Health Self-Management Applications in the Workplace

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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.