situation and the current regulations is still frustrating for the fire department, because the captains wish to protect their firefighters, but the law prevents that from happening.

Autonomy of workers in SPRINT@Work

Case of health care workers

The use of sensor technologies to assist in sustainable employability seems to hinge on offering workers objective feedback and interventions that give them the opportunity to self-regulate their behaviour. In the context of SPRINT@Work, this initiated the question whether developing and implementing sensor technologies aimed at promoting self-regulation is a sufficient condition for ensuring the autonomy of workers?

Illustrative for the ideal of conscientiousness at stake in being autonomous, is a participant who reported to have overweight and being in bad shape and who was eager to partake in an experiment with an activity tracker. The employee was committed to improving her condition: "*I value a healthy lifestyle. I have difficulties keeping up with that for all sorts of reasons and this is an opportunity for me to get some non-intrusive and time-saving support. I also would like to be an example for the patients who visit here. They need people like me as role models, people who struggle but make an effort to improve their health*". She refers to what she values, which is personal health. Receiving an activity tracker in itself does not give autonomy, but due to the HSMA, she can autonomously commit to her own value of becoming healthy. This value, however, receives a different meaning in her work context, a health care organization, where she also wants to set an example for others. She wants to show that increasing your daily exercise, by walking more and taking the stairs, is an important commitment to improving health. For this employee, in the work context, in addition to achieving a healthy life style, the moral value of being an example plays a role. She translates both the personal value and the value resulting from her position at work into the daily practical commitment of taking more steps. The use of the HSMA helps her to achieve her ideal.

The commitment of the employee, however, was not only shaped by a momentous decision to accept the activity tracker. It was confirmed (by making small progress in walking more steps) but also disaffirmed over time. The employee felt disaffirmation when a colleague from higher management rebuked her when taking the elevator, saying that was not why she was given the activity-tracker. It made her question whether the entire experiment was about her own improvement in health and realizing her own values or was it about control and reducing costs for the organization?

Context-specific approach of autonomy

This example, even though at first sight it might seem about an individual experience, illustrates how personal autonomy, as seen in the small every-day practical commitments, can easily be threatened in the context of a work environment if personal values are not acknowledged. Giving employees technologies, be it a health device or sensor technologies, is not only giving them a means for self-regulation. The technology is embedded in a context that can promote or disavow the responsible commitment to the norms with which one binds oneself. This calls for reflection on how the mere introduction of a technology can affect the autonomy of employees, and how the context of the implemented technology influences the perceptions regarding autonomy of the worker.

Employee autonomy as a prerequisite for health self-regulation was empirically investigated in one of the studies of SPRINT@Work. It examined activity trackers, that give feedback information on health-related behaviours to employees. The example of activity trackers is of interest because it is used as a HSMA that enables employees to self-regulate a healthy lifestyle (Bravata et al., 2007; Mattila et al., 2013). The basic assumption was that the use of HSMA provides employees with autonomy, i.e., feedback information and the room to decide what to do with this information, to self-regulate their health-related behaviour. This autonomy assumption was empirically investigated. Findings revealed that the use of an HSMA did not significantly increase perceived autonomy, and may have even reduced it under certain conditions, especially for less healthy employees (Bonvanie et al., 2020). Additional to this, workers in this experimental study that had already used an HSMA themselves before they started to wear one that was provided by the employer, experienced the same decrease in autonomy as workers who used an HSMA for the first time. This shows that the activity tracker itself does not limit the autonomy of workers: it is the specific context of the work environment, with the hierarchical relationship between worker and employer, that makes that the perceived autonomy decreases.

Kukla coined the idea of conscientious autonomy, that autonomy can be about commitment to one's own willed ideals, but also a commitment to the norms and standards people encounter because of where they are, and take those as their own normative standards (Kukla, 2005). If we work with that idea, we can put a finger on why the autonomy of certain workers declines when they use an HSMA. The normative standards of the activity tracker that were applied were externally imposed: the goal was to walk 10.000 steps per day, and take 10 flights of stairs. Some of the participants agreed with this goal and internalized the normative standard; Others however did not, and perceived the feedback as pressure that forced them to still aim for 10.000 steps. The employer at the same time also showed they valued healthy workers: before the experiment there were several activities, such as a week of taking the stairs and a healthy cafeteria project, which showed what the values and norms of the employer were. Participants that share the value of healthy living of the employer, but have other ideas about what healthy living means in daily life, feel as if the HSMA forces them to commit to someone else's normative standards. Therefore, there is a need for caution by employers about how HSMA can be responsibly implemented in the workplace.

Responsibilities of stakeholders

In the case of health care workers, we see that participation in the study caused the employer to reconsider the workplace health promotion policies. Their workplace health promotion program was mainly aimed at physical health, using interventions such as providing employees with an activity tracker, a smoke-free property, a week of taking the stairs, and a healthy cafeteria. Seeing the impact this had on some of the employees with worse health, they realized that this approach may work counterproductive. Therefore, they decided to alter their strategy and include a more diverse group of workers in the decision-making process regarding new technologies. Thereby, they hope to facilitate a healthy workplace and lifestyle for all workers.

Discussion and conclusion

Three unmet problems were identified in the literature about responsible development of sensor technologies that are used in the workplace: How to prevent compartmentalization of focus regarding inherent values in the HSMA design and its implementation? How to prevent out of context generalisation? How to make inherent responsibilities in the design and its implementation explicit? In SPRINT@Work, these challenges were met in several meetings aimed at identifying the core ethical questions. The two major overall questions, as explained above, were '*what kind of intrusion in the lives of employees is acceptable in a work environment?*' and '*what implications do sensor technologies have on the autonomous self-regulation of behaviour by workers?*'. We will now explain how using a context-specific approach to answer these core ethical questions contributed to answering the three unmet problems.

Compartmentalization of focus

The identification in the project SPRINT@Work of two core ethical problems, resulting from reflection on both design and field experiments, made that the researchers needed to reflect on how they interpreted and used values as privacy and autonomy. The question about '*what kind of intrusion in the lives of employees is acceptable in a work environment?*' asked for clarification of the concept of privacy. The concept was discussed in the legal context, focussing on protection of the personal sphere, and from the perspective of privacy as a moral value. The analysis of privacy as a moral value resulted in the description of an agency-based concept of privacy. The agency-based concept of privacy frames the problem in such a way that design and implementation phase need to be seen as a continuum. The need to protect data from unwanted intrusion from the employer while making the data available for monitoring the health of the employee has two consequences. On the one hand, the design should incorporate all conditions set by an agency-based privacy. The design should include the possibility that employees can share data with designated persons. In the example of SPRINT@Work, the firefighter indicates that the captain may view the data in the context of fire-fighting. On the other hand, agency-based privacy indicates that where the technology is implemented, the designated persons need to have the possibility, and power to act on what is requested on predefined terms. In the example this means that the captain is equipped with the power to use the data, but that is only possible in the context of the fire extinguishing work, with explicit consent of the individual firefighter, and when confidentiality is guaranteed.

Prevention of out-of-context generalization

A responsible decision to provide workers with smart devices that can help them sustain their workability requires careful analysis of the values at stake in the context of the specific workplace and individual worker. The examples provided in SPRINT@Work showed that generalized ideas of privacy as protection from unwanted intrusion and autonomy as self-regulation were insufficient because these generalized ideas did not answer contextualized questions specific for the work environment. Concepts that guide reflection towards identifying what is at stake in a specific context are more helpful. Both the agency-based model of privacy and the notion of conscientious autonomy set up a framework of specific description of what is at stake in a specific context. The examples of the firefighters and of the healthcare professionals using an HSMA are illustrations of how these concepts help identifying bottlenecks, implicit norms, and what to act on. These examples go beyond merely being examples. They also were a source of moral knowledge as the experiences in the field informed the researchers about what users value. The dynamics between developer, employer, and user were used by testing our conceptualisation of ethical principles in the work environment, and further adjust them where deemed necessary.

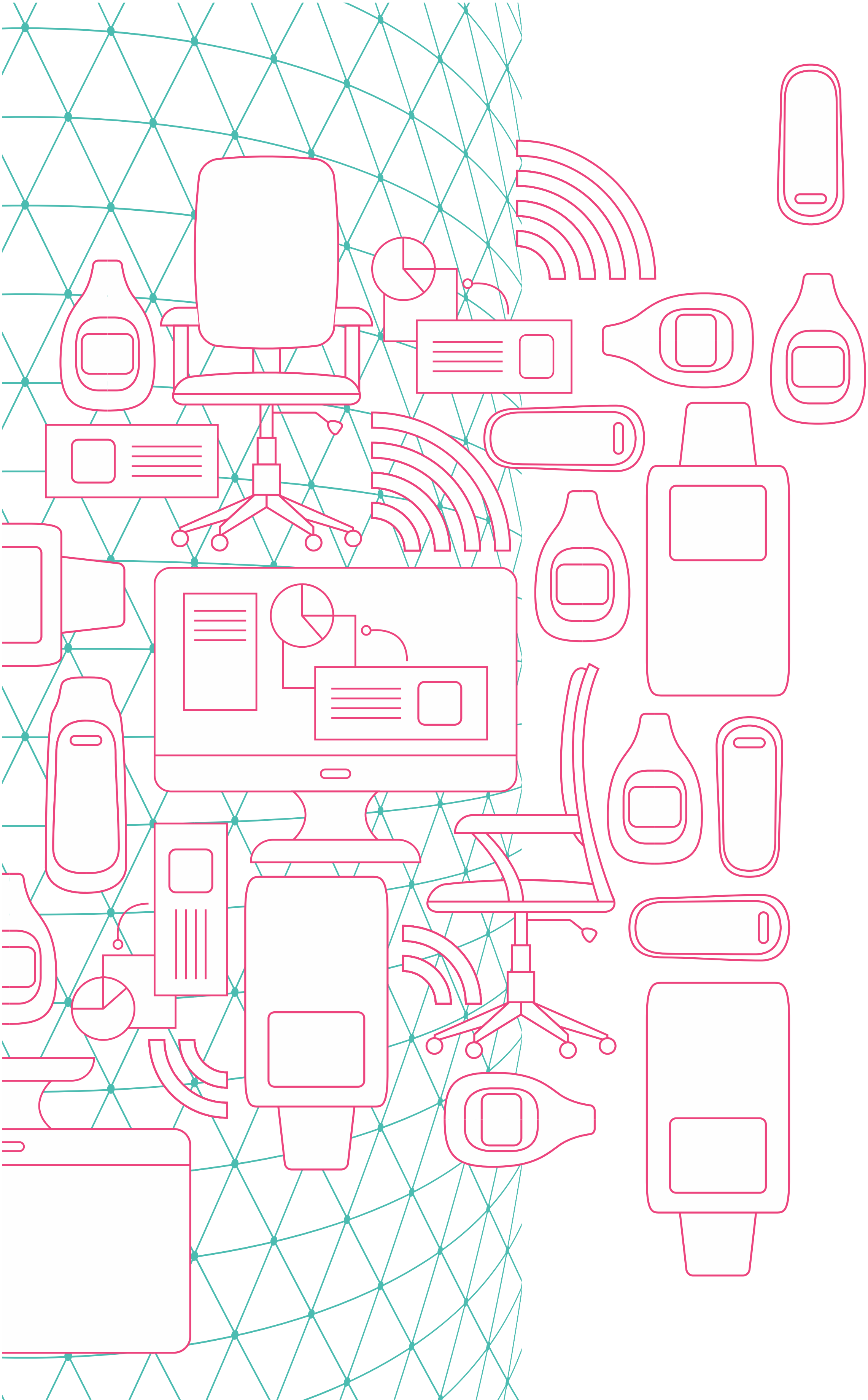
Making implied responsibilities explicit

The two core ethical concepts of privacy and autonomy are used to contribute to identifying responsibilities. Both the example of firefighters and healthcare professionals using an HSMA demonstrate that designers and researchers of such technologies need to reflect explicitly on which ethical principles are critical to what they design and what the implications of these principles are for the implementation and use of the design. A commitment to ensuring privacy as described in the context of SPRINT@Work gives the team the responsibility to design an agency-based data handling.

The reflection on this responsibility of worker and employer is not a one-time action. As stated before, differences in interpretations of responsibilities can cause large problems between worker and employer (van Berkel et al., 2014) and the use of a technology often alters the original function (Kiran, 2012). When using new technologies, workers and employers should therefore, together with the designers, discuss the responsibilities and intended actions they identify when using the technology. This also entails a continuous reflection of the employer on whether or not the conscientious autonomy of the worker is improved: the example of the healthcare workers using an HSMA indicated that with sensor technologies, workers might be enabled to take their responsibility to target work-related health parameters within the workplace. In general, however, this is most effective when workers feel autonomous in the self-regulation of their health-relevant actions. Due to the reflection of the employer on the decrease of autonomy felt by some employees when they were provided with activity tracker, and the actions taken in order to alter the workplace health promotion program, this taking of responsibility is enabled. The employers ought to be alert for non-intended effects of sensor technologies and should ensure an environment that facilitate workers to take their responsibility. Especially if there are shared values between worker and employer, such as health, HSMAs that support the workers' personal goals could increase the conscientious autonomy of the workers, thereby improving their self-regulation of healthy behaviour.

Final remarks

In the project SPRINT@Work, we learned that focusing on a contextual conceptualization of the core ethical principles identified during the project helps to avoid compartmentalization, generalization and neglect of identifying responsibilities. By using the design-use dynamics and context-specific ethics in a reiterating process of development and small-scale implementation, we have overcome these three large challenges for responsible research and innovation of sensor and intervention technology for a sustainable workforce. This method of developing a context-specific ethics makes it possible to look at the particular implications of a certain value for a specific situation, and we feel this can be applied in many real-life development and implementation projects. We have shown how a context-specific ethics can improve worker conscientious autonomy, how the balance between privacy and health can be improved by using an agency-based approach, and how focusing on values in their context can improve the responsible use of technologies. Thereby, we add an interesting view on the responsible research and innovation of health-related technologies to be used in the workplace, and we give employers more hands-on advice on how to responsibly implement these technologies.



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General Discussion and Conclusions

The need to create a workforce that is healthy and remains healthy has increased the demand for sensor technologies or health self-management applications (HSMAs) that stimulate workers to self-regulate their health-related behaviour in the workplace. The development and use of HSMAs however are not as straightforward as it seems: interventions such as HSMAs seem to be less effective in the work environment than they are in the general population, causing questions about how the feedback on health behaviour provided by HSMAs can be optimized to increase effectivity. Also, the use of HSMAs can lead to a decrease in users' perceived autonomy (Owens & Cribb, 2017), raising questions on how to responsibly develop and use HSMAs.

The the central theme of this research was to study how HSMAs can responsibly and effectively be developed and used to stimulate workers to adopt more healthy behaviours. In the previous chapters, we have investigated the impact of HSMAs on office workers' prolonged sitting behaviour and mental fatigue (Chapter 2) and on hospital workers' perceived autonomy to self-regulate their health behaviour (Chapter 3). Moreover, we have examined how developers, employers, and users can address the ethical issues of privacy and autonomy in the development and use of HSMAs (Chapter 4). In this chapter, a summary of the main research findings is presented. Subsequently, we discuss the scientific and practical implications, the limitations of this research, and potential areas for future research. We end with the main conclusions of this research.

Main Findings

Our main findings answer the questions that we presented in the introduction of this thesis:

- How do HSMAs that provide both real-time and actionable feedback impact workers' health-related behaviour?
- Does the use of HSMAs in the workplace promote workers' perceptions of autonomy in self-regulating their health-related behaviour?

- How can HSMAs for the work environment be responsibly developed and implemented, with attention for inherent ethical values as privacy and autonomy, and responsibilities of the relevant stakeholders?

Effects of real-time feedback on office workers' sitting behaviour and mental fatigue

Chapter 2 investigates the effects of real-time actionable feedback on workers' sitting behaviour and typing behaviour. In this experimental field study, we have collected data from participants that used a smart chair registering their sitting behaviour and a typing tool to monitor their mental fatigue in the work environment for a period of six weeks. During this period, data was collected on the duration of sitting behaviour, and the continued duration of typing after the moment where workers became fatigued. Workers were able to self-control the frequency at which they received feedback messages on their behaviour. This study has provided three main findings.

Firstly, this chapter shows that real-time actionable feedback messages have a short-term effect on typing behaviour: workers take a break from typing quicker if they receive a feedback message about their typing behaviour and emerging mental fatigue than if they do not receive a feedback message. However, over the course of time, we did not find that they quit typing earlier after they became fatigued. So, a learning effect across time was not found. Secondly, we show that real-time actionable feedback messages influence workers' sitting behaviour only in the long-term: workers who received a real-time actionable feedback message when they sat for more than 55 minutes did not stand up quicker than those who did not receive a feedback message, but they do alter their sitting duration over time, suggesting that over the course of the experiment they learn to sit for shorter periods of time. Third and last, we find that self-controlled feedback frequency does not influence the effect of feedback on typing or sitting behaviour. Hereby, we show that HSMAs can add to the improvement of sitting and typing behaviour of workers, but that the type of work and the timespan influence the effects.

HSMAs in the work environment: the effects on employee autonomy

Chapter 3 studies the effects of workers' use of HSMAs in the work environment on their perceived autonomy in self-regulating their health-related behaviour. In an experimental field study, healthcare workers used an HSMA, the Fitbit One activity tracker. They received performance feedback, stating the number of steps and stairs taken per day, and half of the participants received supplementary developmental feedback. We have collected questionnaire data from the study population (N=102) in order to see whether workers' perception of autonomy changed due to using the HSMA. Perceived autonomy was examined for both the workplace (i.e. the autonomy to self-regulate health-related behaviour at work) and at home (i.e. the autonomy to self-regulate health-related behaviour in the private time). Based on the analysis of the questionnaire data and the differences we found in the results between workers with high and low BMI, we decided to conduct a series of additional interviews with a selection of participants in this study for a more in-depth exploration of the differences found (N=11). This multi-method has led to the following findings.

Our first finding is that the use of HSMAs has a negative effect on workers' perceived autonomy to self-regulate health behaviour at home (i.e., home health autonomy (HHA)). Secondly, we find that the supplementary developmental feedback information from the Fitbit only marginally enhances workers' perceived autonomy to self-regulate health behaviour at work (i.e., work health autonomy (WHA)); receiving just performance feedback generates no effect. Thirdly, and most importantly, we find that using an HSMA negatively affects both WHA and HHA for workers with poorer health status (using BMI as proxy). That is, employees with a higher BMI suffer a greater loss of perceived autonomy in self-managing their health. The addition of developmental feedback mitigates this effect for WHA, but decreases the HHA even stronger. So, for employees with higher BMI, the supplementary developmental feedback made that the loss of perceived autonomy in self-regulating health behaviour in the workplace reduces, but at the same time this developmental feedback increases the perceived loss of autonomy in the private time. In contrast, employees with a lower BMI who received only performance feedback, suffer less decline in WHA and report an increase in HHA due to using an HSMA. This means that employees with low BMI seem to experience a smaller loss of autonomy in the workplace, and an increase of autonomy at home, when they only receive the performance feedback.

The additional interviews confirmed the findings that employees with higher BMI experienced less autonomy in self-regulating their health behaviour both at work and at home. The interviews showed that employees with low BMI often see norms from the HSMA (i.e. taking 10.000 steps per day) as a guideline that is optional, but pleasant to achieve, whereas employees with high BMI have strong negative emotions every time they fail to meet the standards. Also, employees with low BMI often seamlessly apply their health goals to both the work and home environment, whereas employees with high BMI more strictly divide these two environments. This makes that if high-BMI employees did not reach their activity goal during working hours, they feel additional pressure to exercise more during their private time, which results in a decrease of perceived autonomy. Lastly, we find that limitations that are present in the work environment, such as a desk-bound job, or being on call during working hours, become more obvious hindrances to employees with higher BMI. By using the HSMA, they wish to alter their behaviour, but then become aware of the limitations in their surroundings. Employees with lower BMI on the other hand do not report these limitations, and find more other ways to alter their behaviour during working hours.

Ethics in design and implementation of sensor technology applications for workplace health promotion: a case study

Chapter 4 uses the multidisciplinary research project SPRINT@Work as a case study to describe how HSMAs for the work environment can responsibly be developed and implemented. Three problems are identified in the existing Responsible Research and Innovation literature:

- Regarding compartmentalization: there is a lack of knowledge on how to overcome the divide between development and implementation with regard to ethical issues and values at stake
- Regarding generalization: there is a lack of knowledge on how context specific ways can be used to address critical ethical issues such as privacy and autonomy
- Regarding responsibilities: there is a lack of knowledge on how the responsibilities regarding development and use of different stakeholders can be identified and taken.

We provide insight in how these three problems can be addressed and overcome by developing a context-sensitive ethics. Specifically, by continuously reflecting on how the values of privacy and autonomy appeared for the different stakeholders (i.e., developers, employers, users) in the individual SPRINT@Work studies, we have developed a context-sensitive perspective enabling us to contextualize the identified ethical issues in both the development and implementation of sensor and intervention technologies for the work environment. Doing so, we identified two main questions, related to the issues of privacy and autonomy: what kind of intrusion in the lives of employees is acceptable in a work environment? and what implications do HSMAs have on the autonomous self-regulation of behaviour by workers? In answering these questions, we show that the current legal framework for privacy of workers is limiting the opportunities of employers to take full responsibility for the health of workers. This could be solved by using an agency-based approach, in which specific agents (i.e. a firefighter captain) has the power to use personal data of the workers for specific causes (i.e. preventing overheating of the worker). Also, we show that the autonomy of workers using HSMAs is affected, because workers are not by default enabled to uphold their own norms and values but perceive the norms (e.g., 10.000 steps a day) inherent to the design as pressing. We have shown how a context-specific ethics can improve worker conscientious autonomy by giving workers the autonomy to act in line with their own values, how the balance between privacy and health can be improved by using an agency-based approach, and how explicating the privacy and autonomy of workers in the work environment can improve the responsible use of technologies. Thereby, we add an interesting context-sensitive perspective on responsible research and innovation of health-related technologies to be used in the workplace, and we give employers more hands-on advice on how to responsibly implement these technologies.

Scientific contributions and implications

This research provided a multidisciplinary approach to examining how the development and use of HSMAs may improve health-related behaviour of workers. Doing so, we made several contributions to the field of workplace health promotion, and the field of responsible research and innovation.

Contributions to the Field of Workplace Health Promotion

Feedback interventions and self-determination in the workplace

The use of feedback interventions for influencing work performance in the workplace is a well-studied field (Kluger & DeNisi, 1996). Providing feedback via HSMAs to enable employees to self-regulate their health-related behaviour, however, has received much less attention (Malik et al., 2014). Also, the way how these technologies potentially improve autonomy and drive self-regulation is still underexposed. In this research, we add to the field of workplace health promotion by using Feedback Intervention Theory (FIT) and Self-Determination Theory (SDT) to examine how HSMAs can facilitate workers in self-regulating their health behaviour in the workplace.

Our research shows that real-time actionable feedback, in comparison to non-actionable real-time feedback (Roossien et al., 2017), did influence workers in their break-taking behaviour to recover from mental fatigue but hardly in their prolonged sitting behaviour. These different effects suggest that participants give different meanings to real-time actionable feedback provided on different types of health behaviours. Workers are usually rather well aware of how long they sit on a chair, but have more difficulty in detecting the first signs of mental fatigue they develop during typing on a computer (Zhang et al., 2011). Therefore, feedback information on exceeding the standards for healthy sitting behaviour is usually not completely new and surprising to the worker, while feedback information on their emerging mental fatigue during typing often comes as a surprise because they do not yet feel really tired. Workers are likely to spend more attention to the surprising information on their mental fatigue than the expected information on their sitting behaviour, thereby enhancing the likelihood of taking a break from typing to recover from their mental fatigue. This is in line with the idea of West (West, 2000) that new feedback information tends to be better processed and have a greater chance of leading to alteration of behaviour. The latter explanation could be related to the different effect-horizons of the different feedback messages for sitting behaviour and mental fatigue: acting upon a feedback message regarding typing behaviour does not only affect long term health but also the immediate typing performance of the worker, whereas the feedback on sitting behaviour only aims at long-term effects. This explanation is complementary to findings of Lorig and Holman (2003). They state that main drivers of success in health self-management are goal-setting and action planning, which are very hard for behaviour that only affects the health of workers in the long term, and that self-management works best when it is problem-based, which is not the case for sitting behaviour, because the problems caused by prolonged sitting reveal themselves in the long term.

When looking at the effect of performance vs developmental feedback on the autonomy of users, we see that the perceived autonomy is not automatically improved by providing developmental feedback. This contradicts the literature suggesting that the goal-setting nature and future-oriented nature of developmental feedback should have a positive effect on autonomy (Li et al., 2011; Zhou, 2003). An explanation for this can be found in chapter 3, where we see that workers who agree with the feedback and internalize the feedback do not show a decrease in perceived autonomy. Looking at SDT, this shows that the autonomy to self-regulate health behaviour is only supported if the HSMA does not impose norms that are not in line with the values of the worker.

HSMAs and worker autonomy

With regard to workplace health promotion, we know that preventive health measures raise fears among workers that their privacy and autonomy will be harmed (Damman et al., 2015). In our research, we have examined whether this fear of loss of autonomy indeed happens, and what the explanations for this loss are. Thereby, we aim to enable employers to develop preventive health programs for the workplace while taking these considerations into account.

Abundant research has been conducted on employee work autonomy (Alder, 2007; de Jonge, 1995; Hackman & Oldham, 1974, 1980; Palm, 2009), but the autonomy regarding the self-regulation of health behaviour in the workplace is often overlooked (Alder & Ambrose, 2005; Damman et al., 2015). When HSMAs give feedback on health-related behaviour such as daily exercise, the standards set for physical activity (e.g., 10,000 steps a day) are not specified exclusively for the workplace but are fluid goals for health-relevant behaviours in both work and private lives. Thus, besides their influence on autonomy and control of health-related behaviour in the workplace, HSMAs may also affect the sense of autonomy that employees experience in regulating their health-related behaviour at home. We therefore adapted the three items of the Autonomy scale of the Job Diagnostic Survey (Hackman & Oldham, 1974) developed by Hackman and Oldham (1980) to assess participants' perceptions of work health autonomy (WHA) and home health autonomy (HHA). Applying these scales of WHA and HHA, we see that the autonomy of workers with a higher BMI is harmed when using HSMAs in the work environment. This shows that the use of HSMAs in the work environment indeed can harm perceived worker autonomy, as was already feared by participants in Damman et al. (2015) and hypothesized by Owens and Cribb (2017).

In chapter 3, we saw that the decrease in perceived autonomy of workers as a consequence of using an HSMA can be mitigated by combining performance feedback with developmental feedback. This developmental feedback gives specific advices on how to alter behaviour, and offers alternative ways to improve behaviour in the workplace. The finding that providing developmental feedback with advice and alternatives attenuates the loss of perceived autonomy workers is in line with the idea of Kukla (2005) on conscientious autonomy. This means that autonomy is the extent to which you are able to self-decide on which norms you want to adhere to, and the experienced ability to act upon these norms. Additional developmental feedback allowed workers to act upon their own norms, by offering different ways to reach their goals.

In chapter 3 we cannot confirm an important assumption of the working of HSMAs. Using an HSMA like a Fitbit in a work environment does not automatically improve the perceived autonomy of workers; for workers with higher BMIs, the use of HSMAs can even decrease autonomy. We are the first to observe this loss of perceived autonomy in an experimental setting, thereby showing that the assumptions regarding HSMAs are not by definition applicable to the work environment. Further, our research shows that users with a high BMI experience a bigger loss of perceived autonomy, and identify more limitations in their surroundings that keep them from altering their behaviour, than workers with lower BMI.

Mental fatigue in the workplace

Current workplace health promotion programs often aim to include mental health next to physical health. Part of this mental health is fatigue-related: when workers suffer from mental fatigue and cannot recover from this fatigue enough during (Kim et al., 2017) and after working hours, this can cause productivity loss (Ricci et al., 2007) and a loss of general health (Sluiter et al., 2003). Measuring mental fatigue in the workplace however is difficult, because measurement methods are either subjective, retrospective, or very invasive, which makes that they cannot be used in the workplace continuously[4]. In our research, real-time objective monitoring of mental fatigue in a regular workplace was technically possible due to findings by Pimenta (2014) and de Jong (2018). They show that the alterations in interval between keystrokes is a valid proxy for mental health, and that this measuring method is applicable in the work environment (de Jong et al., 2020). Our research is the first to combine this new objective measurement method with a feedback intervention, in order to improve worker behaviour regarding break-taking and mental fatigue. We found that real-time actionable feedback on emerging mental fatigue during typing events results in improved break-taking behaviour of workers, thereby opening up a field of new and promising research on how to prevent severe mental fatigue among workers.

[4] Known methods for measuring mental fatigue are a psychomotor vigilance task (PVT) at the end of the day (Riethmeister et al., 2018), questionnaires (Sluiter et al., 2005, 2003), or an Electroencephalogram (EEG) (Liu et al., 2018; Wascher et al., 2014), requiring the subjects to use an EEG device mounted on their head for the time of the study.

Contributions to the field of Responsible Research and Innovation

Development of HSMAs for the work environment

In chapter 4, we show how the implementation and use of HSMAs in the workplace bring privacy and autonomy issues to the surface that were not identified during the development phase. This is in line with Kiran (2012), because his idea of interdependent design-use dynamics shows that many innovations are developed with a certain use in mind, but after implementation the users start to use the product differently or attribute different values to the innovation. Using a context-sensitive ethics, we have identified the ways in which privacy and autonomy play a role in the use of HSMAs in the workplace. We have reiterated on these values continuously in order to adjust our implementation studies. By doing so, we show that a continuous cycle of reflection during the development and implementation of HSMAs in the work environment incrementally improves the way that these values in design and use are aligned. Thereby, it improves the responsibilities taken and expected by worker and employer.

Multidisciplinary Responsible Research and Innovation

Throughout this research, we have combined knowledge from many scientific fields to focus on one main theme: the development and implementation of HSMAs for the work environment. This research was situated in the larger multidisciplinary research consortium SPRINT@Work and chapter 4 was developed using cases from and collaborating with colleagues from SPRINT@Work. In doing so we were supported by an ethicist, facilitating the intervision with the PhD candidates in the project, who served as executing researchers. During the project, the responsibility for incorporating knowledge on values and norms regarding health, healthy behaviour, and the context of the workplace, became more and more shared between all researchers involved, due to a process of reflection and responsiveness. This shows that the approach of Flipse et al. (2014), where social scientists and natural scientists work together full-time to develop a common language, can also work in a project such as SPRINT@Work. Other than in Flipse et al., SPRINT@Work was an interdisciplinary project where a large part of the research was conducted independent of the other researchers in the project. The main goal was shared, but researchers mainly conducted their own research, and aligned their outcomes to reach the main goal. We have shown that a research consortium with no shared background in ethics or responsible innovation, that only limitedly collaborated, can still develop a common language regarding ethical issues and responsibilities. Our approach of part-time collaboration with an ethicist, resulting in a shared uptake of the responsibility for responsible research and innovation, has not been reported upon before. We think that this approach can change the way multidisciplinary research groups work, improving the RRI-practices, and thereby facilitating not only preaching but also practicing RRI.

Practical implications

This research has shown that the use of HSMAs in the workplace can help improve the health behaviour of employees, but also that this behavioural improvement is not obvious and self-evident, and the use of HSMAs can even harm the worker. As such, the present results have a number of implications for both the use of HSMAs themselves, and the implementation of a wider workplace health promotion program in a company.

Looking at the implications from chapter 2, we see that the effects of HSMAs on alteration of suboptimal behaviour depends on the newness of feedback information and the type of behaviour that is targeted. This shows that employers should test whether a desired HSMA indeed affects the targeted behaviour as aimed for. Findings from other research (Larouche et al., 2018; Shrestha et al., 2018) suggests that these outcomes may be improved by combining feedback with practical tools to facilitate improvement of behaviour (e.g. sit-stand desks). From chapter 3, we learn that the perceived autonomy of workers to self-regulate their health behaviour both at work and at home can be harmed by using an HSMA. This mainly happens when people experience that HSMAs use standards for behaviour (e.g., 10.000 steps a day) that are not in line with their own personal norms. Therefore, employers should prevent that HSMAs impose external goals on workers who can or will not transfer these into their own norms. Instead, HSMAs might work more effective when workers are able to self-decide what behaviour they wish to change, and what standards they want to use to monitor and self-regulate their health behaviour. In order to further facilitate this, employers could combine the use of HSMAs with personal lifestyle coaching, in order to make sure that the goals the worker sets are realistic and in line with their personal needs and health condition .

Regarding workplace health promotion programs, multiple studies have already examined and proposed how to improve the implementation of these programs (Delahanty et al., 2002; Hendriksen et al., 2016). In the implementation phase, employers can include groups of employees and other stakeholders in order to address and evaluate (morally) relevant features and issues of the use of HSMAs. Regarding the inclusion of workers with high and low BMIs, we see that employees with higher BMI can feel stigmatized by the workplace health promotion program of employers. Stigmatization makes it harder for people to lose weight and remain stable on a lower weight (Puhl & Heuer, 2010). In order to successfully adapt a lifestyle, lifestyle coaching and flexible goal-setting could be considered as ways to increase the experienced feasibility of lifestyle changes for less healthy employees(Delahanty et al., 2002; Hendriksen et al., 2016), thereby increasing the autonomy of employees to pursue their health goals.

Limitations and future research directions

Our research has some interesting findings and makes valuable contributions to the research literature and practice. On the other hand, the work has limitations, that make it worthwhile to pursue further research in this area. These limitations are found in the research field, the research execution, and our research assumptions, and they offer interesting directions for further research.

Limitations and future research directions related to the research field

Effective use of HSMA in the work environment

In our research we have focused on examining HSMA effects on worker self-regulation of mental fatigue, sitting behaviour, and physical exercise. HSMAs are used to alter suboptimal behaviour, in order to prevent illnesses and inabilities in the long term. We found that the effectivity of HSMAs in the workplace depends on the health condition of the worker, the divergence between personal norms and the norms of the HSMA, the type of behaviour, and the timespan in which to expect improvements. Our diverse findings show that there is still a lot to learn: interesting avenues would for instance be using self-learning HSMAs in order to facilitate personal goal-setting and incremental improvement, the use of HSMAs as part of a broader workplace health promotion program, or how to effectively decide what the optimal feedback strategy for individual workers would be.

In a broader perspective, an interesting avenue for future research would be to find out how the workplace can be designed in such a way, that the workplace itself facilitates and nudges healthy behaviour in the workplace. One could think about interventions such as meeting rooms for stand-up meeting, coffee machines and printers on locations that urge workers to walk a bit more during the day, and systems that stimulate alternating between taking the elevator and the stairs or between sitting and standing while performing tasks. Also, the health-related culture in a company is an interesting area to further explore, because for instance working pressure, pressure from managers, social pressure, and experienced pressure from colleagues are known to be large barriers to act healthy in the workplace.

Multidisciplinary RRI

Our research is situated in a niche area in science: responsible research and innovation of technologies for the work environment. In this field, although case studies are quite common (Cuppen, Pesch, Remmerswaal, & Taanman, 2015; Stilgoe et al., 2013), there is hardly any explorative case research examining both the development and implementation of technologies, and end-users are often outside the scope of the RRI-researcher (Jakobsen et al., 2019). In the field of RRI, the researcher often is either studying a case using a retrospective approach or empirical approach (Cuppen et al., 2015), so not participating but continuously (real-time) observing the process, or the researcher is involved in the process as the one responsible for 'the ethics'(Stilgoe et al., 2013).

In this research, we have conducted three studies using a range of methods. Data was conducted using two experimental field studies and a case study, including questionnaire data, interviews, sensor data, observations, and peer intervision. This approach, in which the executing researchers did not have any background in responsible innovation or ethics, but learned how to cope with the challenges along the way, is quite rare. We initially had little knowledge on how such a research project can be shaped. This caused us to especially struggle with the linguistic confusion about issues such as privacy, autonomy, and responsibility, because these terms are defined differently in all disciplines represented in SPRINT@Work. We felt it was necessary to all have the same understanding of what privacy, responsibility and autonomy meant in our context, because we believed that the first R of RRI cannot be assigned to only one or a few of the project members, but has to be broadly supported by the whole project group. Because we had no experience in how to develop such a common language, the process of getting that common language took quite a long time. Therefore, the first individual studies of the executing researchers were already on their way or finished, before this common understanding of autonomy, privacy and responsibility was reached. This impacted the way these values could be taken into account during the individual projects. For future projects, we would advise to start an open conversation regarding values and ethical issues with the whole project group right from the start, in order to deal with these issues as soon as possible.

Future research on inclusion of the whole research group in RRI projects is necessary, and needs to fill the gap between current RRI guidelines and the reality, in which often the executing researchers do not have an active role in discovering the ethical agenda and implied values of the project. There is a lack of knowledge from RRI case studies that are set up in this way, which makes it impossible to draw conclusions on the effects of including all executing researchers on the RRI-related outcomes of projects. Lastly, we believe that in multidisciplinary projects the linguistic confusion is a problem that more often appears, because different disciplines have different languages (Flipse et al., 2014). In order to solve this, as an addition to Flipse et al., research should focus on how researchers without a background in ethics and responsible innovation can use ideas from linguistic socialization (Collins, 2011). By adopting ideas from Collins (2011), the mutual understanding of each other's jargon and each other's explanations of ethical values increases. This can help in developing interactional expertise on the field of responsible innovation, and embedding that expertise in their own respective disciplines.

Limitations and further research directions related to the research execution

For the first experimental field study, we had only 18 participants. We started with 46 participants in two yoked cohorts, in order to test both the effect of control over feedback frequency as well as feedback frequency itself. However, the yoked cohort dropped out of the experiment due to technical and feedback generation issues that emerged during the execution of the experiment. It turned out that their initial feedback setting was wrong, and therefore they received feedback on a different frequency than their yoked counterpart in cohort 1. Therefore, this cohort was ended early, and a new second cohort was recruited. This cohort received feedback in the right frequency, but later on during analysis it turned out that the experimental conditions were altered between these cohorts. This made that the second cohort received reminder feedback messages after 5 minutes, instead of 15 minutes as in the first cohort. Therefore, the two cohorts became incomparable and the (new) second cohort was excluded from analysis. As a consequence, we were unable to test potential effects of control over feedback frequency on worker self-regulation of sitting behaviour and mental fatigue during typing. Summarizing, we found 70 workers willing to participate, and only 18 of them are included in analysis, due to technical errors and bad luck.

In order to overcome these limitations, we would urge future researchers to examine effects of real-time actionable feedback on sitting behaviour and mental fatigue again using a larger sample size. Also, based on the research literature on the roles of self-control over feedback (Chiviacowsky & Wulf, 2002; Wulf, 2007) and feedback frequency (Hermsen et al., 2016; Lam et al., 2011), we would recommend to examine how these feedback factors might moderate and optimize the effects of real-time actionable feedback provided by HSMAs on healthy behaviour in the workplace, and continuously test and improve the experimental setup.

Regarding our study (Chapter 2) on the role of real-time actionable feedback on sitting and typing behaviour, we did not use validation measures such as activity trackers or diaries to check whether the smart chair gave a good picture of the daily behaviour of workers. We have based our analysis of daily sitting events on only those events where the participant was sitting on the smart chair. Therefore, we may have missed sitting events on other chairs during the day. Also, we have no data on typing behaviour on other devices, or on the behaviour of workers during their typing breaks. It therefore can be that breaks from typing were used to do other work, such as reading or meeting. Therefore, this may have influenced our analysis of the effect of breaks on mental fatigue.

In both experimental field studies (Chapter 2 and 3), workers voluntarily participated. For the study in chapter two, workers were randomly asked by the Health and Safety Coordinator of the institution, which gives a good selection of the total population. In chapter three, however, the workers received an invitation to participate in the study, and it is likely that workers with a higher motivation or interest in their personal health have signed up to participate in the study. This selection bias in is comparable with the selection bias that occurs when this type of workplace health promotion program is introduced in a regular working environment, because these programs are offered on a voluntary basis. Therefore, we believe a potential selection bias has no significant impact on the outcomes.

Limitations and further research directions related to our research assumptions

The use of BMI as a proxy of health status in health research is much discussed (MacLean et al., 2009; Puhl & Heuer, 2010). For the present study, we believe that BMI sufficiently captures the differences in perceptions of health promotion interventions between individuals who consider themselves 'healthy' or 'unhealthy'. We have adopted BMI as a suitable proxy of health because it has been proposed as a holistic measure of health, has high predictive validity across many health outcomes, is widely used in population and medical research, and can simply be self-reported by participants (Gutin, 2018). We do however share the concerns about the quality of BMI as an operationalization of people's health as discussed in literature and realize that its use is a limitation of the present research. Therefore, future research might examine effects of HSMAs by including a complete health check pre- and post-experiment, in order to find out whether workers who are metabolically and cardiovascularly unhealthy, which in many cases is not predicted by BMI (Puhl & Heuer, 2010), show similar declines in autonomy. This could show whether the loss of autonomy is something that is experienced by less healthy workers, or mainly by stigmatized workers, which then could lead to alterations to public and occupational health programs.

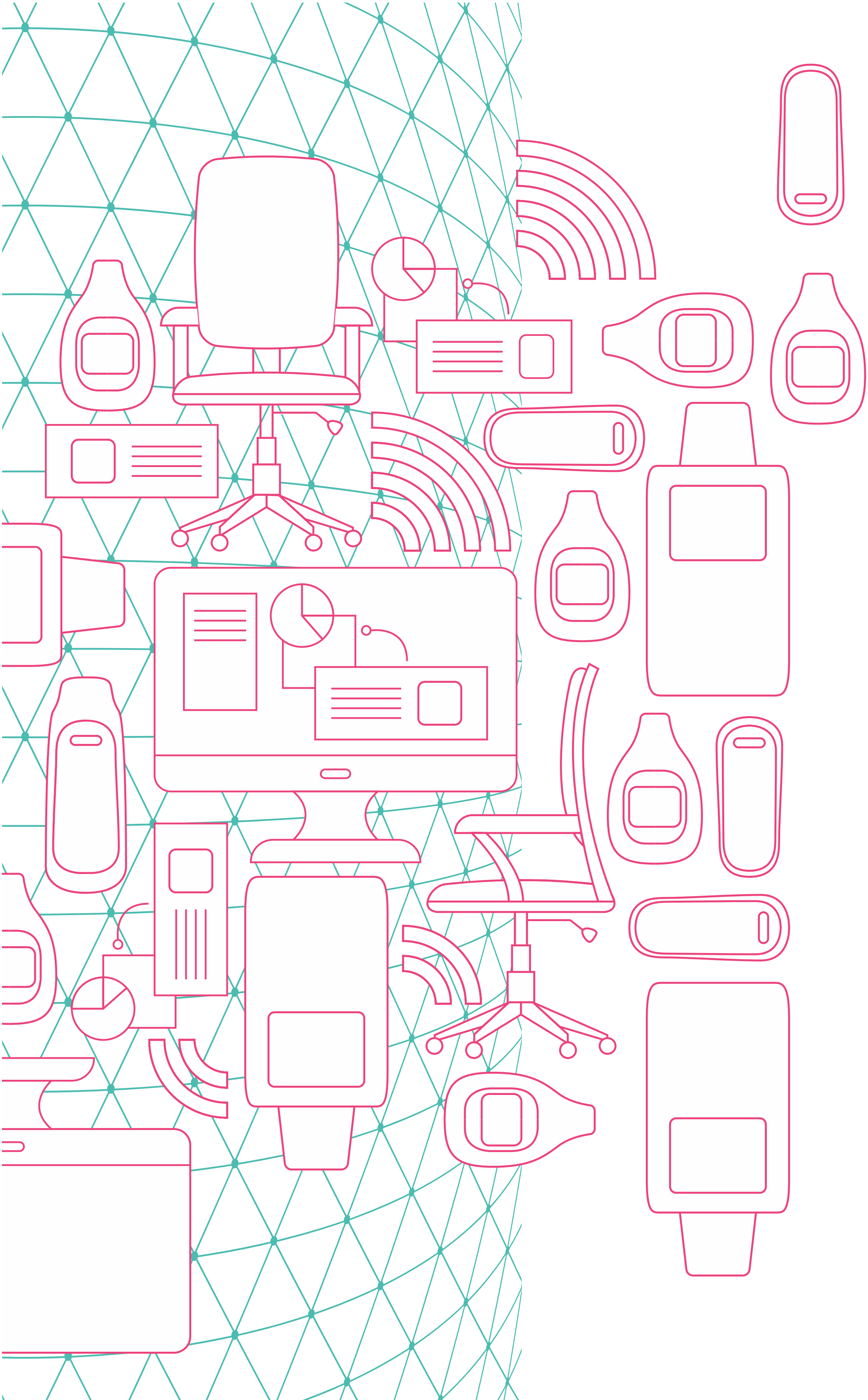
Regarding the given feedback and norms, there are some differences between the executed experimental field studies, that might change the impact on the participating workers. For the feedback on daily step count (chapter 3) and sitting behaviour (chapter 2), we have used the general norm of resp. 10.000 steps per day (Johnman et al., 2017) and a maximum duration of a sitting event of 55 minutes (Netten et al., 2013). Although these norms are widely known and accepted, there are alternative guidelines for these behaviours, such as the Active 10 (He & Agu, 2014) for daily exercise, and guidelines of 20 and 35 minutes sitting (Netten et al., 2013). Regarding the 10.000 steps per day, we have chosen this norm because it is widely known in society, including the vast majority of our study population. The 55-minute norm was chosen because it is one of the main known norms regarding sitting behaviour, and targets the most severe long sitting bouts. We do however realize that other choices would have been justifiable and could have resulted in different findings. For the break-taking behaviour (chapter 2) we used a personal benchmark, based on research from de Jong et al. This feedback is not generated based on a general guideline, and no other guidelines for inobtrusive monitoring of mental fatigue are known. In line with the practical implications that are sketched above, we believe it would be an interesting research direction to explore the effects of personalized goal-setting using HSMAs. This may increase the effects of the feedback intervention, given that the goals are reachable and therefore the are more motivating to act upon (Kluger & DeNisi, 1996).

Regarding the effect of breaks on mental fatigue, additional research is needed. Our research shows that the break behaviour of workers receiving real-time actionable feedback improves. Unfortunately, regarding the effect of breaks on mental fatigue, we could not confirm the findings of Kim, Park, and Niu (2017) who state that breaks reduce the mental fatigue of office workers. There are some major differences between our research and the study of Kim et al, that may explain this difference, and that ask for further study. The study by Kim et al uses questionnaire data whereas we use sensor data. Moreover, in Kim et al.'s study, participants themselves defined what they considered to be a break, including micro breaks of a few minutes, while our study included breaks longer than 15 minutes. Furthermore, the breaks in our study are non-specified and might have been spent on reading an article, or meeting with colleagues , whereas the breaks in Kim et al.'s study are breaks in which workers actually relax. These differences in the assessment and type of breaks may have caused the difference in outcomes, but do not give direction to which outcome is more reliable. Therefore, more research is needed to better understand what the effects of breaks are on mental fatigue of workers.

Final remarks

The main aim of this research was to give insight into how HSMAs can be responsibly developed and used to help workers adopt healthier behaviours. We formulated and answered research questions about the role of real-time actionable feedback in changing health behaviour of office workers, about effects of HSMAs on perceived autonomy in self-regulation of health behaviour among hospital employees, and about responsible design and use of HSMAs in a multidisciplinary research project. The present results contribute to the research areas of workplace health promotion, and responsible research and innovation.

Employers, innovators, and workers are looking for effective ways to ensure that workers can remain sustainably employable. Our research shows that HSMAs can contribute to healthy behaviour of workers by providing real-time actionable feedback on suboptimal current behaviour. However, we also show, that this real-time feedback is not just a driver of beneficial behavioural change, but can also reduce the perceived autonomy of less healthy employees. We used strategies from the field of Responsible Research and Innovation to identify potential privacy and user autonomy issues, both in the design and implementation of HSMAs, and developed a context-sensitive ethics approach to addressing those issues. This context-sensitive ethics approach enabled researchers to explore how to take into account the inherent values of a technology during development and use, and how the implementation of HSMAs can benefit from a contextualized understanding of privacy and autonomy issues in the workplace. We combined both quantitative and qualitative research, and experimental and case study research into a truly multidisciplinary view on a responsible and effective development and use of HSMAs aimed at improving the health-related behaviour of employees. By doing so, we hope to pave the way for future research into this scientifically interesting and societally relevant topic.



Appendix

Appendix 1: Examples of feedback messages

<u>Performance feedback condition</u>

Feedback on request (available through the Fitbit One):

- Current daily step count
- Current number of stairs taken
- Estimated number of calories burned today
- Estimated distance walked today

Feedback by e-mail (sent on average once a week):

- Daily step count for the last 7 days
- Daily number of stairs taken for the last 7 days
- Number of minutes per day of daily activity (low, medium or high intensity)

<u>Developmental feedback condition</u>

Feedback on request (available through the Fitbit One):

- Current daily step count
- Current number of stairs taken
- Estimated number of calories burned today
- Estimated distance walked today

Feedback by e-mail (sent on average once a week):

- Daily step count for the last 7 days
- Daily number of stairs taken for the last 7 days
- Number of minutes per day of daily activity (low, medium or high intensity)

Added in week 1:

- Information on low, medium and high intensity activity
    - o Feedback on activity levels
    - o Advice on how to alter activity levels
    - o Link to website with more information about these activity levels

Added in week 2:

- Information on medium intensity activity and increasing physical activity
    - o Feedback on medium intensity activity level

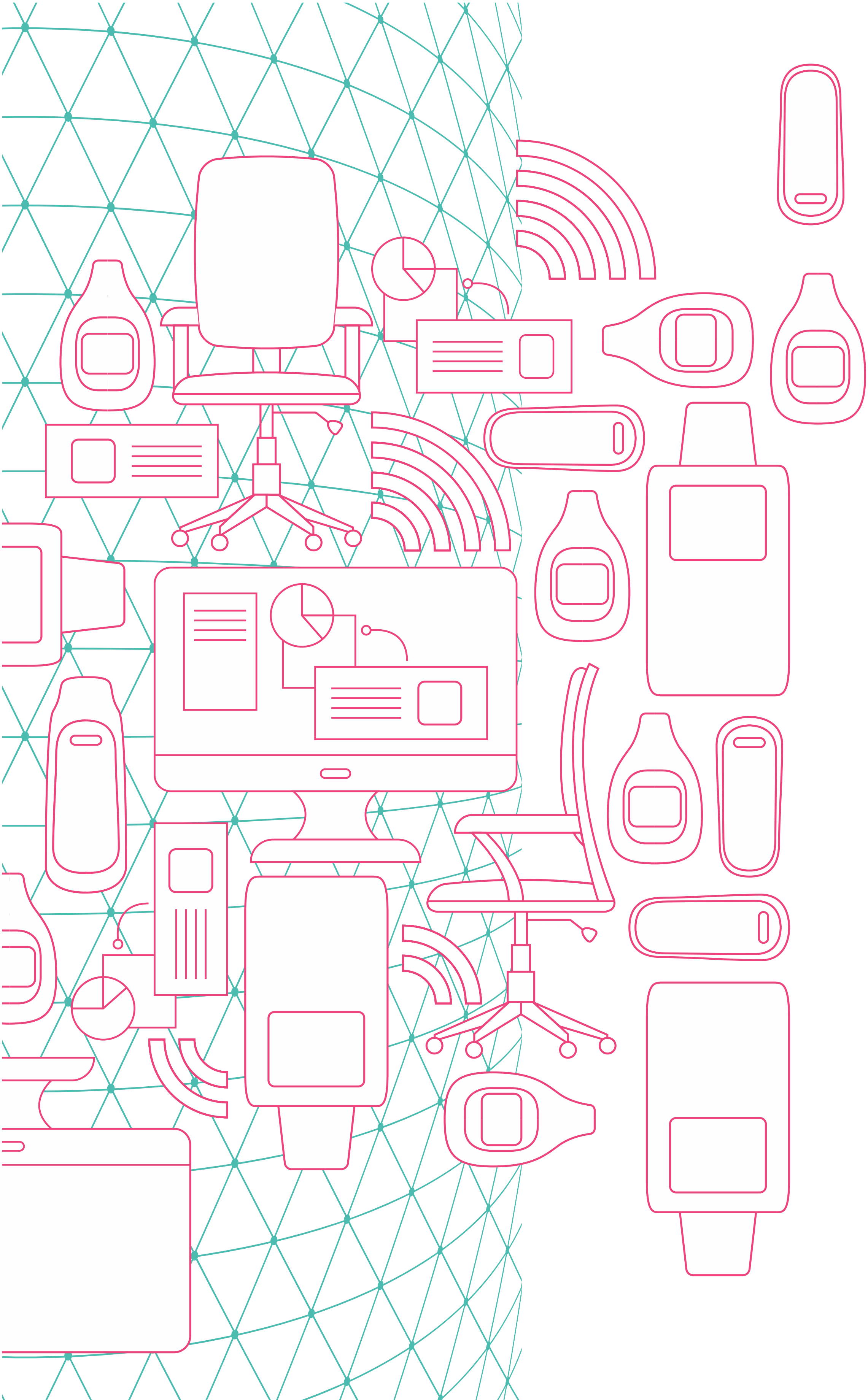
  - o Information about activities that are of medium intensity
  - o Advice on how to set goals and reach goals regarding physical activity levels

Added in week 3:

- Information on high intensity activity and exercising together
  - o Feedback on high intensity activity level
  - o Information on how exercising with others can affect and improve behaviour
  - o Link to website where people can find a 'Beweegmaatje' (someone to exercise with)

Added in week 4:

- Information on continuing behavioural change
  - o Feedback on activity levels
  - o Information on how to persist behavioural change
  - o Mitigation strategies to avoid risks that keep one from exercising



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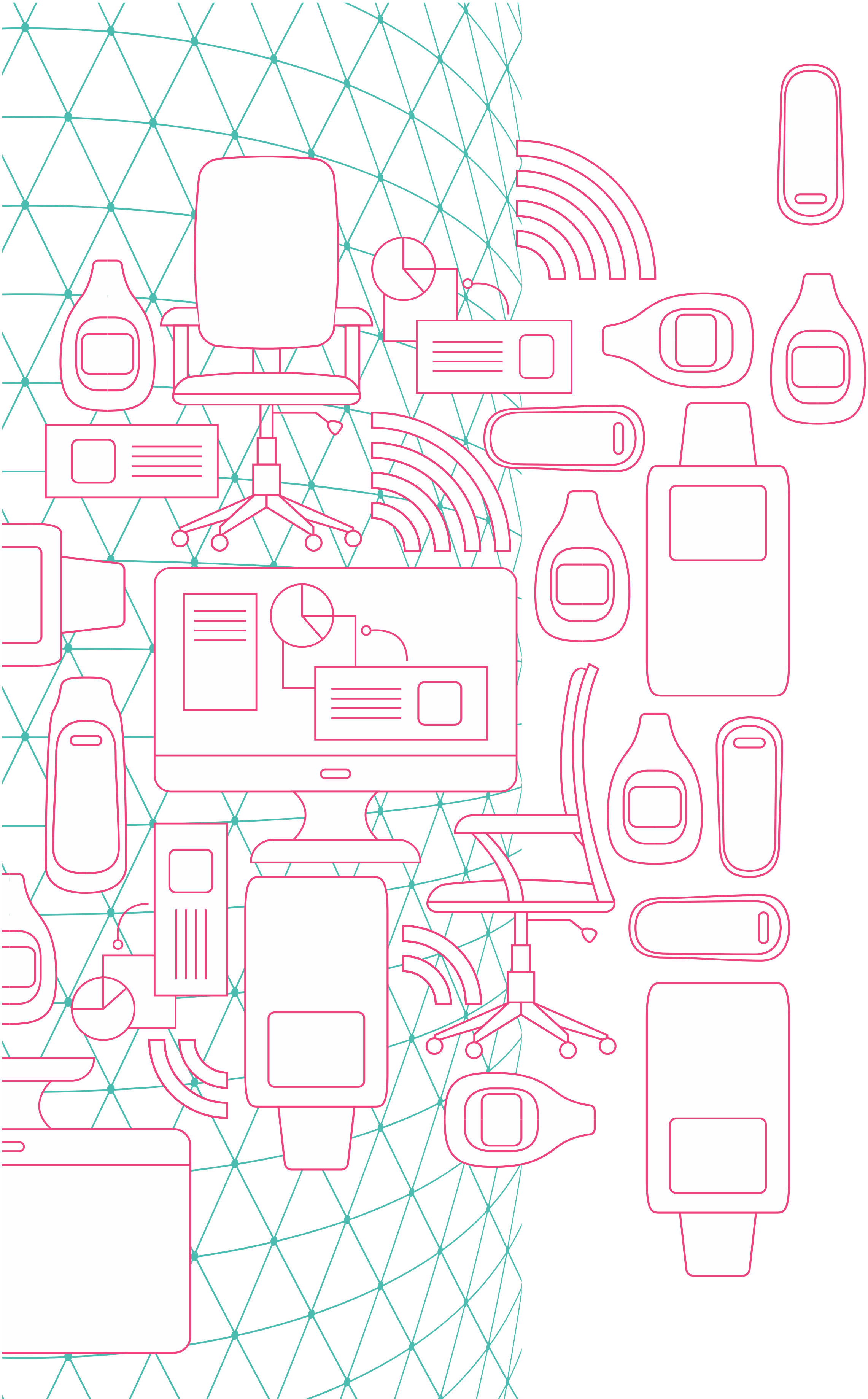


Summary

Health Self-management Applications (HSMAs) are sensor and intervention technologies that provide users with key metrics about their bodily functioning and health-related behaviours. These HSMAs are increasingly used in the work environment to facilitate workers to monitor their health behaviour and improve it where necessary (Jacobs et al., 2019; Kalantari, 2017). While the usefulness of HSMAs has been proven in the consumer and patient population (de Vries et al., 2016; Lorig et al., 2001), the use of HSMAs in the work environment suffers from high user dropout (Eysenbach, 2005) and does not seem to be effective in reducing sick leave (Linden et al., 2014). Also, the use of technologies such as HSMAs raises questions whether these technologies violate worker autonomy (Leclercq-Vandelannoitte, 2017).

Current HSMAs are able to provide different types of feedback, that can be adjusted to personal goals of the users instead of providing them with general norms (Bravata et al., 2007; Schermer, 2009). This personal attunement in the provision of feedback can improve their effectiveness, by giving feedback real-time and actionable (Kluger & DeNisi, 1996; Kulik & Kulik, 1988) instead of delayed, by giving developmental feedback in addition to performance feedback (Li et al., 2011) and by adjusting the feedback frequency to the receivers' preferences (Chiviacowsky & Wulf, 2002; Lam et al., 2011). Based on the self-determination theory (Ryan & Deci, 2006), it is also assumed that the self-management function of HSMAs would increase the autonomy and intrinsic motivation of workers to self-regulate their health behaviour. In order to ensure that personal values such as autonomy are guarded, researchers can use knowledge from the field of Responsible Research and Innovation (RRI), supporting them in developing responsible technologies (Stilgoe et al., 2013; Von Schomberg, 2013)

Therefore, this thesis aims to examine how HSMAs can responsibly and effectively be developed and used to stimulate workers to show more healthy behaviours. This main goal is pursued by seeking answers to the following three sub questions:

1. How do HSMAs that provide both real-time and actionable feedback impact worker's health-related work behaviour? (Chapter 2)

2. Does the use of HSMAs in the workplace promote employees' perceptions of autonomy in self-regulating their health-related behaviour? (Chapter 3)

3. How can HSMAs for the work environment be responsibly developed, with attention for inherent values in and identification of stakeholder responsibilities for both design and implementation? (Chapter 4)

In chapter 2, we report on our first experimental study. This experimental study existed of a 6-week field experiment in an office environment where participants used a set of sensor tools for 6 weeks. In this study we examine the effect of real-time actionable feedback on the behavioural change of office workers using a set of HSMAs in the workplace aimed at reducing prolonged sitting behaviour and preventing mental fatigue. Findings show that receiving real-time actionable feedback messages on sitting behaviour does not impact the immediate duration of the sitting event. However, during the experimental period, we observed a decrease in average sitting duration over time. In contrast, feedback messages on mental fatigue, which were based on typing behaviour, does influence participants in immediately taking a break from typing.
These findings suggest that in response to real-time actionable feedback, workers are unlikely to immediately alter harmful behaviour that they can identify themselves, such as prolonged sitting behaviour, but nevertheless tend to improve sitting behaviour over time. Real-time actionable feedback on fatigue during typing, however, was found to be effective in immediately adapting that behaviour. This pattern of results seems to suggest that real-time actionable feedback has direct effects on unhealthy behaviour that workers are unaware of, while it has delayed but lasting effects on

unhealthy behaviours that workers can identify themselves. This implies that in order to improve the long-term health behaviour of the worker, the sitting behaviour can be monitored for relatively short periods, whereas monitoring of fatigue during typing behaviour must be continued in order to ensure that workers can take timely breaks.

Chapter 3 describes the results from the second experimental study, in which healthcare workers used a Fitbit One for 4 weeks. In this chapter, we use questionnaire and interview data to explain how the use of an HSMA in the work environment affects the degree to which workers feel able to self-decide upon health-related behaviour in the workplace, their so-called ‘perceived autonomy’. This perceived autonomy can be affected in both the work and home environment, referred to as work health autonomy (WHA) and home health autonomy (HHA), respectively. This chapter investigates what the effect is of differences in focus of feedback provided by an HSMA on employees’ autonomy perceptions. Regarding feedback focus, we differentiate between performance feedback, which shows the discrepancies between one’s actual behaviour and the standards set for such behaviour, and developmental feedback, which aims at facilitating learning and behavioural change. Moreover, we examine how differences in BMI (i.e., a proxy for health) moderate employees’ autonomy responses to the feedback they received from the HSMA. Findings reveal that the use of an HSMA does not significantly increase perceived autonomy in self-regulation of health behaviour, and may even reduce it under certain conditions. Specifically, employees who receive mere performance feedback from their HSMA tend to perceive lower WHA than when they received additional developmental feedback. Furthermore, employees with higher BMI who received performance feedback perceive a greater loss of WHA than employees with lower BMI, and employees with higher BMI who received additional developmental feedback experienced a greater loss of HHA. Findings from our in-depth interviews show that higher-BMI employees felt external norms and standards for healthy behaviour as more salient and experienced more negative emotions when those norms are not met, thereby making these employees more aware of their limitations in the pursuit of health goals. These results show that there is no 'one-size-fits-all' approach when it comes to health promotion in the workplace. To avoid negative consequences of HSMAs in the workplace, we suggest to make it part of a broader program on workplace health promotion. These programs should be implemented using input and ideas from a varied group of workers, and should preferably aim at a broad range of behaviours, including not only physical exercise, but also diet, mental health, and overall wellbeing.

The research upon which this thesis is built, was conducted in the project SPRINT@Work. In that project, we came across several ethical issues that affect the development and use of health-related technologies in the workplace. In Chapter 4, we explore these ethical issues. We identify three shortcomings in the research literature on ethics regarding new technologies. First, previous studies often focus only on either the development of new technologies or on the implementation of these technologies. Second, prior research overlooks the specific characteristics of the work environment that affect the development and use of technologies. Third, prior work has not addressed how developers as well as users may fail to recognize the ethical values of other stakeholders involved in design and use of new technologies. Using cases from SPRINT@Work, we show how a context-specific form of ethics can overcome these shortcomings. An example of this is the case of firefighters. Under current regulations regarding data protection (GDPR, 2016), an employer is not allowed to obtain personal health data from the worker, not even when the worker agrees on sharing data. On the other hand, however, this employer has the duty to keep the worker from getting harmed (Arbeidsomstandighedenwet, 1999). In case of a fire, these two regulations often clash. Our context-specific ethics takes into account the situational details regarding respective dangers of getting harmed and giving up privacy. Also, it uses the views from stakeholders, such as firefighters and their captains, as input for reiterations of this ethics, resulting in an approach that uses autonomy to protect both worker privacy and employer responsibility. We thereby show that the values of responsibility, privacy and autonomy are not as rigid as reflected in the regulations, but there is an interplay between these three values that is impacted by the context-specific details. Applying this context-specific form of ethics to the work environment in SPRINT@Work can help overcome issues such as a loss of autonomy or privacy of workers.

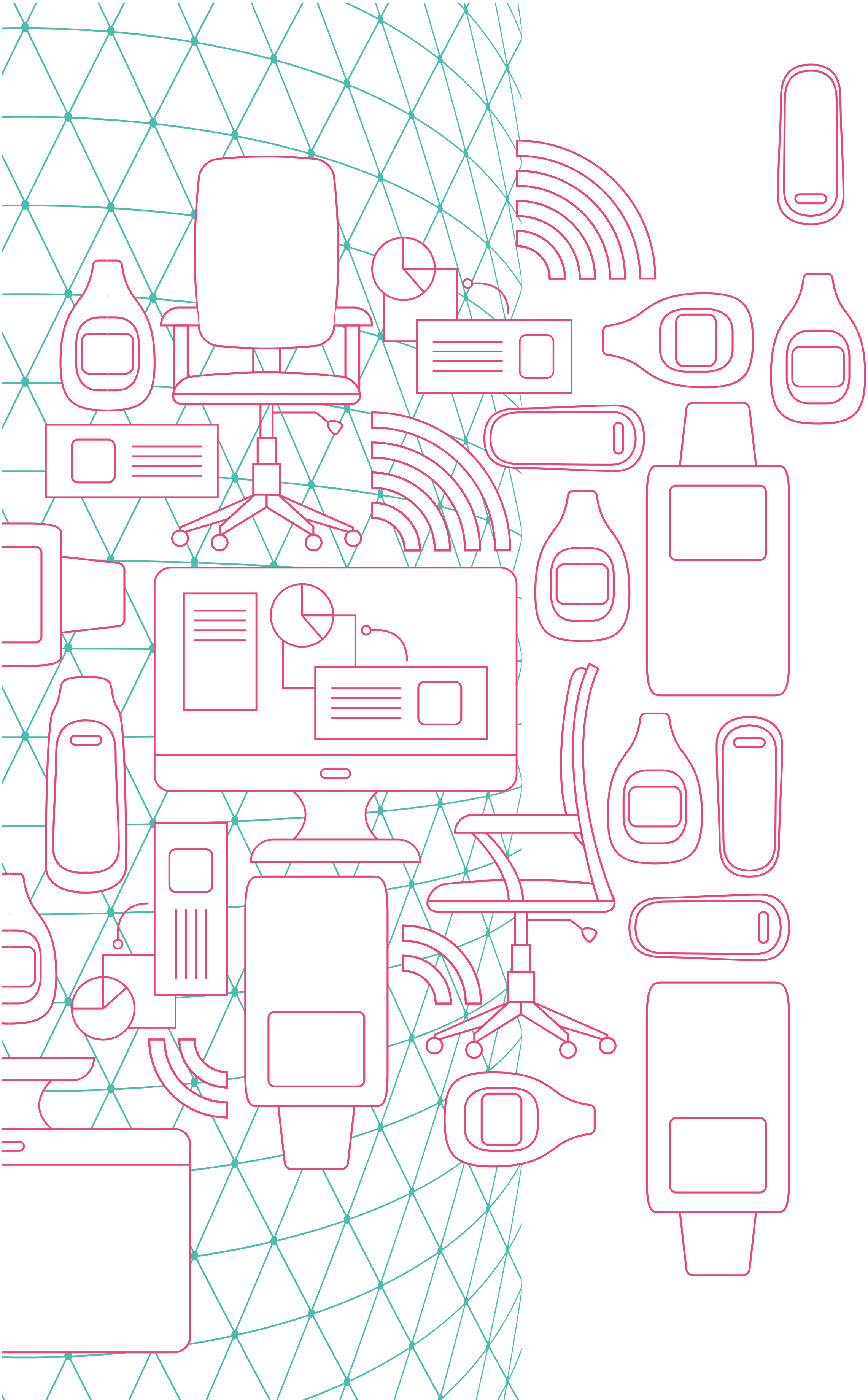
In Chapter 5 we reflect on the main aim of this thesis, and conclude on the scientific and practical implications of this thesis. The main aim was to to examine how HSMAs can responsibly and effectively be developed and used to stimulate workers to show more healthy behaviours. We conclude that HSMAs can contribute to healthy behaviour of workers by providing real-time actionable feedback on suboptimal behaviour. This real-time feedback however is not always a driver of beneficial behavioural change, but can reduce the perceived autonomy of less healthy employees. Our approach of using context-specific ethics enabled us to explore how to take into account the inherent ethical values of a technology during development and use, and how the implementation of HSMAs can benefit from a contextualized understanding of privacy and autonomy issues in the workplace.

We used a multidisciplinary approach to examine the development and use of HSMAs in the work environment. The use of objective measurements of mental fatigue in the workplace is innovative, and opens up promising research directions. We add to the field of workplace health promotion by using Feedback Intervention Theory (FIT) and Self-Determination Theory (SDT) to examine how HSMAs can facilitate workers in self-regulating their health behaviour, and we show how the current health of workers using a HSMAs impacts the perceived autonomy. Also, we show how a context-specific ethics approach building upon the framework for Responsible Research and Innovation (Stilgoe et al., 2013) can facilitate responsible implementation of HSMAs in the workplace.

Regarding the practical implications, this research shows that employers should be aware that there is no panacea for work-related

illnesses. The use of technologies that improve worker health is promising, especially for behaviour that is not noticed by the worker themselves. To let all workers benefit from technologies aimed at health improvement, employers could use groups of employees and stakeholders to address and evaluate features of the technology. The effectiveness of health self-management could be improved further by using a broader workplace health promotion program, also focusing on mental health programs and lifestyle.

We combined insights from the fields of occupational health, job design, human behaviour, and responsible innovation, into a truly multidisciplinary view on a responsible and effective development and use of HSMAs aimed at improving the health-related behaviour of employees. By doing so, using both quantitative and qualitative research and experimental and case study research, we pave the way for future research into this scientifically interesting and societally relevant topic.



Samenvatting

Technologieën voor gezondheidszelfmanagement (HSMA's) zijn onder andere sensor- en interventietechnologieën die gebruikers informatie geven over hun lichamelijk functioneren en gezondheidsgerelateerd gedrag. Deze HSMA's worden in toenemende mate ingezet in de werkomgeving om de gezondheid van werknemers te monitoren, en waar mogelijk het gedrag van werknemers te verbeteren (Jacobs et al., 2019; Kalantari, 2017). Hoewel HSMA's bewezen nuttig zijn bij consumenten en patiënten (de Vries, Kooiman, van Ittersum, van Brussel, & de Groot, 2016; Lorig, Sobel, Ritter, Laurent, & Hobbs, 2001), blijven gebruikers in de werkomgeving niet lang gebruik maken van technologieën zoals HSMA's (Eysenbach, 2005) en lijken HSMA's niet effectief bij het terugdringen van ziekteverzuim (Linden et al., 2014). Daarbij zijn er aanwijzingen dat het gebruik HSMA's de autonomie van werknemers kan schaden (Leclercq-Vandelannoitte, 2017).

Moderne HSMA's kunnen verschillende soorten feedback versturen, die kan worden aangepast aan de persoonlijke doelen van de gebruikers, in plaats van alleen standaardnormen terug te geven (Bravata et al., 2007; Schermer, 2009). Gepersonaliseerde feedback vergroot de effectiviteit door real-time, actiegerichte feedback te geven (Kluger & DeNisi, 1996; Kulik & Kulik, 1988), in tegenstelling tot feedback die achteraf gegeven wordt, door feedback te geven op de ontwikkeling van een werknemer, in plaats van alleen op prestaties (Li, Harris, Boswell, & Xie, 2011), en door het aanpassen van de feedbackfrequentie op de gebruikersvoorkeur (Chiviacowsky & Wulf, 2002; Lam, DeRue, Karam, & Hollenbeck, 2011). Op basis van zelfbeschikkingstheorie (Ryan & Deci, 2006) kan worden aangenomen dat de zelfregulerende functie van HSMA's de autonomie en intrinsieke motivatie van werknemers om gezondheidsgedrag te veranderen kan vergroten. Onderzoekers kunnen, om persoonlijke waarden zoals autonomie te waarborgen, kennis inzetten uit het veld van Responsible Research and Innovation (RRI). Dit ondersteunt hen in het ontwikkelen van verantwoorde technologie (Stilgoe, Owen, & Macnaghten, 2013; Von Schomberg, 2013).

Dit proefschrift heeft daarom als doel om te onderzoeken hoe HSMA's verantwoord en effectief kunnen worden ontwikkeld en gebruikt om werknemers te stimuleren gezonder gedrag te laten zien. Het hoofddoel is uitgewerkt door antwoorden te zoeken op de volgende drie subvragen:

1. Welke impact hebben HSMA's die werknemers voorzien van realtime en actiegerichte feedback op het gezondsgerelateerde werkgedrag van werknemers?

2. Stimuleert het gebruik van HSMA's op de werkvloer de autonomie van werknemers inzake zelfregulering van hun gezondheidsgerelateerd gedrag?

3. Hoe kunnen HSMA's voor de werkplek verantwoord worden ontwikkeld, met in hun ontwerp en uitvoering inachtname van inherente waarden en de verantwoordelijkheden van alle betrokken partijen?

Hoofdstuk 2 beslaat de eerste experimentele veldstudie. Deze studie van zes weken vond plaats in een kantooromgeving, waarbij de werknemers een combinatie van sensoren gebruikten om feedback te krijgen op hun gezondheidsgerelateerde gedrag. In dit experiment werd het effect onderzocht van realtime en actiegerichte feedback op gedragsverandering van kantoormedewerkers die tijdens hun werk gebruik maakten van een aantal HSMA's, gericht op het verkorten van zitduur en het voorkomen van mentale vermoeidheid. De resultaten lieten zien dat het ontvangen van realtime, actiegerichte feedback-SMS'jes over het zitgedrag geen impact hebben op de onmiddellijke duur van het zitten. De gemiddelde zitduur nam daarentegen geleidelijk af voor de rest van observatieperiode. De feedback op mentale vermoeidheid verschilde daarvan, omdat de deelnemers daarbij vaker onmiddellijk een pauze namen van het typen, maar hun gedrag over de observatieperiode niet aanpasten.

Hieruit blijkt dat realtime, actiegerichte feedback er niet voor zorgt dat werknemers schadelijk gedrag direct afbreken als zij zelf al konden waarnemen dat ze schadelijk gedrag vertoonden, zoals te lang zitten. Op lange termijn leren ze echter wel om hun schadelijke gedrag te verkorten. Realtime, actiegerichte feedback op vermoeidheid tijdens het typen leidt wel tot directe aanpassingen van het gedrag. Deze feedback heeft dus een direct effect op gedrag waar werknemers zich nog niet bewust van waren, en een langdurig effect op gedrag waar werknemers zich al wel bewust van waren dat het ongezond was. Dit impliceert dat het zitgedrag voor kortere periodes kan worden gemonitord, terwijl typgedrag continu moet worden gemonitord, om zo te zorgen dat werknemers op de lange termijn gezond gedrag vertonen.

In hoofdstuk 3 zijn de resultaten van de tweede veldstudie beschreven, waarin gezondheidsmedewerkers vier weken lang een Fitbit One droegen. In dit hoofdstuk gebruikten we uitkomsten van een vragenlijst en interviews om uit te leggen hoe het gebruik van een HSMA op de werkplek invloed heeft op de mate waarin werknemers voelen dat zij zelf keuzes kunnen nemen met betrekking tot hun gezondheid, de zogeheten ‘waargenomen autonomie’. De waargenomen autonomie kan op het werk of thuis worden beïnvloed, respectievelijk de werkgerelateerde gezondheidsautonomie (WHA) en de thuisgerelateerde gezondheidsautonomie (HHA). In dit hoofdstuk werd onderzocht wat het effect was van de verschillen in focus van de feedback die werd afgegeven door een HSMA op de waargenomen autonomie van een werknemer. Er werden twee focusvarianten van feedback aangeboden: prestatiegericht, die de het verschil toont tussen het aantal stappen van een medewerker en de standaardnorm, en ontwikkelingsgericht, die zich richt op het faciliteren van gedragsverandering. Daarnaast keken wij hoe verschillen in BMI (als proxy-meetwaarde voor gezondheid) het effect van feedback van de HSMA op autonomie modereerden. Uit de resultaten blijkt dat het gebruik van een HSMA geen significante groei van waargenomen autonomie laat zien bij zelfregulatie van gezondheidsgedrag, en dit zelfs kan doen afnemen onder bepaalde omstandigheden. Juist de werknemers die van de HSMA alleen feedback ontvangen op hun prestaties lieten een lagere WHA zien, dan wanneer zij die ontvingen op hun ontwikkeling.

Bovendien bleken werknemers met een hoger BMI de ervaren WHA sterker te verminderen bij prestatiegerichte feedback, dan werknemers met een lager BMI. Werknemers met een hoger BMI die daarbovenop ontwikkelingsgerichte feedback ontvingen, ervoeren een groter verlies aan HHA. Resultaten uit onze verdiepende interviews hebben laten zien dat werknemers met een hoger BMI de extern opgelegde normen en standaarden voor gezond gedrag als dwingend ervoeren, en meer negatieve emoties hadden als de normen niet werden gehaald. Dit maakte hen bewuster van de beperkingen in hun omgeving die het nastreven van gezond gedrag moeilijker maken.

De resultaten toonden aan dat er geen ‘one-size-fits-all’-benadering is als het gaat om het bevorderen van gezondheid op de werkvloer. Om bovenstaande negatieve bijwerkingen op de werkplek te voorkomen, is het onze aanbeveling op HSMA’s op te nemen als onderdeel van een breder programma van gezondheidspromotie. Bij de implementatie zou gebruik moeten worden gemaakt van de ideeën van een gevarieerde groep werknemers, en zou het niet alleen moeten gaan om beweging, maar om een breed scala aan gedragingen, zoals gezond eten, geestelijke gezondheid en algemeen welzijn.

Het onderzoek in dit proefschrift werd uitgevoerd als onderdeel van het project SPRINT@Work. Binnen dit project kwamen we diverse ethische vraagstukken tegen als het gaat om de ontwikkeling en het gebruik van gezondheidsgerelateerde technologie op de werkplek. Deze vraagstukken worden behandeld in hoofdstuk 4. We hebben drie tekortkomingen geformuleerd in het literatuuronderzoek naar de ethiek van nieuwe technologie. Ten eerste, voorgaande studies focussen alleen op de ontwikkeling van nieuwe technologie of op de implementatie daarvan, maar niet op een combinatie van deze twee. Ten tweede, eerdere onderzoeken hebben geen rekening gehouden met de effecten van de specifieke kenmerken van de werkomgeving op de ontwikkeling en het gebruik van technologie. Ten derde, eerder onderzoek heeft niet in kaart gebracht hoe de ontwikkelaars en gebruikers rekening houden met de ethische waarden van alle partijen die betrokken zijn bij het ontwerp en gebruik van nieuwe technologie.

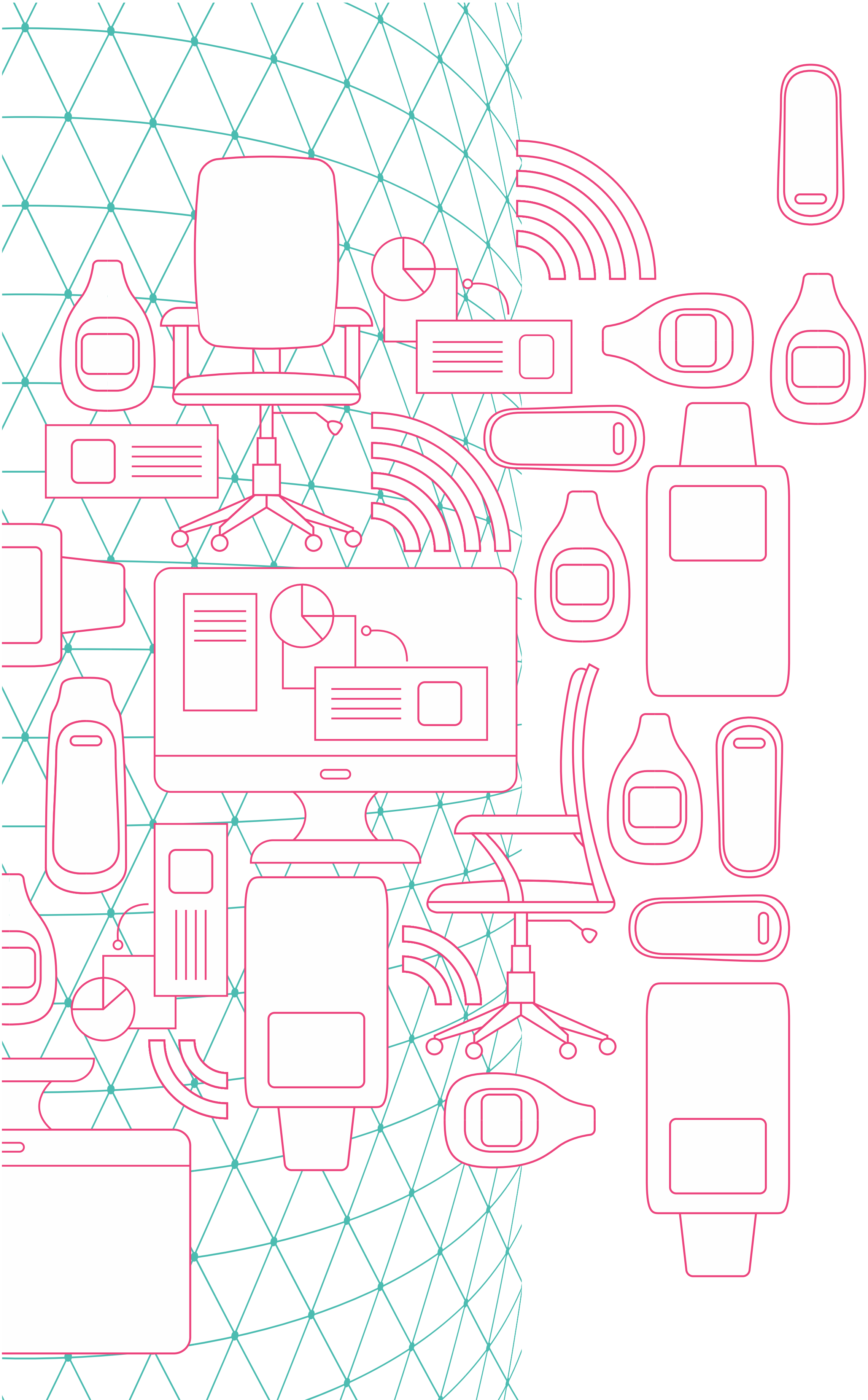
Met de brandweer-casus vanuit SPRINT@Work hebben wij aangetoond hoe contextspecifieke ethiek deze tekortkomingen kon overwinnen. Door huidige privacywetgeving (AVG, 2016), is het een werkgever niet toegestaan om persoonlijke gezondheidsdata van zijn werknemers te verzamelen, zelfs als een werknemer daar toestemming voor zou geven. Niettemin geldt voor de werkgever de plicht zijn werknemers te beschermen (Arbeidsomstandighedenwet, 1999). In geval van brand botst de regelgeving. Onze contextspecifieke ethiek neemt de situationele details mee als het gaat de respectievelijke gevaren van letsel en verlies van privacy. Daarbij gebruiken we de perspectieven van alle belanghebbenden, zoals de brandweerlieden en hun commandanten, als input voor een ethische cyclus, die uitmondde in een aanpak die autonomie gebruikt om de privacy van de werknemer en de verantwoordelijkheid van de werkgever te beschermen. Daarbij lieten we zien dat waarden verantwoordelijkheid, privacy en autonomie niet zo rigide zijn als ze in de regelgeving worden voorgesteld, maar dat de specifieke context hun samenhang bepaalt. Het toepassen van deze contextspecifieke ethiek op de werkplek kan eraan bijdragen om problemen met autonomieverlies te verhelpen.

Hoofdstuk 5 vormt de reflectie op het hoofddoel van dit proefschrift, en de conclusie op de wetenschappelijke en praktische implicatie ervan. Het hoofddoel was om te bestuderen hoe HSMA's verantwoord en effectief kunnen worden ingezet om werknemers te stimuleren gezonder gedrag te vertonen. We concludeerden dat HSMA's kunnen bijdragen aan de gezondheid van werknemers met realtime, actiegerichte feedback op suboptimale gedragingen. Deze realtime feedback leidt in sommige gevallen niet tot gezonder gedrag, maar ook aan de afname van waargenomen autonomie van de minder gezonde werknemers. Door het gebruik van contextspecifieke ethiek kon onderzocht worden hoe inherent ethische waarden werden meegenomen bij de ontwikkeling en het gebruik van technologie, en hoe de implementatie van HSMA’s kunnen bijdragen aan het contextueel begrip van privacy- en autonomieproblemen op de werkplek.

We hebben een multidisciplinaire aanpak gebruikt om de ontwikkeling en het gebruik van HSMA’s op de werkvloer te onderzoeken. Het gebruik van objectieve meetwaarden voor mentale vermoeidheid op de werkplek is innovatief, en biedt nieuwe, veelbelovende onderzoeksrichtingen. Dit proefschrift draagt bij aan het veld van gezondheidsstimulering op de werkplek met het gebruik van feedbackinterventietheorie (FIT) en zelfbeschikkingstheorie (SDT) door te bestuderen hoe HSMA’s werknemers kunnen faciliteren in de zelfregulatie van hun gezondheidsgedrag, en aan te tonen hoe de huidige gezondheid van HSMA-gebruikers de waargenomen autonomie beïnvloedde. Daarnaast toonden we aan hoe contextspecifieke ethiek op basis van het RRI-raamwerk (Stilgoe et al., 2013) verantwoorde HSMA-implementatie op de werkplek kan faciliteren.

Dit onderzoek heeft laten zien dat er geen panacee voor werkgerelateerde aandoeningen bestaat, omdat er te veel practische implicaties zijn die de uitkomsten beïnvloeden. Het gebruik van technologie om de gezondheid van werknemers te verbeteren is veelbelovend, vooral voor nog ongezond gedrag dat werknemers niet zelf kunnen waarnemen. Om alle werknemers te laten profiteren van gezondheidsbevorderende technologie, kunnen werkgevers samen met hun medewerkers en andere belanghebbenden werken aan de implementatie en evaluatie van mogelijke innovaties. Tot slot kan de effectiviteit van zelfmanagement van gezondheid worden verbeterd door een breder gezondheidsprogramma op te zetten binnen het bedrijf, met daarin ook oog voor dieet, geestelijke gezondheid, en leefstijl.

In dit proefschrift hebben we inzichten uit de wetenschapsgebieden sociale geneeskunde, gedragswetenschappen, en verantwoord innoveren gebruikt om een multidisciplinaire blik te geven op het effectief en verantwoord ontwikkelen en gebruiken van HSMA's voor gedragsverandering bij werknemers. Door onze combinatie van kwantitatief en kwalitatief onderzoek, en experimenteel en case-study onderzoek, bieden we een opening voor toekomstig onderzoek naar dit interessante en maatschappelijk relevante onderwerp.



Dankwoord

Ik had mijn promotietraject niet af kunnen ronden zonder een aantal belangrijke mensen, die ik graag in dit dankwoord wil noemen. Mijn promotoren hebben mij afwisselend gemotiveerd, gefrustreerd, en geïnspireerd, waardoor ik het onderzoek uit heb kunnen voeren zoals ik dat gedaan heb. Ik waardeer erg dat we konden samenwerken bij het bedenken, uitvoeren en opschrijven van het onderzoek, maar ook onderling op elkaars expertise durfden te vertrouwen wanneer dat nodig was. Daarnaast heb ik een aantal eigenschappen bijzonder gewaardeerd. Allereerst Hans, bedankt voor je eindeloze en aanstekelijke vertrouwen in een goede afloop. Manda, dankjewel voor je enorme enthousiasmerend vermogen, en Onne bedankt voor het feit dat je me altijd nét iets verder liet kijken. Tot slot, Els, dankjewel voor het toevoegen van het narratief aan mijn promotietraject.

Hartelijk dank aan de leescommissie voor hun waardevolle input. Ute, Stefan en Erik, jullie verschillende perspectieven op mijn onderzoek en de uitkomsten daarvan lieten mij nogmaals zien hoe interessant multidisciplinair wetenschappelijk werk kan zijn.

Tijdens mijn tijd bij Operations ben ik altijd een vreemde eend in de bijt geweest – ik doe namelijk niets dat met operations te maken heeft. Desalniettemin heb ik me er altijd thuis gevoeld, waarvoor mijn hartelijke dank aan de afdeling. Een speciaal dankjewel aan Sabine, mijn onvolprezen kamergenoot en paranimf, en alle andere Smooth Operators, voor alle gezellige lunches, borrels, en weekendjes weg.

Er hebben veel collega's meegedacht over en meegewerkt aan mijn onderzoeksopzetten, de uitvoering van experimenten, en de data-analyse. Ik wil in het bijzonder mijn student-assistenten en afstudeerders bedanken voor hun hulp tijdens en na de experimenten, en mijn collega's Marijke, Hans, en Thom voor hun advies en hulp. Ondanks de eindeloze analyses zonder resultaat ben ik heel blij met jullie hulp, en ik heb erg veel van jullie geleerd.

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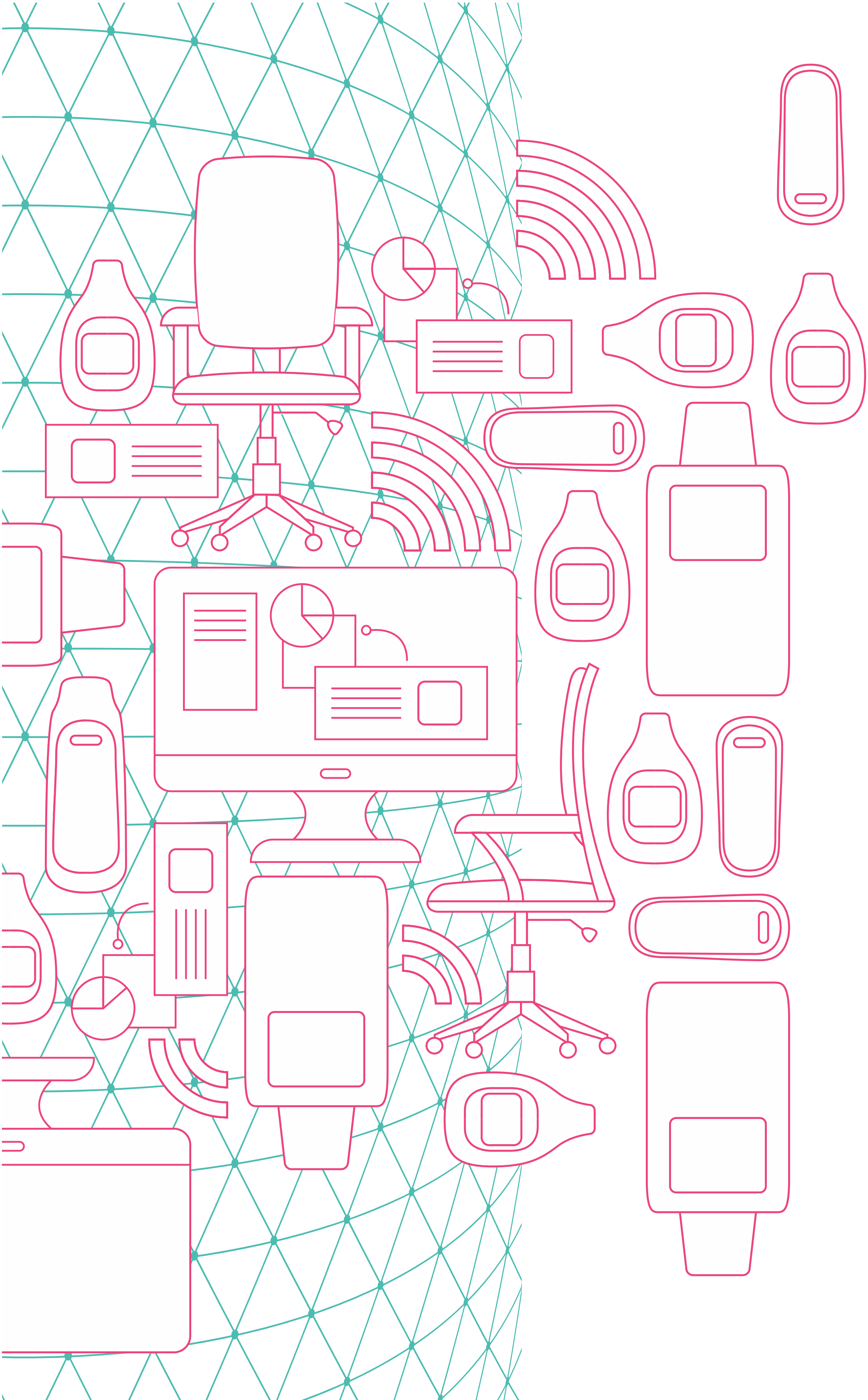
Fleringen, december 2020,
Anne Bonvanie-Lenferink

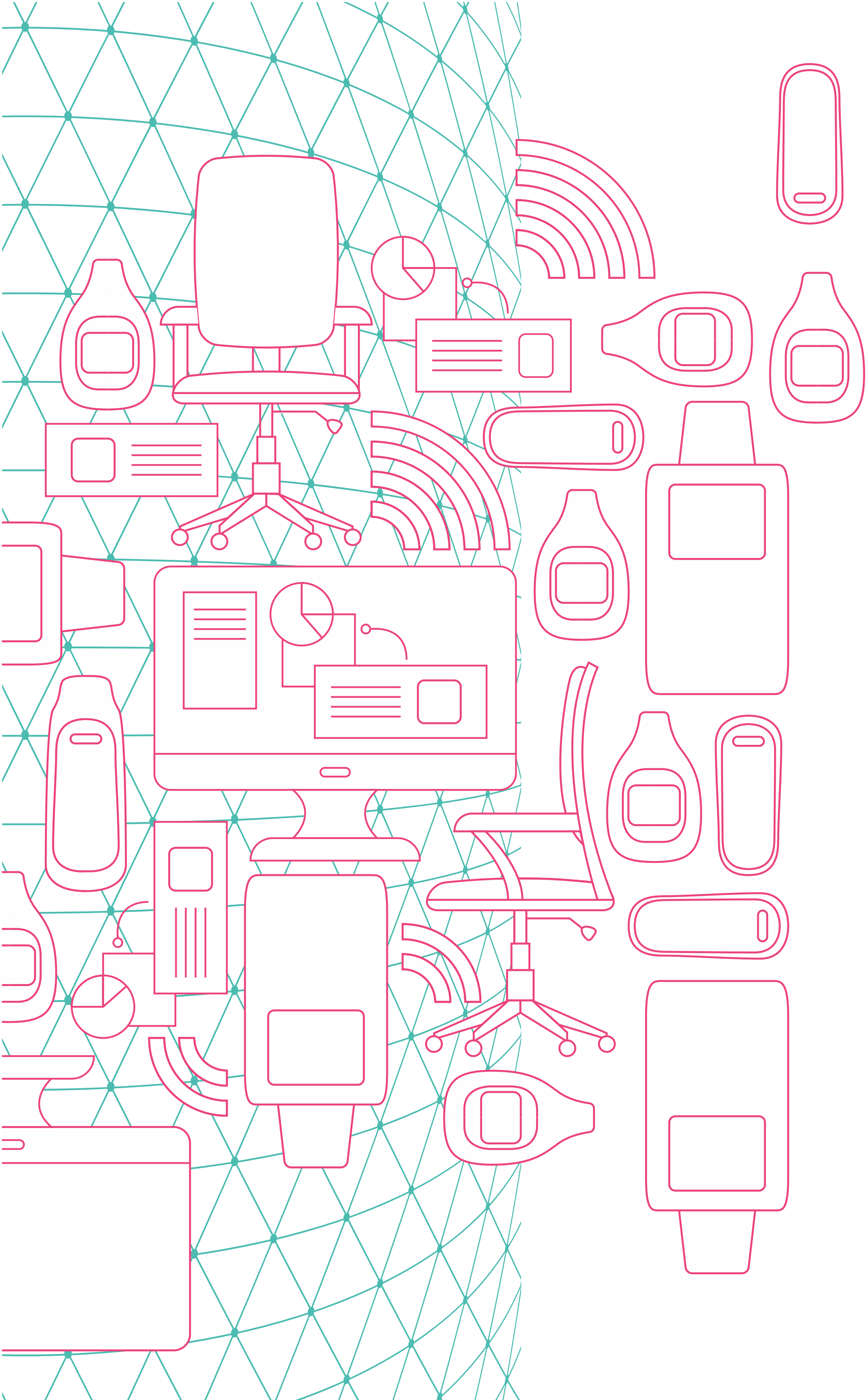


Curriculum Vitae

Anne Maria Lenferink was born on January 17, 1990, in Tubbergen, the Netherlands. She graduated from VWO at Pius X College in Almelo in 2008, and then started in the bachelor program of Industrial Engineering and Management (Technische Bedrijfskunde) at the University of Groningen. In 2012 she obtained her bachelor's degree, with a specialization in Information Engineering. She continued in the master program of Industrial Engineering and Management, and obtained her master's degree (cum laude) in 2014 with two specializations: Information Engineering and Healthcare Management. During her studies, she was a member of multiple representative councils in the faculty and university, was a board and committee member for several student organizations, and was employed as a student assistant for several courses linked to her study program and for the Scholierenacademie.

Starting in the summer of 2014, Anne worked at the department of Operations at the University of Groningen. She was involved in the interdisciplinary research project 'SPRINT@Work', where she was one of four PhD's. SPRINT@Work focused on the development and implementation of technologies that support sustainable employability. She conducted two field experiments and collaborated with companies, researchers, and data-analists in the development and use of a platform for sensor data collection and analysis. During her PhD, she was a member of the faculty council of the Faculty of Economics and Business for four years, in which she paid special attention to improving the opportunities of minorities and junior researchers in the faculty.

Anne currently works as a coordinator Innovation and Healthcare Technologies at Livio, an organization for elderly care in Enschede.



SPRINT@Work

Project description

SPRINT@Work is a project that focused on sustainable employability and specifically on investigating how to keep the aging population healthy and employable until and even beyond their expected retirement. To realise sustainable employability, workers were made aware of their condition by (1) objectively monitoring their cognitive and physical workload and capacity and (2) providing interventions to alter their behaviour to improve their work capacity or lower the workload. Moreover, sensor technologies were developed to enable monitoring, and interventions were created. All of these innovative technologies were validated in controlled laboratory studies, as well as in real-life working situations. Multiple aspects related to workload were investigated, such as cognitive and physical demands, individual responses to these exposures and feedback responses. The project was split into four PhD trajectories:

1. User requirements and needs assessment (Public and Occupational Health, University Medical Center Groningen)
2. Physical workload (Rehabilitation Medicine, University Medical Center Groningen)
3. Cognitive workload (Experimental Psychology, Behavioural and Social Sciences, University of Groningen)
4. Feedback effects and optimisation (Operations, Faculty of Economics and Business, University of Groningen)

SPRINT@Work comprised a broad consortium that included five knowledge institutes, 13 companies involved in the development of sensor technologies and seven pilot companies with workers and employers wishing to maintain a healthy working situation and willing to test the developed sensor and intervention technologies.

Outcomes

According to the needs assessment for workplace health promotion, several workers pointed out that priority should be given to monitoring fatigue, occupational heat stress and exposure to physically demanding jobs using sensor technologies (Spook et al., 2019). Mental fatigue negatively influences productivity during regular working activities.

One way to detect productivity deteriorations in the office environment is by monitoring computer usage, for instance, by monitoring typing behaviour. Therefore, a study was performed to investigate whether typing indices can monitor deteriorations in attentional and memory processes by monitoring changes in neural activation (de Jong et al., 2018). This study was performed in a lab setting. The results showed that both younger and older participants became slower over time, which was reflected in the interkey interval. Moreover, younger adults became less accurate with prolonged task performance. However, they partly corrected for their mistakes using the backspace key. Such changes in the typing indices were correlated with changes in neural activation; that is, those who showed larger deteriorations in attentional and memory processes also showed larger deteriorations in typing performance.

The next question was whether the markers that were found to be susceptible to the effects of mental fatigue in the a lab setting can also describe the behavioural dynamics in the work environment. To answer this question, typing performance data from a real-life office environment were analysed (de Jong et al., 2020). The results showed that the workers' typing speed decreased over time, which was reflected in a larger interkey interval. In addition, the workers used the backspace key more often. Interestingly, these effects of prolonged task performance interacted with the effects of time of day. That is, in the morning, workers were able to perform at a constant speed, with an increase in backspace keystrokes, whereas in the afternoon, both the typing speed, measured by the interkey interval, and accuracy, measured by the percentage of backspace keystrokes, decreased. These results suggest that even though these workers take precautions to counteract the effects of mental fatigue during the day (e.g. drinking coffee or taking breaks), the effects of prolonged task performance accumulate over the day.

A different study investigated how consuming caffeinated beverages may help counteract the effects of mental fatigue (van den Berg et al., 2020). The results showed that, besides its general arousing effects, caffeine can enhance attention towards relevant information, which is specifically helpful in the work environment, where it is important to pay attention to specific tasks.

To monitor the energetic workload of physically active workers as a parameter of physical fatigue, a portable breathing gas analyser was developed and validated (patent pending; Roossien et al., 2021). The proof of concept of this analyser was found to be more valid than heart rate monitoring and more practical than indirect calorimetry with a mouth mask. Its users reported that the headset is more comfortable and more usable than mouth-mask systems. This proof-of-concept version is not yet as good as mouth masks; however, it has potential and provides opportunities for further professionalisation. This headset will be further developed and validated in a follow-up study together with a company specialised in breathing analysis, with the aim of making this system available not only for a large target group of workers, but also for rehabilitation and sports applications.

To monitor occupational heat stress, a wearable core thermometer was developed and validated against a commercially available wearable thermometer. Despite the good usability of these thermometers, they are not yet suitable for measuring the core temperature while performing physically demanding jobs (Roossien et al., 2020). In a follow-up project, a new technology will be developed to fulfil the need for such a device. A suit equipped with sensors was used to investigate the exposure of physically demanding jobs. This suit monitored work postures and related back muscle activity and automatically calculated the net moment of the lower back with a specially developed artificial neural network based method. This technology was validated on different types of workers, and its function was also demonstrated. However, both the sensor system and software require further development before validating the function of the system in an operational work environment. A smart chair equipped with sensors was used to measure the physical load of office workers. Although the feedback signal did not improve the sedentary behaviour, this smart chair was a useful non-obstructive tool for monitoring the sitting behaviour of office workers (Roossien et al., 2020). Indeed, these systems and technologies will be further developed and validated in follow-up studies and will be made available for workplace health promotion.

To allow workers to benefit from such sensor and intervention technologies in the workplace, the effectiveness and effects of such technologies on employee autonomy were studied in two experimental field studies. The first study investigated the effects of real-time actionable feedback on workers' sitting and typing behaviour, in which the typing behaviour is considered a measure of fatigue. If a worker receives feedback messages on fatigue, they alter their typing behaviour almost immediately. However, if they receive feedback on their sitting behaviour, they alter their sitting behaviour only in the long term. This difference is explained by the fact that workers are considerably able to estimate their sitting bouts but hardly able to assess their level of fatigue. These findings show that workers are willing to alter their behaviour if they receive new information, as in the case of the typing behaviour. However, if they can self-monitor their behaviour, as in the case of the sitting behaviour, they show a learning effect over a longer period of time (Bonvanie, 2021).

The second study examined the effects of workers' use of health self-management applications in the work environment on their perceived autonomy in self-regulating their health-related behaviour. The results showed that workers experience a decline in their perceived autonomy either at home or at work or even both, depending on the type of feedback that they receive, and that this effect is strongest for employees with a high body mass index (BMI). Employees with a high BMI experience more negative emotions when they receive feedback pertaining to not reaching the given norm for physical exercise, and they become more aware of their work environment limitations that prevent them from altering their daily behaviour.

During SPRINT@Work, a context-sensitive perspective was used to contextualise ethical issues in both the development and implementation of sensor and intervention technologies for the work environment. The results of this context-sensitive analysis of ethics showed that the current legal framework for the privacy of workers limits the employers' opportunities to take full responsibility for the workers' health. This can, however, be solved using an agency-based approach, in which specific employees with clear roles (agents) have the power to use the personal data of other workers for specific reasons. Additionally, the autonomy of workers using sensor and intervention technologies is affected when the workers are not by default enabled to uphold their own norms and values but rather perceive the norms inherent to the design of these sensor and intervention technologies as pressing. These insights show that applying a context-sensitive approach of ethics may enhance the position of both workers and employers and provide valuable input for future research regarding technologies aimed at health improvement in the workplace.

Contribution to journals

The following scientific contributions are the current result of SPRINT@Work.

Journal publications and patents

Roossien, C.C., Krops, L.A., Wempe, J.B., Verkerke, G.J. & Reneman, M.F. (2021). Can we analyze breathing gasses without a mouth mask? Proof-of-concept and concurrent validity of a newly developed breathing gasses analyzing headset. Applied Ergonomics, vol. 90, pp. 103266.

De Jong, M., Bonvanie, A.M., Jolij, J. & Lorist, M.M. (2020). Dynamics in typewriting performance reflect mental fatigue during real-life office work. PloS ONE 15(10):e0239984.

Van den Berg, B., de Jong, M., Woldorff, M.G. & Lorist, M.M. (2020). Caffeine boosts preparatory attention for reward-related stimulus information. Journal of Cognitive Neuroscience, 1-15.

Bonvanie, A., Broekhuis, H., Maeckelberghe, E., Janssen, O. & Wortmann, J.C. (2020). Health Self-Management Applications in the Work Environment: the Effects on Employee Autonomy. Frontiers in Digital Health, 9:2.

Roossien, C.C., Heus, R., Reneman, M.F. & Verkerke, G.J. (2020). Monitoring core temperature of firefighters to validate a wearable non-invasive core thermometer in different types of protective clothing: concurrent in-vivo validation. Applied Ergonomics, vol. 83, pp. 103001.

Spook, S., Koolhaas, W., Bultmann, U. & Brouwer, S. (2019). Implementing sensor technology applications for workplace health promotion: A needs assessment among workers with physically demanding work. BMC Public Health, vol. 19, pp. 1100.

Roossien, C.C., Verkerke, G.J. & Reneman, M.F. (2019). Patent: Instrument, system and method for use in respiratory exchange ratio measurement, application number: EP19189792.5.

Riethmeister, V. (2019). Sleep and fatigue offshore. PhD thesis.

de Jong, M., Jolij, J., Pimenta, A. & Lorist, M. (2018). Age Modulates the Effects of Mental Fatigue on Typewriting. Frontiers in Psychology, vol. 9, nr. 15, p. 1113.

Roossien, C.C., Reneman, M.F. & Verkerke, G.J. (2018). Werkbelasting meten met sensortechnologie (Dutch). Fysiopraxis, vol. 3, pp 18-20.

Roossien, C.C., Stegenga, J., Hodselmans, A.P., Spook, S.M., Koolhaas, W., Brouwer, S., Verkerke, G.J. & Reneman, M.F. (2017). Can a smart chair improve the sitting behavior of office workers? Applied Ergonomics, vol. 65, pp.335-361.

Other work

Roossien, C.C., Hodselmans, A.P., Heus, R., Reneman, M.F. & Verkerke, G.J. (submitted). Evaluation of wearable non-invasive thermometer for monitoring deep body temperature in performing physically demanding occupations.

Roossien, C.C., Bonvanie, A.M., de Jong, M. & Maeckelberghe, E.L.M. (submitted). Ethics in Design and Implementation of Technologies for Workplace Health Promotion.

Bonvanie, A.M. (2021). Real-time, actionable feedback and office workers' sitting behaviour and mental fatigue: An experimental field study. Thesis chapter.