Tampere University

PÄIVI HEIKKILÄ

Design Research Studies of Digital Solutions for Supporting Well-Being at the Changing Workplace

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Tampere University, Faculty of Information Technology and Communication Sciences
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Responsible supervisor and Custos
Professor Kaisa Väänänen
Tampere University
Finland

Supervisors
Dr Eija Kaasinen
VTT Technical Research Centre of Finland
Finland

Pre-examiners
Professor Åsa Fast-Berglund
Chalmers University of Technology
Sweden

Professor of Practice Virpi Roto
Aalto University
Finland

Opponent
Professor Marko Nieminen
Aalto University
Finland

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PREFACE

I started my work for this thesis in 2014, when we kicked off the project for studying the positive side of stress. After conducting numerous user experience studies and human-driven research related to different topics, this was the first project at VTT that I had been preparing from the very beginning, and thus it felt special. For the first time as a researcher, I knew that I could spend a longer time for design research on the same topic, and saw this as an opportunity to start my post-gradual studies and thesis work.

I feel grateful for the support and opportunities that I have been given during this design research journey. First, I want to thank my supervisor Professor Kaisa Väänänen, who has given me encouraging guidance throughout my work. It has always been easy to ask for help and support from Kaisa, and she has given excellent advice both in defining the aims of the research as well as in practicalities related to the process. I also want to thank my VTT supervisor, Principal Scientist Eija Kaasinen, who has given insightful comments of all the articles of the thesis as well as the final manuscript – even when being busy or on vacation! They both helped me finding the right track and staying on it while the work proceeded.

I want to thank Professor of Practice Virpi Roto and Professor Åsa Fast-Berglund for pre-examination of the thesis and their valuable feedback. I also want to thank Professor Marko Nieminen for kindly accepting the invitation to be the opponent of my doctoral defence.

I want to thank all the co-authors of the publications of the thesis as well members of the two research projects in which the studies have been conducted. Related to Eustress research project I want to thank Virpi Oksman, who initiated the project with me, as well as Mari Ainasoja, Kati Tikkamäki and Sanna Rytövuori, who did not only give their valuable professional expertise for the research but also made the project work inspirational and fun, and became more than colleagues to me. I want to thank Elina Mattila for fruitful co-operation, for increasing my knowledge of digital health interventions and for co-authoring the articles. I also want to thank Kirsikka Kaipainen for the excellent implementation of the Eustress service, co-designed in the project, and flexibility in the maintenance of the service.

Related to Factory2Fit research project, I want to thank Anita Honka for inspirational co-design of the digital solution and for co-authoring the publications. I also want to thank Eija Kaasinen, again, for excellent coordination of the project and Susanna Aromaa and Marja Liinasuo for smooth and fun collaboration. In addition, I want to thank Timo Kinnunen and Juha Leppänen for their implementation work of the created digital worker feedback application.

During the thesis work, I have also been involved in other research projects, mainly related to social and service robotics. This project work has given good counterbalance to the thesis work by enabling me to focus also on other interesting research topics, besides well-being at work. This work has strengthened my research skills and provided a plenty of fun experiences in the field and the lab. I want to thank Hanna Lammi, Marketta Niemelä, Antti Tammela, Petri Tikka and others who have collaborated in the projects. In addition, I want to thank my dear colleagues who have helped me to recover and detach from work at the coffee breaks: Minna Kulju, Jaana Leikas, Janika Miettinen, Antti Väätänen, Tiina Kymäläinen and others. I also want to thank Antti Väätänen for technical support for the thesis.

This work would not have been possible without funding organisations for the research. I want to thank Business Finland (former Finnish Funding Agency for Innovation, Tekes) for funding the research project 'Eustress – Energy from stress' (2014-2016). The research conducted within Factory2Fit project (2016-2019) was enabled by funding from Horizon 2020, the European Union's Programme for Research and Innovation under grant agreement no. 723277. I also want to thank the Finnish Society of Automation for a grant for finalising my thesis.

Finally, I want to express my warmest thanks to my family. You mean the most to me. Thank you Olli for supporting me, listening to my informal status reports of this work and helping me to detach from thesis-related thoughts by taking me to walks and outdoors after workdays. Thank you Anni and Aleksi for bringing so much joy and meaning to my life, and patiently giving me the opportunity to concentrate on my thesis - even though it was not always easy during the exceptional spring 2020 when we all were studying and working from home due to COVID-19 pandemic. I also want to thank my parents Helka and Seppo, my parent-in-laws Leena and Pekka, and all dear friends for your love and support.

Tampere 6.10. 2020
Päivi Heikkilä

ABSTRACT

Working life is constantly changing, which requires adaptation from workers. In several fields and occupations, from entrepreneurs to factory workers, the nature of work is changing, for example due to increased digitalization and automation. Workers need self-reflection and self-leadership skills to manage with the new requirements and uncertainties related to the changes. In addition, paying attention to one's well-being, along with work results, becomes increasingly important.

Different approaches can be utilized to support well-being at the changing workplace. This compound thesis approaches this with two design research studies. In the entrepreneurial context, well-being is approached from the perspective of the positive side of stress (eustress). The entrepreneurs' experiences of positive stress are studied with multiple qualitative methods, and based on the results, a web service for fostering positive stress is designed and implemented. In the factory floor context, well-being is approached from the perspective of providing quantified feedback for workers. Based on a background study, a smart phone optimized web application is designed and implemented to enable workers to receive personal and encouraging feedback related to their personal well-being and productivity. The user experience, acceptance and perceived benefits of both digital services are studied through a long-term field study. The research results in five design recommendations for designing digital solutions that support well-being at the changing workplace. The recommendations encourage designers to design digital solutions that *provide encouragement and recognition*, *enable self-reflection*, *support focusing on the essential*, *integrate to daily practices*, and *inspire and inform through peer experiences.*

This research contributes primarily to the field of human-computer interaction by widening the prevalent approaches of design for well-being and providing pragmatic design guidance through empirical understanding of two different user groups that are at the forefront in facing the demands of the changing working life. The research gives new knowledge of means to foster positive stress in daily life and the potential of applying the approach of Quantified Self to the modern factory floor. Furthermore, the research raises the importance of ethical questions that need to be considered when designing new solutions or adopting them at workplaces.

CONTENTS

ORIGINAL PUBLICATIONS

This thesis is based on the following six original publications, which are referred to as P1-P6. The publications are reproduced with the permission of the publishers.

Publication I Heikkilä, P., Ainasoja, M., & Oksman, V. (2015). The potential of technology in facilitating positive stress experiences. In *Proceedings of the European Conference on Cognitive Ergonomics 2015 (ECCE'15)*, 27-37. ACM, New York, NY, USA.

Publication II Heikkilä, P., Mattila, E., & Ainasoja, M. (2018). Designing a eustress toolbox: From entrepreneur experiences to an online service. *Human Technology*, *14*(2), 233-257.

Publication III Heikkilä, P., Mattila, E., & Ainasoja, M. (2019) Field study of a web service for stimulating the positive side of stress: entrepreneurs' experiences and design implications. *BMC Medical Informatics and Decision Making 19 (200).*

Publication IV Heikkilä, P., Honka, A., Mach, S., Schmalfuß, F., Kaasinen, E., & Väänänen, K. (2018) Quantified factory worker – expert evaluation and ethical considerations of wearable self-tracking devices. In *Proceedings of the 22nd International Academic Mindtrek conference (Mindtrek'18),* 202-211. ACM, New York, NY, USA.

Publication V Heikkilä, P., Honka, A., & Kaasinen, E. (2018) Quantified factory worker: designing a worker feedback dashboard. In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction (NordiCHI'18),* 515-523. ACM, New York, NY, USA.

Publication VI Heikkilä, P., Honka, A., Kaasinen, E., & Väänänen, K. Quantified factory worker: field study of a data-driven feedback application supporting well-being at work. **Submitted to** *Cognition, Technology & Work*.

AUTHOR'S CONTRIBUTIONS

Publication 1: The user study was conducted together with the project members, led by Heikkilä. Heikkilä was responsible for the user research, analysis of the data, formulating the findings and writing the publication.

Publication 2: The design study was conducted together with project members, led by Heikkilä. The research data was analyzed and the service was designed together with the project members. Heikkilä was responsible for user research and writing the publication.

Publication 3: The field study was designed and carried out together with the project members, led by Heikkilä. While Mattila was responsible for the usage analysis and the statistical analysis of the data, Heikkilä was responsible for conducting the user interviews, analyzing the qualitative data, deriving the design implications and writing the publication.

Publication 4: The study was conducted together with the project members. While Honka was the main responsible for conducting the expert evaluation, Heikkilä was responsible for analysis of the data, conducting the ethics assessment and writing the publication.

Publication 5: The design study was carried out together with the project members. While Honka had the main responsibility of the application design, Heikkilä was responsible for data collection and analysis, defining the user experience goals, deriving the design guidelines and writing the publication.

Publication 6: The field study was designed and conducted together with the project members. Heikkilä was responsible for collecting the user data. While Honka was responsible for the usage analysis, Heikkilä was responsible for analyzing the rest of the data, deriving the design implications and writing the publication.

1 INTRODUCTION

This chapter first describes the motivation for this research. Second, it defines the research scope and the research contexts. Then, it states the objective of this research, lists the research questions, and gives an overview of the research approach and process. Finally, it describes the scientific and practical contributions of the thesis.

1.1 Motivation

Working life is constantly changing, which requires adaptation from workers. In several fields and occupations, from entrepreneurs to factory workers, automation and digitalization are changing the nature of work. During the recent decades, work has been seen to become more demanding, for example requiring more flexibility and entrepreneurship from workers (Hautamäki, 2001). The workers need self-reflection and self-leadership skills to manage with the new requirements and uncertainties related to the changes. These skills become particularly important when the level of freedom in designing one's work increases and the worker is expected to take more responsibility of one's ways of working and reaching one's goals. In the middle of new requirements and expectations, taking care of one's well-being, along with work results, is increasingly important.

Even though the changes in working life concern almost all fields and occupations, the challenges that the workers face vary in different work contexts. In entrepreneurial work, positive drive is needed to be able to use one's full potential when working. Entrepreneurs often have the freedom to arrange their schedules and ways of working. This creates a possibility and a need to balance one's time to achieve the intended work results and to ensure sufficient recovery from work. In factory floor work, the work is far more controlled, but increasing digitalization and automatisation decrease the amount of routine tasks and gradually change the nature of work towards knowledge work. Factory floor work is becoming more autonomous, demanding problem-solving skills as well as managing of complexity

(Gorecky et al., 2014). The changing workplace creates a need for paying attention to one's well-being and following one's progress in work related tasks. At the same time, it provides opportunities for self-development.

Different methods and approaches can be utilized to support workers at the changing workplace. Workers' well-being can be supported on individual, group or organisational level, for example through improving working conditions, providing opportunities to competence development, or implementing health promotion campaigns (e.g. Buffet et al., 2013). The methods can be related to improving work practices, for example through organisational renewal, encouraging leadership, mentoring or job design or they can aim at disease prevention and health promotion for example through stress management interventions. Digital solutions, such as web services, mobile applications and wearable health trackers, have increased the range of possibilities to track and enhance well-being at work, both on organisational level and individually. Digital platforms can facilitate adoption of well-being services by offering affordable, anonymous and self-paced access to the services (Portnoy et al., 2008). Still, digital well-being solutions share the challenges of low participation and low engagement (Eysenbach, 2005, Mattila et al., 2013).

Novel digital solutions are needed to support workers at the changing working place – not only to receive information on health and well-being, but also to challenge workers to see their ways of working from a new perspective. This design research aims at studying engaging technological solutions that approach this challenge from novel, positive perspectives: through the phenomenon of *positive stress* and through providing encouraging *quantified feedback* for workers.

1.2 Research scope and contexts

This research belongs primarily to the field of *Human-Computer Interaction* (HCI). More specifically, this design research can be seen contributing to the areas of *human-centered design* (ISO, 2010) as well as *design for well-being* and *positive approaches to design* (Desmet & Hassenzahl, 2012; Desmet & Pohlmeyer, 2013; Calvo & Peters, 2014). In this research, user experience, user acceptance and perceived benefits of the designed artefacts are studied, but assessing long-term impacts of the solutions is beyond the research scope.

Besides the field of HCI, the contributions benefit the understanding of well-being at work. Well-being at work is approached as a combination of job satisfaction and work engagement (Schaufeli & Bakker, 2010). As engaged workers are

characterized as energetic, willing to invest efforts in their work as well as persistent when facing challenges (Schaufeli et al., 2002), their well-being has potential to contribute to their personal productivity. Well-being and productivity at work are intertwined, and research has suggested a reciprocal relationship between them. For example, work engagement has been associated with personal initiative and performance (Schaufeli and Bakker, 2010), important for productivity. Furthermore, achieving results enhances the sense of competence and confidence, which have been associated with enhanced well-being (Carver & Scheier, 1999; McGregor & Little, 1998).

The themes of the research are studied in two work contexts: entrepreneurial work and factory floor work. In the entrepreneurial context, the research gives new information of the phenomenon of positive stress in the daily lives of entrepreneurs and means to feed it through new ways of thinking and working. In the factory context, the research contributes to the theme of worker-centered research for factories of the future by applying the approach of *Quantified Self* (Wolf, 2010) to the factory floor, and thus giving understanding of the concept of *quantified worker*, which is used in this thesis to refer to the practice of self-tracking in work contexts.

The experiences of positive stress were studied in the entrepreneurial work context. In this research, the term entrepreneur refers to small business owners or self-employed workers. Beyond that, we expect the results of the study to be applicable to the work contexts that demand entrepreneur-like mindset and skills from employees. Entrepreneurs were selected as a user group for this research, as entrepreneurial work may subject them to high levels of stress due to the risks in business activities (Palmer, 1971), heavy workloads and a higher-than-average need for achievement (Langan-Fox & Roth, 1995). However, many entrepreneurs have traits and skills that help them in stressful situations, such as high stress tolerance (Frese, 2009) or high levels of psychological capital, constructed of self-efficacy, optimism, hope and resilience (Baron et al., 2016). These reasons make entrepreneurs an interesting user group for our research. Due to their strengths in stress management, their ways of managing stress can provide a lot to learn to other entrepreneurs or employees. In addition, they may be interested in finding new ways of managing stress, because effective stress management is critical in entrepreneurial work. Besides this, considering one's well-being is especially important for entrepreneurs, since in Finland, they often lack preventative occupational health services (WHO, 2012).

The theme of quantified feedback was studied in the factory floor context. In factory floor work, the fourth industrial revolution, *Industry 4.0*, is increasing

digitalization and automation, which are assumed to make the work more autonomous and to create opportunities for self-development (Gorecky et al., 2014). The change in the factory floor has been characterized as *Operator 4.0* (Romero et al., 2016), referring to the factory workers of the future, who are assisted by automated systems and allowed to use their creative skills. Factory floor workers form an interesting user group, as the trends of automation and digitalization are changing their work towards knowledge work, and skills, such as problem solving and managing complexity, become increasingly important for them (Gorecky et al., 2014). The change comes with many positive aspects, such as opportunities to make the work more interesting and meaningful, but it creates also needs for staying aware of one's work performance and paying attention to one's well-being along with work results. Quantified feedback can be one opportunity to enhance awareness of work results and personal well-being in an interesting way in the factory floor context.

1.3 Research objective and questions

The aim of this design research is to study new human-centric technology-mediated ways to enhance well-being at the changing workplace. This is addressed through two studies that approach well-being from novel, positive perspectives: by fostering the positive side of stress in the context of entrepreneurial work and by providing encouraging quantified feedback in the factory floor context. The research questions (RQs) of the study are following.

RQ1: What are the central design elements for fostering positive stress through a digital solution in the context of entrepreneurial work?

From the perspective of user understanding, this RQ focuses on design elements that include ways of thinking and working that facilitate entrepreneurs' experiences of positive stress. This understanding is applied in designing a digital solution, a web-based digital service for fostering positive stress.

RQ2: What are the central design elements for providing quantified feedback through a digital solution in the context of factory floor work?

This RQ addresses the targeted user experience for a digital service for providing quantified feedback in factory floor work. The targeted user experience is expressed as user experience goals, which guide the design of a personal digital application and realize as design elements.

RQ3: What design recommendations can be identified for digital solutions that support well-being at the changing workplace?

This RQ focuses on design recommendations for digital solutions that support well-being at work, particularly when facing changes that require self-leadership and self-reflection skills from workers. Based on the knowledge gained through RQ1 and RQ2, as well as design implications of field studies of the created digital solutions, this RQ synthesizes the gained insights. The insights are synthesized to the form of design recommendations relevant in the design of digital solutions that can foster well-being at work, and through increased well-being have potential to enhance also personal productivity.

1.4 Overview of the research approach and process

This design research consists of two human-centric user studies. Both studies follow *Research through Design* approach (Zimmerman et al., 2007) as well as human-centered design process (ISO, 2010) from gaining insights of the experiences and needs of the target group, designing a digital service based on the gained insights and evaluating the service through a field study. The experiences of the target group were relevant in all stages of the process: experiences of the phenomenon studied when gaining initial understanding, user experience goals and users' impressions while designing a prototype and user experience of the designed and implemented prototype during the field study.

To gain a rich understanding of the research subjects and meaningful experiences, an empirical and mainly qualitative research approach was selected. The approach was based on a dialogue with users following the principles of the *participatory design* process (Schuler & Namioka, 1993; Muller & Kuhn, 1993), involving users in the design in several phases of the studies. Multiple methods were used especially when gaining initial understanding, but also when evaluating the user experience, user acceptance and perceived benefits of the designed digital solutions.

Figure 1 presents the two studies and their phases. Each publication of the thesis focuses primarily on one study phase.

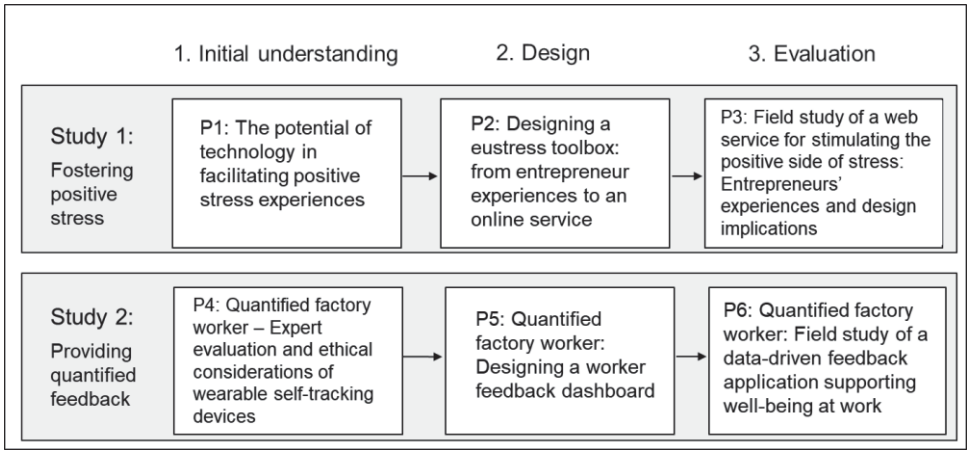

Figure 1. Research process of the studies, following the Research through Design approach.

1.5 Contributions

The primary contribution of the research is to provide knowledge of design recommendations for designing for well-being at the changing workplace. The contributions of this work are both theoretical and practical. In the theoretical level, the research increases understanding of means to foster positive stress, especially in entrepreneurial context, and highlights relevant factors in providing quantified worker feedback in a factory floor context. We apply this knowledge in practice in designing two fully functioning, high-fidelity service prototypes that aim at enhancing workers' well-being in the selected work contexts. The results of the user experience, user acceptance and perceived benefits of the service prototypes lead to design recommendations that benefit also HCI practitioners designing for well-being, in the selected work contexts and beyond. More broadly, this work contributes to HCI by widening the prevalent approaches of design for well-being and by providing empirical understanding of user groups that have received less attention in HCI research.

This research sheds light on the positive side of stress, which has remained as an understudied area in HCI as well as in stress research. Even though literature describes the positive side of stress as a concept, empirical research is needed to understand the everyday experiences of it and ways to foster it in one's daily work and life. Positive stress is studied through the experiences of entrepreneurs, with a goal to learn from their experiences and work practices, and share the insights

through a digital service. As entrepreneurial mindset and self-leadership are required from a growing number of employees, the contributions of this study extend to these employees, who may struggle with effective stress management even more than entrepreneurs.

Applying Quantified Self approach to a factory context is a novel research topic in HCI. Although trials of tracking health and well-being metrics at work have rapidly increased in recent years, only few studies focus on the user experience of the workers (Chung et al., 2017). The studies have typically been conducted in office context, and thus understanding of other work contexts is scarce. Besides the theme of quantification, factory floor is not a very typical user context in other HCI related research either. While safety and ergonomics aspects have been considerably addressed in the factory context, research focusing on user experience or HCI has been less prominent (Meneweger et al., 2018). In particular, the number of field studies has remained low, which may be due to the restricted accessibility and complexity of the factory context (Ardito et al., 2014). Besides shedding light to factory floor context with a new field study, this work contributes to the theme of factories of the future, by including participants who can be seen as early representatives of Operator 4.0 vision (Romero et al., 2016).

The results of our research are addressed through the three research questions. Responses to the research questions crystallize the main contributions of the research. First, RQ1 and RQ2 provide knowledge of the design guidelines and central design elements that support fostering positive stress and providing encouraging quantified feedback. Based on the gained knowledge, digital solutions are designed and implemented. RQ3 provides understanding of the design implications gained through long-term field studies of the new solutions, and synthetizes these implications to the design guidelines, addressed by RQ1 and RQ2. Finally, RQ3 synthetizes the results to a form of design recommendations that support also other designers to design for well-being at work, especially when facing changes of the working life, which require self-leadership and self-reflection skills from the workers. Table 1 shows the relation of the research questions and the publications 1-6 (P1-P6) of the thesis.

Table 1. The publications' contributions to the research questions.

Research questions		Publications					
		P1	P2	P3	P4	P5	P6
RQ1	What are the central design elements for fostering positive stress through a digital solution in the context of entrepreneurial work?	x	x				
RQ2	What are the central design elements for providing quantified feedback through a digital solution in the context of factory floor work?				x	x	
RQ3	What design recommendations can be identified for digital solutions that support well-being at the changing workplace?		x	x		x	x

1.6 Structure of the thesis

The rest of this thesis is structured as follows. Chapter 2 introduces the key concepts and presents the selected approaches, fostering positive stress and providing quantified feedback, for enhancing well-being at the changing workplace. In addition, relevant design frameworks are introduced. Chapter 3 presents the design research process and methods of each research phase. Chapter 4 summarizes the results of the publications, before Chapter 5, which presents the results of the research by responding to the three research questions of the thesis. Finally, Chapter 6 discusses the scientific and practical contributions of the thesis, ethical considerations, trustworthiness of the research and opportunities for future research.

2 BACKGROUND AND RELATED WORK

This chapter grounds the research of this thesis by providing background and related work on design for well-being at work as well as the themes of positive stress and quantified worker. In addition, the section introduces design frameworks relevant to our research. First, we define the central concepts of the thesis.

2.1 Central concepts

Well-being: The Oxford dictionary defines well-being as "the state of being comfortable, healthy or happy" (www.lexico.com). More precisely, according to Diener et al. (2009), the components of subjective well-being include people's emotional responses (positive and negative affect), domain satisfactions (satisfaction related to domains of life, such as work or health) and overall judgment of life satisfaction. Subjective well-being is connected to the person's physiological reactions. In this thesis, Study 2 approaches well-being through physiological indicators, such as heart rate and quality of sleep that are referred to as well-being metrics.

Well-being at work: Well-being at work can be defined broadly as a concept that concerns all aspects of working life, from the quality and safety of the working environment to the workers' feelings about their work (ILO, 2020). According to a more precise definition by Schaufeli and Bakker (2010), the concept refers to the psychological state of job satisfaction and work engagement. Job satisfaction results from appraisal of one's job and job experiences (Locke, 1976), while work engagement refers to a positive, fulfilling work-related state of mind (Schaufeli et al, 2002). As engaged workers are characterized as energetic, willing to invest efforts in their work as well as persistent when facing challenges (Schaufeli et al., 2002), the impact on well-being has potential to contribute also to the personal productivity of workers.

Positive stress or **eustress**: The term positive stress, also known as eustress, refers to the beneficial side of stress (Selye, 1974) or more exactly, to the positive response to stressors (Simmons & Nelson, 2007). Based on interpretation of stressors, a

person may perceive a stressor as a negative threat or a positive challenge (Le Fevre et al., 2006), and a response to it can take a form of positive or negative psychological states, emotions, attitudes and behaviors (Simmons & Nelson, 2007).

Quantified Self: The term Quantified Self refers to self-tracking of biological, physical, behavioral or environmental data (Swan, 2013). The term was introduced by Wolf and Kelly, who created a website for sharing self-tracking practices in 2007 (www.quantifiedself.com) and thus promoted the movement of gaining "self-knowledge through numbers" (Wolf, 2010). After that, the term has been used for the practice of self-tracking as well as for the movement and international community of people practicing self-tracking. The main goal of the Quantified Self practice is to gain meaningful insights based on the self-tracking data, which has the potential to lead to positive behavioral changes (Choe et al., 2014).

Quantified worker: Based on the approach of Quantified Self (Wolf, 2010), in this thesis, a term quantified worker is used to refer to the practice of self-tracking in work contexts, which may be enabled or proposed by the employer. Consequently, the term *quantified worker solution* refers to a digital solution employing self-tracking data, such as a data-driven feedback application.

Quantified feedback: The term quantified feedback or *data-driven feedback* refers to worker feedback that is provided through a digital system based on data collected of the worker, work performance or other quantifiable metrics at the workplace. The intention is to give meaningful insights for the worker, in line with the goal of the Quantified Self practice (Choe et al., 2014). In the research of this thesis, quantified feedback in a factory context is aggregated of well-being metrics collected through a wearable self-tracking device used by a worker and production data from the manufacturing line operated by the worker. In the context of this thesis, quantified feedback is provided only for the worker, not for the employer.

2.2 Design for well-being at work

This section presents background and related work of perspectives central to understanding the potential and approaches of design for well-being at work. Concerning more practical design guidance, the section refers to relevant frameworks, which are explained in more detail in Section 2.4.

2.2.1 Well-being at work

The term subjective well-being is a complex construct that can be approached from several perspectives. The perspectives can be divided to a medical approach, which approaches well-being mainly as the absence of illness or dysfunction, a hedonic approach, which emphasizes positive emotions and pleasurable experiences and eudaimonic approach, which approaches well-being through fulfilling one's potential and finding meaning in life (see e.g. Calvo & Peters, 2014). According to Diener et al. (2009), the components of subjective well-being include people's emotional responses (positive and negative affect), domain satisfactions (satisfaction related to domains of life, such as work or health) and overall judgment of life satisfaction.

In the work context, well-being can be approached as a broad concept that relates to all aspects of working life, from the quality and safety of the working environment to the workers' feelings about their work (ILO, 2020). According to a more specific definition by Schaufeli and Bakker (2010), well-being at work refers to the psychological state of *job satisfaction* and *work engagement*. Job satisfaction can be described as a positive emotional state resulting from appraisal of one's job or job experiences (Locke, 1976) or more straightforwardly, as the extent to which people like or dislike their jobs (Spector, 1997). It incorporates various aspects related to work, such as the nature of work, salary, colleagues and working conditions (Spector, 1997).

Although job satisfaction is important for workers, work engagement is a deeper and more intrinsic construct. It is defined as "a positive, fulfilling work-related state of mind, which is characterized by vigor, dedication and absorption" (Schaufeli et al., 2002, p.74). Consequently, engaged workers are described as energetic, willing to invest efforts in their work as well as persistent when facing challenges (Schaufeli et al., 2002). Both job resources and personal resources predict work engagement (Bakker & Demerouti, 2007). Furthermore, according to Hobfoll (1989), engaged workers are able to generate and reinforce their resources, which enables a positive spiral (Llorens et al., 2007). Work engagement is associated with organizational commitment, personal initiative, and performance (Schaufeli & Bakker, 2010).

A recent study in manufacturing context (Molino et al., 2020) connects work engagement to technology acceptance. The study proposes a positive relationship between work engagement and technology acceptance, supported through results among both white-collar workers and blue-collar workers. The finding indicates that technology acceptance can be seen as a resource that may make the workers more

engaged with their work. In addition, personal well-being can be seen as a goal for design, which is addressed in the next sub section.

2.2.2 Design for well-being

In the field of HCI, design for well-being and positive approaches to design have become growing research and design interests (Desmet & Hassenzahl, 2012; Desmet & Pohlmeyer, 2013; Riva et al., 2012, Calvo & Peters, 2014). This follows the increased trend of scientific research on subjective well-being, which has developed partly as a counter reaction to the vast number of psychological studies concentrating only on negative states (Diener et al., 2009). The discipline of positive psychology has shifted the research focus from negative to positive, by viewing health as the presence of the positive, not only the absence of the negative (Seligman & Csikszentmihalyi, 2014). Instead of negative states and problems, the discipline focuses on subjective well-being, positive emotions and human flourishing.

In line with research for well-being, positive approaches in design, such as *Experience design* (Hassenzahl, 2010), *Possibility-driven design* (Desmet & Hassenzahl, 2012), *Positive design* (Desmet & Pohlmeyer, 2013), *Positive technology* (Riva et al., 2012) and *Positive computing* (Calvo & Peters, 2014) have been introduced as alternatives to more dominant problem-driven design approaches. Experience design (Hassenzahl, 2010) proposes providing meaningful experiences for the user by fulfilling psychological needs with use of technology itself. Possibility-driven design (Desmet & Hassenzahl, 2012), calls for shifting from solving problems to exploring possibilities in design. According to this approach, design can contribute to well-being through two ways: by creating or mediating positive experiences and by stimulating people's awareness of their abilities to increase their well-being. To support design for well-being, Desmet and Pohlmeyer (2013) combined the approaches of positive psychology and design to Positive design framework, which is introduced in Section 2.4.1. Riva et al. (2012), in turn, use the term Positive Technology of their approach of studying how technology can be used to enhance personal experiences. Positive computing, by Calvo and Peters (2014), is a wider approach that focuses on design and development of technology to support well-being and human potential. The approach grounds itself to psychological research and multiple theories of well-being, aiming at creating a bridge to integrate well-being research and technology design.

More recently, Peters, Calvo and Ryan presented a new model, *Motivation, Engagement and Thriving in User Experience*, for guiding HCI researchers and practitioners to design for well-being (2018). The model aims at giving guidance to satisfying of psychological needs through design based on the three core elements of Self-determination theory (Ryan & Deci, 2000): autonomy, competence and relatedness. Thus, it has a common ground with *Person-based approach to intervention development*, by Yardley et al. (2015), presented in Section 2.4.2. While Yardley et al. propose common and concrete guiding principles for design, Peters and al. (2018) approach design through levels, "spheres on experience", that can be influenced by design: adoption, interaction with the interface, technology-enabled task, technology-supported behaviour and overall life as well as the broadest level of society. To give concrete design guidance, they introduce a variety of evaluation measures to support iteration of designs to better support satisfying of psychological needs leading to well-being.

In work context, the positive experiences of workers have become an important design goal, following the overall shift in HCI from assessing usability problems to identifying new design opportunities to create a good experience (Vermeeren et al., 2016). Zeiner et al. (2016) approached design for well-being at work through experience categories that help understanding of positive experiences at work and can inform designers to foster or generate a positive user experience. Lu and Roto (2015), in turn, applied the positive design framework to work context by combining it to the mechanisms of *meaningful work*. Their aim was to help designers in designing meaningful experience goals to guide design of work tools. Later, they focused particularly on the design strategies to support a specific positive experience goal, pride at work (Lu & Roto, 2016). Recently, Laschke et al. (Laschke et al., 2020) have called for explicit design for meaningful work-related technology that not only adapts to work tasks, but also evokes positive work practices.

To understand well-being at work in a holistic way, it is important to acknowledge also studies related to *personal productivity*, which is closely connected to well-being at work. Achieving of results and the resulting feelings of personal productivity enhance the sense of competence and confidence, which have been associated with enhanced well-being (Carver & Scheier, 1999; McGregor & Little, 1998). Research and design of digital services that aim at enhancing personal productivity include studies related to organisation of work, such as facilitating time management and scheduling (e.g. Blandford & Green, 2001), managing multitasking and interruptions (e.g. Züger et al., 2017), taking breaks from work (e.g. Epstein et al., 2016) and providing effective feedback (e.g. Kim et al., 2016). While a considerable amount of

research has focused on specific areas related to organisation of work, less knowledge exists of more holistic approaches for enhancing personal productivity or approaches that explicitly combine the aims of enhancing both well-being and productivity.

2.2.3 Worker-centricity and ethics in design

In design for well-being at work, a worker-centric approach is important regardless of the work context. In factories, a human-centered orientation has been acknowledged already a few decades ago (see e.g. Corbett, 1990), yet it has not come a prevalent approach until more recently. Early consideration of human factors in production processes has been proposed to improve workers' performance and well-being (Village et al., 2015), and the factories of the future are expected to be increasingly worker-centric to optimize production performance (May et al., 2015). The worker-centricity is emphasized in the vision of *Operator 4.0* (Romero et al., 2016) that refers to factory operators of the future that are assisted by automated systems allowing operators to use their creative skills.

Worker-centricity in design can be supported, for example, by defining *user experience goals* that concretize the targeted user experience and can be interpreted into design implications (Kaasinen et al., 2015; Roto et al., 2017). Concrete and shared user experience goals help focusing on user experience within the design team, in design decisions and in communication with stakeholders (Kaasinen et al., 2015). Another approach is to employ design frameworks that identify aspects relevant to a specific context of work. An example of this for Operator 4.0 context, *Design and evaluation framework for Operator 4.0 solutions* (Kaasinen et al., 2018), is presented in Section 2.4.5.

Worker-centricity is particularly important also in identifying ethical issues related to design and adoption of new solutions at workplaces. Considering ethics should not be left to ethics review boards only, rather it should be actively and flexibly addressed throughout the HCI research (Munteanu et al., 2015). Ethics can be considered in design through several ways, such assessing the impacts of technology (Wright, 2011) identifying the values of target users and responding to them (Friedman et al., 2013) or by following ethical guielines. An example of the approach of following ethical guidelines, *Framework of ethical guidelines for mobile intelligent applications* (Ikonen et al., 2009), is introduced in Section 2.4.4.

Ethics by design approach (Niemelä et al., 2014) promotes positive, forward-looking and proactive ethical thinking to address ethical issues already in the early project phases. Recently, the need for considering ethics in design throughout the design process and embedding it to the everyday practices of practitioners has gained increasing attention in HCI community (e.g. Waycott et al., 2016; Gray et al., 2018). This may be partly due to the expanding role of HCI research in sensitive and complex settings (Waycott et al., 2016), but also due to a more general interest towards design for good and minimizing the adverse consequences of technology.

2.2.4 Digital interventions to enhance well-being and the role of HCI

Digital interventions have become a common way to support health and well-being at work and several web-based programs have been developed to support well-being and especially stress management of employees (Stratton et al., 2017). The benefit of digital interventions is their way to enable affordable, anonymous and self-paced access to the services (Portnoy et al., 2008). Several studies have reported promising stress-related outcomes with web-based and mobile interventions (Hasson et al., 2005; Ly et al., 2014; van Straten et al., 2008; Zarski et al., 2016). For example, Hasson et al. (2005) developed a web-based program for managing stress among employees including stress monitoring and cognitive exercises. During the 6-month program, employees' ratings on their ability to manage stress as well as sleep quality, mental energy and the ability to concentrate improved.

Besides more common problem-based approaches, approaches related to positive psychology, aiming at building resources and enhancing well-being, have been incorporated into digital interventions. Ouweneel et al. (2013) developed a web-based program to promote positive emotions, self-efficacy and work engagement through happiness, goal-setting and resource-building exercises. Luthans et al. (2008) developed a web-based training for increasing positive psychological capital, consisting of hope, self-efficacy, optimism and resilience. Mitchell et al. (2009), in turn, compared an intervention focusing on positive strengths to a problem-based intervention. All these interventions resulted in positive effects on well-being. However, despite the number of interventions related to stress management and the approach of positive psychology, the digital interventions have not focused on the positive side of stress, which will be the focus of Section 2.3.1.

In the context of HCI, it would be beneficial to combine the understanding of health interventions to the perspective of design and user experience.

Complementing health interventions with qualitative studies that focus on user experience as well as demonstrating the implementations of intervention strategies could provide understanding of why and how an intervention or a system is working (Klasnja et al., 2011). HCI research could also provide more understanding of the adoption and acceptance of technologies - why they work or fail in a given environment or with specific target users (Poole, 2013).

The acceptance and adoption of well-being solutions can be enhanced by appropriate design that supports the desired behavioral changes. For example, features and design strategies that integrate technology to the users' life are important in supporting and maintaining the desired behavior changes (see e.g. Consolvo et al., 2009; Ahtinen et al., 2013; Stawarz et al., 2015). *Person-based approach to intervention development* (Yardley et al., 2015) and *Persuasive systems design model* (Oinas-Kukkonen & Harjumaa, 2009) are presented as frameworks to support design for behaviour change, in Sections 2.4.2 and 2.4.3. Another approach is to support positive behaviour changes through self-tracking, enabling insights for self-reflection and thus encouraging behaviour changes. This approach will be the focus of Section 2.3.2.

2.3 The main concepts applied in the thesis: positive stress and quantified worker

This section presents background and related work on the main concepts of the thesis: concepts of positive stress and quantified worker. The first sub section of positive stress focuses more on conceptual understanding of the construct, as only little empirical research exists on the subject. The second sub section sheds light on the concept of quantified worker through related work on self-tracking and its benefits, potential barriers and ethical questions, particularly in work context.

2.3.1 Positive stress: eustress as a resource

The positive side of stress, also known as eustress, is not a new concept, but was recognized already a few decades ago (Lazarus, 1966; Selye, 1974). The term was introduced by Selye (1974), who distinguished the two sides of stress: the harmful side (*distress*) and the beneficial side (*eustress*). According to Selye, one can learn to react to stressors with positive emotions, which is likely to maximize the experiences

of eustress and minimize the experiences of distress. Earlier, positive response to stress was already proposed by Lazarus (1966), who suggested that the cognitive response to stressors can also be positive and thus lead to positive emotions, such as a feeling of fulfillment. Later, Lazarus and Folkman (1984) emphasized that the person's resources and ability to cope define the stress experience.

Despite the early conception of eustress, the theories and research of stress have approached stress primarily as a negative phenomenon with negative impacts. However, transactional theories of stress, based on the cognitive stress theory (Lazarus & Folkman, 1984), acknowledge the role of eustress, as they emphasize the individual interpretation of stressors. According to current understanding, a stressor can be interpreted as a negative threat or a positive challenge (Le Fevre et al., 2006), and consequently, eustress is defined as a positive response to stressors (Simmons & Nelson, 2007). According to Le Fevre et al. (2006), the perceived demand and the contextual characteristics, such as the source, timing and desirability of a stressor, as well as one's perception of having control over the stressor are factors that define the stress response.

Simmons and Nelson (2007) define eustress and distress as distinct qualitative constructs. This means that the stressor is not only interpreted as positive or negative, but it may have both outcomes. The outcomes are complex and indicated as physiological, psychological and behavioral responses. According to Simmons and Nelson, a eustress experience can be characterized with positive emotions, attitudes and behaviors, such as a feeling of joy, excitement and contentment, as well as perceiving the situation as meaningful, manageable and engaging.

In addition to avoiding or minimizing distress, savoring eustress has been proposed to have potential for enhancing well-being (Simmons & Nelson, 2007; Hargrove et al., 2013). Hargrove et al. (2013) proposed three practices for leaders to encourage experiences of eustress of their employees: offering meaningful work, encouraging mindfulness at the workplace and supporting employees in embracing their capacity to meet challenges. In addition, the match between the person's skills and the demands of the task is critical. While experiencing eustress may enhance well-being, an excess of it can lead to exhaustion (Hargrove et al., 2013) Hence, recovery from also eustress is important. Recovery from work stressors can be facilitated, for example, by developing mindfulness, acceptance and self-regulation skills (Sonnentag & Fritz, 2015).

Eustress is closely connected to more established positive work-related concepts, such as *flow experience* and *work engagement*. Experiencing eustress can culminate in flow (Hargrove et al., 2013), in which the individual is fully involved in the present

moment (Csikszentmihalyi, 1990), and thus at work, completely focused on the work task. Experiencing eustress is also connected to the concept of work engagement that is defined as a positive, relatively stable, state of fulfilment at work, characterized by vigour, dedication and absorption (Schaufeli et al., 2002). While work engagement is a relatively stable state, eustress is experienced as a short-term response to stressors (Le Fevre et al., 2006). In line with the concept of eustress, job demands have been seen as a possible means to boost work engagement, when sufficient resources are available (Schaufeli & Bakker, 2004).

Even though not much scholarly research exists on eustress, the concept has recently raised more research interest. Recent research has addressed measuring of eustress, monitoring of stress levels and positive outcomes of *technostress*, referring to the stress that is experienced due to the use of information systems. Branson et al. (2019) introduced a distress-eustress scale, which aims at holistically capture the positive and negative aspects of stress in an adolescent context. Silva et al. (2020) aimed at creating an information system to assess the stress levels of students in order to predict burnout. The assessment was conducted by monitoring the heart rate variability of the students based on a wearable smartband and machine learning techniques. More closely to the subject of our research, Tarafrad et al. (2019) introduced the aspect of eustress to the phenomenon of technostress by proposing that technostress can lead also to positive outcomes, such as improved effectiveness and innovation at work. They present a framework that divides technostress into *techno-eustress* and *techno-distress*, and discuss features that can facilitate techno-eustress or mitigate techno-distress in the design of information systems. For example, minimizing techno-complexity, providing flexibility in features, reassuring the user of successfully accomplished tasks or providing information of improved performance are proposed as possible features to enhance the positive and mitigate the negative effects of technostress. Salo et al. (2018), who conducted a qualitative study of the technostress responses to mobile phone failures, identified four dimensions that shape users' technostress experiences leading to distress or eustress: perceived priority of smart phone and failures, confidence for overcoming the failures, demand for situational resources and excitement potential.

Despite the recent empirical research related to eustress, the phenomenon is not much studied, possibly due to limited understanding of it, lack of validated measures to operationalize it and other positive work-related concepts, such as flow and work engagement, that have gained more research interest. However, design that provides understanding of positive stress and offers tools to facilitate it in one's daily life has potential in enhancing well-being at work, as it provides a novel approach to perceive

stress from the beneficial perspective and modify one's ways of thinking and working to support both well-being and personal productivity.

2.3.2 Quantified worker: insights through personal data

During the last ten years, the practice of self-tracking has become common both in leisure contexts and at work. The practice emerged through the trend of *Quantified Self*, which refers to self-tracking of biological, physical, behavioral or environmental data (Swan, 2013). Wolf and Kelly introduced the term when creating a website for sharing self-tracking practices in 2007 (www.quantifiedself.com). This promoted the movement of gaining "self-knowledge through numbers" (Wolf, 2010), and since that, the term has been used for the practice of self-tracking as well as for the movement and international community of people practicing self-tracking. Also other terms, such as *personal informatics* (Li et al., 2010) and *lifelogging* (e.g. Sellen, et al. 2007; Gurrin et al., 2014), have been used of the practice of gaining self-knowledge by recording personal data.

First, most of the research related to self-tracking focused on leisure contexts and early adopters, the active members of Quantified Self community, sport enthusiasts or users of several trackers (e.g. Choe et al., 2014; Li et al., 2010; Rooksby et al., 2014). Later, the research has expanded to more ordinary users and work contexts, following the expansion of the trend: commercial wearable devices, such as fitness wristbands, have become popular among consumers and an integrated part of a growing number of workplace health and wellness programs (Moore & Piwek, 2017). In this thesis, a term *quantified worker* refers to the practice of self-tracking in work contexts, which may be enabled or proposed by the employer. Consequently, a term *quantified worker solution* refers to a digital solution employing self-tracking data, such as a data-driven feedback application.

Research on health and well-being tracking at work has proposed many benefits for workers, such as early detection of health problems (Li et al., 2017) as well as increasing awareness of one's daily activity and personal accountability towards health goals (Chung et al., 2017). The main goal of Quantified Self movement, gaining meaningful insights based on the self-tracking data, which has the potential to lead to positive behavioral changes (Choe et al., 2014), can benefit also self-trackers in the work context. Meaningful insights can be achieved through reflecting on the data, both when maintaining one's behavior to achieve the identified goals and when making new discoveries based on the data (Li et al., 2011). Supporting

flexible data selection, filtering and comparison features through visual means can support in exploring one's data further (Choe et al., 2017). In addition to exploring the data afterwards, it has been suggested that self-reflection could be supported also with *glanceable information*, by providing snippets of information and fostering surprise (Gouveia et al., 2015).

Wearable trackers have potential to provide a new kind of worker feedback, which is personal, immediate and objective (Piwek et al., 2016). Particularly in the context of factory floor work, wearable trackers are expected to have potential to support the workers' occupational health, safety and productivity (Romero et al., 2018). As the future of factory floor work is expected to increasingly require problem-solving and decision-making skills (Gorecky et al., 2014), self-tracking may provide useful tools for staying aware of one's performance and considering one's well-being.

Despite the potential benefits of self-tracking at work, the approach of quantifying the worker involves ethical issues, such as concerns related to privacy, data security or true voluntariness of self-tracking (Lupton, 2016; Moore & Piwek, 2017). Lupton (2016) divides self-tracking at work into five categories: private, communal, pushed, imposed and exploited. When self-tracking is encouraged or advocated at the workplace, it becomes pushed self-tracking, which may be difficult to refuse. Furthermore, according to Moore and Piwek (2017) opting out from self-tracking at work includes the risk of being excluded and stigmatized.

Potential barriers for self-tracking include mechanistic feedback (Masson et al., 2016) and more generally, focusing on easily measurable metrics, which necessarily do not support personal health goals or holistic well-being (Chung et al., 2017). In addition, tracking fatigue due to tracking too many things (Choe et al., 2014), not receiving meaningful insight due to lack of contextual data (Li et al., 2010; Choe et al., 2014) as well as insufficient motivation, lack of time or forgetting to self-track (Li et al., 2010) may become barriers for self-tracking.

To sum up, to support successful quantification of a worker, considering ethical issues in early phases of design as well as when creating practices for adopting the solutions at workplaces is vital. In addition, design that supports holistic well-being and maintaining of the motivation of a user is important to overcome the possible barriers related to self-tracking.

2.4 Relevant design frameworks

This section introduces design frameworks relevant to our research. Although we have explicitly followed only Design and evaluation framework for Operator 4.0 solutions (Kaasinen et al., 2018), also Person-based approach to intervention development (Yardley et al., 2015), Persuasive systems design model (Oinas-Kukkonen & Harjumaa, 2009) as well as Framework of ethical guidelines for mobile intelligent applications (Ikonen et al., 2009) were consulted in our research. The frameworks are introduced in the order they are employed in this research. In addition, Positive design framework is introduced first as an example of framework for design for well-being.

2.4.1 Positive design framework

Positive design framework, by Desmet and Pohlmeyer (2013), addresses three central components of subjective well-being, resulting in three ingredients of positive design: *design for pleasure*, *design for personal significance* and *design for virtue*, based on the classifications by Parfit (1984) and Ryan and Deci (2001). Each ingredient addresses well-being that stems from a different source: from enjoying the moment, from the sense of personal meaning or as the (by-)product of virtual behaviour. Design for pleasure focuses on evoking positive feelings, either directly through interaction with a product or service or by facilitating pleasurable activities. Design for personal significance addresses one's personal goals and aspirations for example by creating awareness of achievements or by showing the progress toward a future goal. The third ingredient, design for virtue, supports efforts for being virtuous, enabling, for example, helping others. According to the framework, each of the design ingredients can enhance subjective well-being of a person, but the most powerful combination is the one with all three: "all three are needed for a person to flourish" (10). Despite this, positive design can have an emphasis on only one of the ingredients. Still, it must not cause any negative impacts on the other two.

Desmet and Pohlmeyer propose five characteristics of design to be considered when designing for subjective well-being. First, the design should address supporting existing *possibilities* and creating new ones instead of reducing deficiencies. Second, the design should facilitate achieving *balance* for example by focusing both on present as well as on future benefits. As a third characteristic, design should enable *personal*

fit by for example tailored or customisable solutions. Fourth and fifth, to be impactful, the design should enable *active user involvement* and aim at *long-term impact*.

Related to the topics of our research, Lu and Roto (2015) have applied the positive design framework into the work context by combining it to the mechanisms of meaningful work. We did not explicitly apply the framework in our research, but the proposed characteristics are relevant also in the context of our work.

2.4.2 Person-based approach to intervention development

Person-based approach to intervention development, by Yardley et al. (2015), highlights the focus on *target users* in health-related behavior-change interventions, in contrast to more typical theory-based approaches. The person-based approach has two key elements. The first element is to involve *in-depth qualitative research* with target users throughout the intervention development to make the intervention more persuasive, feasible and relevant to its users. The second one is to identify *guiding principles* to inspire and inform the intervention development of the objectives and key features of the intervention.

As the focus of the person-based approach is on the users of the intervention, the approach is highly compatible with human-centered design. The difference is that the person-based approach is rooted in the discipline of health psychology and focuses primarily on the behavior change techniques that the intervention intends to deliver. In addition, the intervention may or may not include a digital product. Still, the approach makes intervention design and human-centred design closer to each other by adopting human-centred process to intervention development.

Yardley et al. (2015) list common guiding principles and features that they have found to improve acceptability and engagement in many digital interventions. The guiding principles are based on three constructs of the self-determination theory (Ryan & Deci, 2000), which predict enhancing intrinsic motivation to engage with health behavior change. The principles address three design objectives: promoting users' *autonomy* (feeling self-directed), increasing users' sense of *competence* (control and confidence), and fostering a *positive intervention experience* that can motivate engagement with it. These objectives can be supported by several design features, such as supporting user choice of content and strategies, enabling graded goal setting and providing feedback on the user's performance and progress.

In our research, this framework was consulted when formulating design guidelines for designing a solution for fostering positive stress (Section 5.1.2). The

framework fitted well to our design research, due to its integration of the approaches of HCI and health interventions research.

2.4.3 Persuasive systems design model

Persuasive systems design model, by Oinas-Kukkonen and Harjumaa (2009), is a framework for designing and evaluating technologies that support behaviour-change. The model is based on the idea of *persuasive technology* (Fogg, 2003), which is designed for changing users' attitudes or behaviour. Oinas-Kukkonen and Harjumaa (2008) define persuasive systems as computerized software or information systems that are designed to reinforce, change or shape attitudes or behaviour or both without coercion or deception. The framework is based on empirical research and conceptual analysis.

The persuasive systems design model divides persuasive features into four categories: *primary task support*, *dialogue support*, *system credibility support* and *social support*, which each list seven design principles, mainly based on conceptualization by Fogg (2003). The first category supports carrying out the primary task of the user with techniques like tunnelling the user through a process, tailored content and rehearsal. The second category includes techniques for helping the user to move towards one's goals, for example, by offering praise, rewards, reminders and suggestions. The third category aims at increasing the credibility of the system, for example, through promoting trustworthiness, expertise and real-world feel. Finally, the fourth category lists principles for leveraging social influence, such as social learning, social comparison, competition and recognition.

The model has become a widely applied framework in design and evaluation of persuasive systems. Systematic reviews of web-based health interventions have suggested that persuasive features can increase adoption and engagement in the interventions (Kelders et al., 2012) and that the number of persuasive features is related to effectiveness of the systems (Wildeboer et al., 2016). However, implementing more principles does not always lead to better outcomes (Wildeboer et al., 2016). Recently, related to the topics of our research, persuasive design has been applied, for example, in design of a persuasive mobile application for helping entrepreneurs to recover from work (Kekkonen et al., 2018) and in design and evaluation of an application for stress self-regulation (Wang et al., 2019).

In our research, the framework was consulted, together with Person-based approach to intervention development, when designing a digital solution for fostering positive stress (Section 5.1.2).

2.4.4 Ethical guidelines for mobile intelligent applications

The framework of ethical guidelines for mobile ambient intelligence applications, by Ikonen at al. (2009) is built on six *ethical principles* and intended to be used as design guidance throughout the design process. The six ethical principles of the framework are *privacy, autonomy, integrity and dignity, reliability, e-inclusion* and *benefit to the society*. The guidelines are created to concretize the ethical principles in practice, as the principles may be easier to accept than to follow in practical design work.

In the framework, privacy is described as the ability to control access to one's data and protect one's own space. Autonomy refers to the user's right to decide the ways and purposes of using technology. Integrity and dignity refer to honesty and truthfulness: individuals shall be respected and technological solutions shall not violate their dignity. Reliability refers to the sufficient reliability of technology; the user should understand to what extent the technical solution can be relied on, and technology shall not threat the user's health. E-inclusion emphasizes that technology should be accessible to all user groups, and finally, benefit to society is described as technology increasing quality of life and causing no harm to anyone.

In our research, this framework was used in ethics assessment of wearable self-tracking devices (Section 5.2.1). It was complemented with *ethical values* related to employing ubiquitous computing technology at workplace, listed by Nihan (2015): *privacy, autonomy, health, safety, security, control, responsibility, justice, performance* as well as *social interactions and integrations*. The list includes values that have been frequently used to explain, justify or challenge the development of ubiquitous computing for work contexts, and they have different meaning and emphases depending on the stakeholders concerned, for example for employees and for management.

2.4.5 Design and evaluation framework for Operator 4.0 solutions

Worker-centric design and evaluation framework for Operator 4.0 solutions, by Kaasinen et al. (2018), gives guidances to design and assessment of solutions designed to be used by future factory workers, referred to as *Operator 4.0* (Romero et al., 2016). The aim of the framework is to guide design and evaluation of solutions

so that they would have a positive impact on well-being at work. The framework is modified from a more general framework of elements related to well-being at work, by Danna and Griffin (1999), to include design and evaluation perspectives relevant to Operator 4.0 context.

The framework consists of *antecedents*, *immediate implications* and *impacts* of an intervention, referring to a new tool or work practice introduced to factory workers. The antecedents include factors related to workers, work tasks, work environment and work organisation. The impacts include well-being at work, indicated by job satisfaction, work engagement and job motivation, and company benefits, such as enhanced productivity or quality. The immediate implications consist of five design and evaluation perspectives: *usability, user experience, user acceptance, safety* and *ethics*. Even though the immediate implications partly overlap, each of them has an important viewpoint to be considered in the design and evaluation activities. The aim is to integrate the perspectives to cover all the important aspects.

Usability refers especially to systems usability (Savioja & Norros, 2013), which focuses on studying and developing not only tools but also work practices to contribute to smooth work processes. User experience focuses on the workers' perceptions and feelings while using the product and extends to a wider implication of how the new tools shape the worker's image as a professional (Roto et al., 2010). User acceptance focuses on users' willingness to adopt new tools and practices, and the factors affecting adoption. Safety highlights the workers' feelings of perceived safety, which is an important aspect related to well-being. It cannot replace risk assessments conducted by safety experts focusing on potential accidents, but it can complement them. The aspect of ethics highlights workers' perspective and creating of ethically sound solutions instead of only identifying potential problems.

In our research, this framework was employed in the evaluation of a digital solution for providing quantified feedback in a factory floor context (Section 5.2.3).

2.5 Research gap

Design for well-being and positive approaches to design have received a substantial research interest and several frameworks and models have been created to support HCI community in the endeavors to design for enhancing well-being. However, the frameworks do not always provide sufficient and easily understandable guidance and examples to support the work of practitioners. Research that would shed light on practical implications and ways to demonstrate design implications would provide

new design-related understanding for the HCI community. This research gap has been pointed out by Vermeeren et al. (2016), who call for more research on the process of user experience design in practice, for example knowledge on how design decisions are made and how they lead to the final design. Furthermore, according to Peters et al. (2018), there has been a gap between existing frameworks for design for well-being and easily applicable design practices.

The need for research on the process of user experience design in practice is connected to the need to combine the approaches of health interventions and HCI research (Klasnja et al., 2011; Poole 2013). Currently, health interventions focus mainly on the effectivity of them without providing understanding of the design strategies, elements or implementations that would explain why an intervention or a system is working. More knowledge is needed of the user experience and design implications related to health interventions.

Recent HCI research has acknowledged the importance of ethical issues in design (e.g. Waycott et al., 2016; Gray et al., 2018). Still, it is a relatively new perspective in the field of HCI, and more knowledge is needed especially to support designers in considering ethics throughout the design process. Several approaches and frameworks have been created to guide designers (e.g. Wright, 2011; Friedman et al., 2013; Ikonen et al., 2009; Niemelä et al., 2014), but the lack of concrete examples of design research process and design decisions involving ethics may hinder the expansion of ethics-aware design.

In the context of stress reseach, studies and interventions have approached stress primarily as a negative phenomenon with negative impacts. More research that focuses on or includes the perspective of positive stress is needed to increase holistic and preventive understanding of stress. The majority of the limited research on positive stress has approached the phenomenon on the conceptual level. The research lacks empirical knowledge of the experience of positive stress and the means to foster it. Hargrove et al. (2013) have proposed means for leaders to encourage eustress experiences of the employees, but eustress has not been approached from the perspective of entrepreneurs and self-leadership. Furthermore, research provides only few linkages between positive stress and technology design. Several web-based programs have been developed to support stress management of employees (Stratton et al., 2017), but to our knowledge, no online services focus particularly on fostering positive stress.

In the context of quantified feedback and practice of self-tracking, research has identified benefits and barriers of self-tracking as well as ethical issues related to self-tracking at work. However, the field would benefit from design research that would

reveal design practices, strategies or elements to support gaining the benefits and overcoming the barriers related to self-tracking. A substantial amount of research has addressed early adapters of self-tracking, but more studies are needed to understand the experiences of ordinary users. In the context of the workplace wellness programs including self-tracking, the field has been lacking studies focusing on the user experience of the workers (Chung et al., 2017) and impacts of the programs (Moore & Piwek, 2017). In addition, the studies have typically been conducted in office context, and thus understanding of other work contexts is scarce.

This research responds to the identified research gaps by providing knowledge of the user experience design in practice, in particular knowledge of design elements and implications supporting design for well-being at work. Study 1 on positive stress provides empirical, experience-based understanding of the phenomenon of positive stress, especially in the context of entrepreneurial work. It employs the approaches of health interventions and HCI by studying both initial effectivity of the intervention as well as the user experience and design implications, which are the main focus of the study. Study 2 adds to the knowledge of self-tracking by adopting the approach of Quantified Self into a factory context, and focusing on the perspectives of user experience and design implications as well as ethics. Both studies address user groups and work contexts that have received less attention in HCI research.

3 RESEARCH APPROACH AND METHODS

This chapter describes the research approach, research process and methodological choices of our research. Finally, it describes central issues concerning research ethics.

3.1 Research approach

This design research follows the *Research through Design* (RtD) approach (Zimmerman et al., 2007), which refers to the process of design in which the designed artefacts form a significant outcome and contribution of the research. Based on the terminology and categorization by Frayling (1994), Zimmerman, et al. (2007) created this approach as a model for interaction design research to integrate the practices of design and research. Even though design is salient in the practical work of interaction designers, it has not been a central focus in HCI research (Zimmerman et al., 2007). As Cockton (2012) criticizes, "user-centered design is strong on problems, but weak on solutions" (p.1), pointing out that HCI research has rather focused on understanding usage contexts and on evaluating designs, not on creating design and innovations. However, the role of design has become more important, as HCI research has shifted more from evaluating usability of products to creating a good user experience by identifying design opportunities (Vermeeren et al., 2016). Building upon the RtD approach, Vermeeren et al. (2016) use the term *Design-inclusive UX research* to refer to user experience research where design activities form an integral part of the research. They call for more research on the process of UX design in practice, such as design decisions and how they lead to the final design. Zimmerman et al. (2010) emphasize also the need for producing theoretical knowledge as a research outcome from the RtD process and rigorous documenting of it, to be able to evolve to a formalized and an established research approach. By successful integration of research and design practice, generating new design artefacts and thorough documentation of them, the impact of HCI research could be higher.

According to Zimmerman et al. (2007), the RtD process aims at "transforming the world from the current state to the *preferred state*" (497) through the created

artefacts. Therefore, the approach has a benefit of motivating the HCI community to discuss the preferred states, which facilitates making a significant impact on the society. In addition, this aim guides researchers to focus on research of the future and on the ethics of the design (Zimmerman et al., 2010). This connects the approach to the areas of design for well-being and positive approaches to design. For example, *Positive Design* (Desmet & Pohlmeyer, 2013), *Positive Computing* (Calvo & Peters, 2014) and *Possibility-driven Design* (Desmet & Hassenzahl, 2012) have all been introduced as alternatives to problem-driven approaches. They all focus on possibilities and preferred states, aiming at designing for happiness, personal well-being and human potential. Furthermore, in the context of well-being, the approach is connected to design and technologies for *behavior change* – as an aim to achieve the preferred state.

In the research of this thesis, research and design are integrated, and created artefacts illustrate the research findings. Even though our research in Study 1 started from exploring the experience of positive stress without an idea of potential technological solutions, it had a purpose of gathering knowledge for design. However, it does not mean that the results of that phase could not provide also other scientific value and theoretical contributions. In Study 2, the starting point for design was more fundamentally connected to technological potential, as the study focused on the potential of applying the Quantified Self approach in the factory context. Still, the first phase of the study was not restricted to concern only attitudes towards self-tracking, but explored the factory context, ethical issues and potential wearable devices more broadly, to ground our design and provide new knowledge to the research community.

The preferred state, enhancing well-being of workers, was focal throughout the research. The research led to creation of two design artefacts that primarily aimed at enhancing well-being at entrepreneurial work and factory floor work, but the results can be applied wider to support workers facing requirements of the changing working life. The design of the artefacts illustrates our design decisions and application of the research findings, and concretizes the research results in a format that enables testing the approaches through field studies. The gained design implications and recommendations aim at informing and inspiring HCI practitioners to design for preferred states, well-being at the changing workplace in particular.

3.2 Research process

The Research through Design approach was applied in the studies via *human-centric design process* (ISO, 2010). The studies proceeded from gaining understanding of the needs and experiences of the target group to designing a prototype and testing it in everyday use during a field study. Consequently, the research process of our studies can be divided into three research phases: 1) *Gathering initial understanding*, 2) *Design of a digital solution,* and 3) *Evaluation through a field study*. In both studies, a high-fidelity prototype of a digital solution was created. In Study 1, the design outcome was a web-based service for fostering positive stress and in Study 2, a mobile application providing encouraging quantified feedback. In addition to the human-centric design process, the research followed the principles of *participatory design* (Schuler & Namioka, 1993; Muller & Kuhn, 1993) by involving potential target users and relevant stakeholders in several phases of the design.

Figure 2 illustrates the research process, outlining the research phases and their sub phases. The research process is presented on a timeline, which shows the approximate timing of the studies and each research phase.

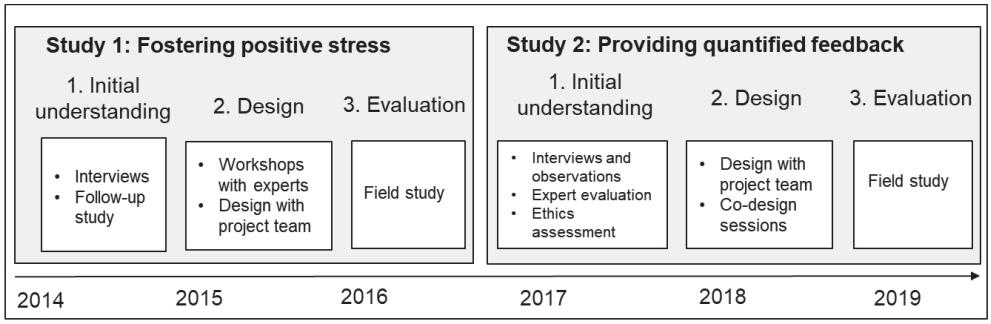

Figure 2. Research process of the two design studies presented on a timeline, divided into three research phases and sub phases.

In Study 1, initial understanding of eustress experiences was gathered through two sub phases. The phenomenon was first explored with thematic interviews focusing on the entrepreneurs' retrospective depictions of eustress experiences. To gain deeper knowledge of eustress experiences, the phase was complemented with a mixed-method follow-up step including a eustress diary, physiological measurements and interviews. In Study 2, the phase of gathering initial understanding comprised of three sub phases: interviews and observations of factory workers, expert evaluation

of wearable self-tracking devices and ethics assessment for identifying ethical issues related to adopting self-tracking in a factory context. In Study 1, the aim was to gain deep understanding of the understudied research subject, while in Study 2, a broader perspective of the issues to be considered in a factory context was needed first, to confirm that conducting a study of self-tracking is feasible and to define the scope of the study appropriately.

The design phase of both studies was based mainly on the collected user data, but also utilized literature and relevant frameworks. In the design phase of Study 1, broader expertise on the topic was gained by organizing three workshops with experts. As Study 1 had concentrated on the experiences of the target group without involving experts or other stakeholders before, this broader perspective verified the potential of the concept idea. In Study 2, factory workers were involved in the design by gathering their feedback, ideas and perceptions for the concept prototype. The perspective of factory floor workers was focused on to gain understanding of user acceptance.

In both studies, the final field study phase consisted of independent use of the created digital solution, which was studied through questionnaires, interviews and analysis of the log data of the service. The duration of the field study in an entrepreneurial work context was approximately six weeks to ensure the users adequate time to engage with the digital service. We considered this duration sufficient due to the typically busy schedules of entrepreneurs and research results showing that short-to-medium stress interventions have been more effective than over 9 weeks long interventions (Heber et al., 2017). The field study with factory workers was designed to be 2-3 months, depending on the preferences of the three factories involved, to gain knowledge of the longer-term impacts of the application.

3.3 Research methods and participants

The design research process was empirical and mainly qualitative, consisting of multiple research methods. Table 2 and Table 3 summarize the research methods and participants in each research phase. Outcomes of each research phase are categorized to more theoretical research results and more practical design outcomes to highlight the integrated role of research and design. The table lists also the publications covering each research phase.

Table 2. Research methods, participants and outcomes in terms of research and design in each research phase of Study 1: Fostering positive stress.

Study 1: Fostering positive stress			
Research phase (publication)	**Method**	**Participants**	**Outcome**
1a Interviews (P1, P2)	Thematic interviews	21 entrepreneurs	*Research:* Knowledge of eustress, especially current and potential role of technology in facilitating it and ways to foster eustress in daily life *Design:* Potential areas for design; initial service content
1b Follow-up (P2)	Eustress diary, physiological measurements and follow-up interviews	9 entrepreneurs of the sub phase 1a	*Research:* Further knowledge of eustress experiences *Design:* Validation of the initial service content, refinements
2a Concept design (P2)	3 workshops with experts; data-driven concept design within the project team	16 experts on health technology, well-being or coaching; 4 researchers of the project team	*Research*: Focus areas for design, core content elements (toolsets and tools to foster eustress in daily work and life), design guidelines *Design:* Initial structure and functionality of the service
2b Detailed design (P2, P3)	Content and user interface design based on the study findings and literature	4 researchers of the project team: specialists in user experience design, digital health, education, and technical development	*Research*: Application of design guidelines *Design:* Eustress Toolbox service prototype providing knowledge, exercises and illustrating quotes from entrepreneurs; content and design elements
3 Field study (P3)	6-week field study, stress questionnaire 1 & 2, 2 user experience questionnaires, log data, interviews	22 in total: 13 entrepreneurs and 9 persons having an entrepreneur-like job description Questionnaires: 16-22 Interviews: 10	*Research:* Knowledge based on user experience, user acceptance and perceived benefits of the use of the service *Design:* Design implications for design for well-being, especially for entrepreneurial context

Table 3. Research methods, participants and outcomes in terms of research and design in each research phase of Study 2: Providing quantified feedback.

Study 2: Providing quantified feedback			
Research phase (publication)	**Method**	**Participants**	**Outcome**
1a Interviews (P5)	Thematic interviews with observations of work	13 factory workers: 6 machine operators, 4 managers and 3 development engineers	*Research:* Understanding of factory work and context; initial attitudes towards self-tracking at work *Design:* Contextual and user requirements; user experience goals
1b Expert evaluation (P4)	Expert evaluation of potential self-tracking devices based on daily use	9 experts on user experience design, user acceptance and/or digital health	*Research:* Potential of wearable self-tracking devices for factory work *Design:* Requirements for a self-tracking device at a factory context
1c Ethics assessment (P4)	Expert workshop for ethics assessment based on scenarios	4 of the experts participating in the phase 2	*Research:* Ethical considerations related to self-tracking in a factory context *Design:* Ethical issues to be considered already in the early phases of design
2a Concept design (P5)	Design based on UX goals with the project team; co-design with factory workers	3 specialists in user experience design, data science or implementation; 7 factory workers from 2 factories	*Research:* Design guidelines for data-driven feedback solutions in a factory context *Design:* Initial Worker Feedback Dashboard prototype; content and design elements
2b Detailed design (P5, P6)	Content and user interface design based on design implications	4 specialists in user experience design, data science or technical implementation	*Research:* Application of user experience goals and design guidelines *Design:* Iterated Worker Feedback Dashboard prototype
3 Field study (P6)	2−3-month field study, 2 user experience questionnaires, log data, interviews	10 machine operators from 3 factories Questionnaires: 8-9 Interviews: 8	*Research:* Knowledge based on user experience, user acceptance and perceived benefits of the use of the solution *Design*: Verification of user experience goals; design implications for quantified worker solutions

The studies involved altogether 70 participants of the targeted user groups and 25 experts. In Study 1, we interviewed first 21 entrepreneurs and in Phase 3, 22 entrepreneurs or people having an entrepreneur-like job participated in the field study. In Study 2, we interviewed first 13 factory workers from two factories and in Phase 3, 10 factory workers from three factories were involved. As entrepreneurs work in diverse fields and occupations, and thus have different work practices, a larger number of participants were considered necessary for Study 1. In Study 2, the

involved factory floor workers all operated the same highly automated manufacturing machine, which provided data on the metrics related to the personal work performance. Due to the similarity of the job role, a smaller number of participants was considered sufficient. Furthermore, as all the machine operators using the selected machinery at the three factories were involved in Phase 3, involving more participants would not have been feasible.

In Study 1, the 21 participants of Phase 1 were all entrepreneurs (11 males and 10 females aged 30-52), representing fields ranging from education and consulting to building industry and software design. The majority of the participants were relatively new entrepreneurs and had a small company with fewer than 10 employees. In Phase 3, 13 entrepreneurs and 9 employees (18 females, 4 males, aged 26-52 years) having an entrepreneur-type job description participated in the field study. Although imbalanced in gender, the participants were working in various fields from consulting to well-being and legal services.

In Study 2, the interviews of Phase 1 included both factory floor workers as well as managers and development engineers to gain understanding of their perspective as well as commitment for conducting the study. In Phase 3, 10 machine operators (7 males and 3 females aged 22-50 years) of a highly automated manufacturing machine from three metal industry factories participated in the study. Three of the participants operated the manufacturing machine full time, whilst others used it as a part of their work. Most of the participants had worked in their current role for less than two years.

When conducting interviews in the beginning of the studies, a *semis-structured interview* was selected as a method to enable the participants freely describe their experiences while maintaining a systematic process for the questions asked. To complement the data in Study 1, a *diary* method was used to collect data on near-real-time experiences over a course of one week. Like interviews, it enabled free describing of eustress experiences, but provided structure and guiding questions to help elaborating them in detail. *Physiological measurements* were used for supporting participants to self-reflect on their experiences. In Study 2, the theme interviews included *observation* of work, to gain understanding of the work context. In addition, an *expert evaluation* method was used to lay ground to the user perspective. The method was selected as it has proven efficient in finding user experience issues in a systematic manner (see e.g. Väänänen-Vainio-Mattila & Wäljas, 2010) and it enabled excluding inappropriate self-tracking devices to be introduced to factory workers. In addition, *ethics assessment* was conducted to identify ethical considerations already in

the early stage of design and to guide the project team to consider ethics throughout the study.

The design phase was grounded on the data from the field as well as relevant literature, which guided defining of design guidelines or user experience goals for a service prototype. In Study 1, *Person-based approach to intervention development* by Yardley et al. (2015) was consulted, emphasising human-centred approach and principles drawn from self-determination theory as well as *Persuasive systems design model* (Oinas-Kukkonen & Harjumaa, 2009), listing persuasive features, which could facilitate adoption of the service and engagement with it. The design phase in Study 2 was influenced by *Quantified Self approach* and *Design and evaluation framework for Operator 4.0 solutions* (Kaasinen et al., 2018), developed during the research project. The prototypes were designed iteratively within the multi-disciplinary design team with the support of data from expert workshops or co-design sessions with the target group.

During the final field studies, online questionnaires, interviews and usage logs were used to study the usage activity, user experience, user acceptance and perceived benefits of the digital solutions. In Study 1, questionnaires that focused on user experience as well as user acceptance based on the *Technology acceptance model for mobile services TAMM* (Kaasinen, 2009) were created. In addition, due to the lack of validated measures for measuring eustress, two validated questionnaires, *Perceived stress scale PSS* (Cohen & Williamson, 1988) and the 9-item version of the *Utrecht work engagement scale UWES-9* (Schaufeli & Bakker, 2003) were selected to gain further data on possible effects on perceived stress and work engagement during the field study. When designing the questionnaires and the themes of interviews in Study 2, the design and evaluation framework for Operator 4.0 solutions was employed (Kaasinen et al., 2018). Based on the framework, the use of the digital solution was studied through the aspects of user acceptance, user experience, usability, safety and ethics.

All interview data of the first study phase were audio recorded, transcribed and collaboratively analyzed by the project team, following either the steps of *thematic analysis* (Braun & Clarke, 2006) or principles of creating an *affinity diagram*, an analysis phase of the contextual design method (Holtzblatt & Beyer, 1997). When thematically analyzed, the data was first read through as a whole and then systematically coded. Then, the codes were grouped into wider themes, and finally, the themes were defined and reviewed as well as illustrated with quotations from the data. When creating an affinity-diagram, the insightful parts of the data were first captured and then organized into a diagram on a wall, based on their similarities in a

bottom-up manner. The data-driven analysis led to the themes that formed the content or the user experience goals for designing the digital solutions.

Analysis related to the expert evaluation of wearable devices and ethics assessment were conducted based on pre-defined categories. In expert evaluation, the data was coded and analyzed using the categories of user experience, perceived accuracy of the device and the applicability to factory context. In the data analysis of the ethics assessment, two analysis frameworks were employed to identify ethical considerations. *Framework of ethical guidelines for intelligent applications* (Ikonen, et al., 2009) was used as such, and complemented with additional *ethical values related to ubiquitous computing in the workplace* (Nihan, 2015).

The questionnaire data of the final field studies were analyzed both quantitatively and qualitatively, and the log data were analyzed quantitatively to extract metrics for describing usage activity. Final interviews were thematically analyzed.

3.4 Research ethics

Research ethics was considered in both studies in all phases of the research. The research was conducted following the principles of the Finnish Advisory Board of Research Integrity TENK (Kohonen et al., 2019). All research participants participated in the studies voluntarily. As this principle was considered particularly important in the study phases including employees, both employees and their superiors were highlighted that the participation is voluntary and the potential participants have the right to refuse to participate without any consequences. The employer cannot assign any worker to participate and no one from the work community cannot make the decision for others. However, in Study 2, it was important to inform the management about the objectives and content of the research, to gain their commitment to allow the participants to use the solution at work during the field study. It was also important that the management knew the central principles of using the digital solution, in particular the idea that the data is intended for the employee only, not for the management or the employer.

An ethical review was applied from the Ethics Committee of the Tampere region for the follow-up phase of Study 1, which included physiological heart rate variability measurements. Similarly, an ethical review was applied from the Ethics Review Board of VTT Technical Research Centre of Finland for the field research of Study 2, in which factory floor workers used the designed digital solution and a wearable fitness tracker. The committees identified no barriers for conducting the studies.

The potential research participants received information on the objective and content of the research, practical steps, processing of personal data and their rights to discontinue participation or withdraw their consent to participate at any time with no negative consequences. They were informed that the digital solutions to be used during the field study were prototypes and thus the impacts of use were not known yet. However, no potential risks for participation were foreseen. After receiving the information and having a possibility to ask further questions, those who wanted to participate filled in the informed consent forms.

Personal data gathered during the studies were processed following the requirements of General Data Protection Regulation GDPR (Voigt & Von dem Bussche, 2017). The research data were analyzed without personal information by giving a coded identification number to the data of each participant. For example, the audio-recorded interviews were analyzed as coded transcriptions. The access to the research data was limited to the researchers of the research case and the personal data was removed from the research data as soon as it was not needed for research purposes. Privacy of the research participants was protected when publishing the results of the studies. The pictures of the participants were used to illustrate the use of the solutions or the work context only if a participant had given a written permission for that.

4 SUMMARY OF THE PUBLICATIONS

This chapter summarizes the aims and results of the publications of the thesis. The publications are presented under Studies 1 and 2, referring to them as P1-P6.

4.1 Study 1: Fostering positive stress

Study 1 consists of research for fostering positive stress in an entrepreneurial context, which we present by Publications 1-3 (P1-3). Each publication covers primarily one design research phase.

4.1.1 P1: Potential of technology in facilitating positive stress experiences

P1 focuses on the current and potential role of technology in facilitating positive stress experiences. The aim was to understand the understudied phenomenon of positive stress and the potential of technology in facilitating it, to contribute to the area of design for well-being from a new perspective. The role of technology was studied through twenty-one theme interviews in which entrepreneurs elaborated their work-related experiences of positive stress. The entrepreneurs were encouraged to describe their everyday experiences including eustress without guiding them to talk about technology before the very end of the interviews, which contained explicit questions of the role of technology. The aim of this was to focus on the role of technology that emerged from the descriptions of eustress.

The results revealed that technology did not currently possess a major role in experiencing positive stress, but it was identified to be one of the barriers or enablers for it, similar to the working environment, social interaction and the content of one's work. The entrepreneurs perceived the role of technology significant in enhancing their feeling of control, for example through reachability, and in enabling flexible and fluent ways for co-operation and sharing one's efforts and success. However, often technology was perceived as opposite: poor functionality of technological tools or exhausting pervasiveness hindered experiencing of eustress.

The potential of technology was assessed through the entrepreneurs' current ways of working that facilitate eustress and could be aided by technology. Based on a theme analysis, we identified the potential of technology in facilitating eustress to extend to the areas of *co-creation and collaboration, planning and scheduling, togetherness and shared success, the means for mental preparing and ways to recover*. Even though technology has significant potential in supporting flexible working methods, it should also support detaching from work by blocking of work issues and enabling unavailability when wanted.

The findings of P1 suggest that experiencing eustress can be supported by an appropriate design of technological tools in general, or by providing new tools to facilitate experiences, mind-sets or ways of working that may lead to eustress. The potential areas for technology-mediated facilitating of eustress experiences give guidance for design that supports experiencing eustress. On the theoretical level, the results of P1 provide new knowledge of the nascent area of positive stress. On practical level, the insights guide HCI practitioners in design to facilitate eustress in particular or in design of any digital solutions to support experiencing eustress rather than hindering it.

4.1.2 P2: Designing a eustress toolbox: from entrepreneur experiences to an online service

P2 presents the design process and outcome of a web-based service prototype for fostering positive stress of entrepreneurs. Twenty-one thematic entrepreneur interviews, used as data also in P1, and a follow-up study consisting of a eustress diary, physiological measurements and follow-up interviews were used as material to systematically analyze the entrepreneurs' ways of thinking and working that helped them to feel and stimulate eustress in their daily lives. The entrepreneurs' eustress experiences were facilitated by self-reflection of one's thoughts, feelings and actions, practices to manage one's work, means to create pressure for accomplishing tasks, harnessing the positive aspects of one's work, means to prepare for and concentrate on challenging situations and practices to recover from work. These six themes formed the six toolsets for developing skills and practices to foster eustress in the Eustress Toolbox service: 1) *Self-reflection and changing the mind-set*, 2) *Organizing work*, 3) *Stimulating positive pressure*, 4) *Harnessing a feeling of joy*, 5) *Mental preparation* and 6) *Recovery*. The themes are in line with the potential areas for technology-mediated facilitating of eustress experiences that are presented in P1. However, the analysis in

P1 focused on ways of working, while in P2 we conducted a new analysis, including also ways of thinking, which led to the theme of self-reflection and shifted the categorisation to include more holistic themes entailing both ways of working as well as ways of thinking.

In addition to the two-phased collection of user data and the insights gained and the content formulated based on it, the design process of the Eustress Toolbox service included identifying central design elements based on three co-design workshops with experts and selected design frameworks. The consulted frameworks emphasized human-centred approach and principles drawn from self-determination theory (person-based approach by Yardley et al., 2015) as well as persuasive features (Persuasive systems design model by Oinas-Kukkonen & Harjumaa, 2009) that could facilitate adoption and engagement with the service. We defined five design guidelines to focus on central elements when designing the service. The guidelines used in design were 1) *Minimizing user effort*, 2) *Providing freedom to discover*, 3*) Enabling follow-up of progress*, 4) *Enabling learning from peers* and 5) *Supporting of integration of skills into daily life*. The Eustress service was designed to increase understanding of eustress and to help users to develop skills to stimulate eustress in their daily lives. More specifically, the goals of the service were to enable users to familiarize themselves with the phenomenon of eustress and multiple ways to stimulate it, allow them to reflect on their current ways of thinking and working, and subtly suggest areas for development, guide them to learn new skills and provide practical tools to rehearse the new skills in their daily lives.

In addition to the design process, P2 presents the structure and content of the Eustress Toolbox service prototype, which concretizes how the design elements are implemented to the service. On the theoretical level, P2 provides knowledge of the entrepreneurs' ways to achieve eustress as well as sheds light to the potential connections of eustress and a more established positive work-related concept, work engagement. As a design outcome, it presents the experience-based design of a novel digital solution, providing design insights of design for well-being as well as productivity through a new perspective of positive stress.

4.1.3 P3: Field study of the eustress toolbox web service: entrepreneurs' experiences and design implications

P3 presents the results of a field study of Eustress Toolbox, a web service designed for stimulating positive stress and introduced in P2. Twenty-two entrepreneurs or

people having an entrepreneur-type of job used the web service for six weeks. User experience, user acceptance and perceived benefits of the service were studied through UX questionnaires and interviews. In addition, usage logs were analyzed to assess how actively the participants used the service, and a pre and post questionnaire on stress and work engagement were conducted to indicate preliminary effects of the service.

The results revealed that the user experience of the service was positive: the participants found the content interesting and the reflection and off-line exercises useful as they helped linking the content into the users' life. Entrepreneur quotes provided insights from the peer group and helped reflect on one's thoughts. Furthermore, after the field study period, almost all the users wanted to continue using the service. However, the usage frequency was lower than expected and most users were not able to incorporate the service use into their daily routines. This could have been affected by several reasons: the lack of reminders due to a technical problem during the field study, lack of optimisation for mobile usage, design of the service toolsets for selective use and off-line rehearsal that was not shown in the log data. However, despite relatively low usage frequency, the results indicate preliminary effects on stress. During the usage period, the participants' negative stress measured by the perceived stress scale decreased and they reported more positive stress experiences and adoption of new practices.

Based on user experience and users' development ideas, four design implications were proposed: 1) *Make me put it into practice! – Integrate into the daily hassle of entrepreneurs*, 2) *Guide me! – Provide personal guidance while maintaining a possibility to explore*, 3) *Recognize me! – Recognize the user's progress and accomplishments in a meaningful way* and 4) *Show me what the others do! – Support implicit learning from peer entrepreneurs*. The design implications support the user in adoption and engagement with a digital solution and highlight design aspects particularly relevant in the entrepreneurial context. P3 combines the approaches of HCI and health interventions by focusing on design implications along with preliminary effects on stress. Therefore, the results provide insights to HCI community as well as to the discipline of health interventions, and potentially even facilitate a dialogue between these fields.

4.2 Study 2: Providing quantified feedback

Study 2 consists of research for providing quantified feedback in a factory context, which we present by Publications 4-6 (P4-6). Each publication covers primarily one design research phase.

4.2.1 P4: Expert evaluation and ethical considerations of wearable self-tracking devices

P4 presents an expert evaluation and ethics assessment to study the potential of the use of self-tracking devices in a factory context. The research stems from the Quantified Self approach, which has made self-tracking practices common in everyday use. Self-tracking of employees' activities, mental state and emotions enables data-driven feedback, which has potential to improve the employees' awareness of issues influencing their well-being and work performance. This is especially important in the modern and future factory work, which is assumed to come closer to knowledge work, requiring more decision-making and problem-solving skills from the workers than before.

An expert evaluation method was selected for assessment to enable the research team to gain expertise of commercially available wearable self-tracking devices and evaluate their potential, to be able to select appropriate devices for a forthcoming field study with factory floor workers. Through an expert evaluation of user experience, perceived accuracy and fit to a factory context of five wearable self-tracking devices, two wrist devices measuring activity, heart rate and sleep were identified as suitable for the use of factory floor workers. None of the devices detecting emotions was deemed suitable, due to impracticality in the factory floor context or perceived shortcomings in the accuracy of the measurements.

The ethics assessment emphasized the importance of a variety of ethical issues, in particular related to privacy and autonomy of users as well as their health and safety. The purpose of self-tracking needs to be clearly defined and collection and use of the data kept as transparent as possible. As self-tracking data is sensitive and personal in nature, privacy of it should be guaranteed by ensuring data security and providing possible immediate feedback in a discrete way. Special attention should be paid in the true voluntariness of self-tracking, as in a work context the user may feel social pressure to participate or be afraid of negative consequences if opting out. Dignity of users can be respected, for example, by giving gentle but truthful worker

feedback and recognising positive moments and trends. As factories are safety-critical contexts, it is also important to ensure that self-tracking does not distract the worker's attention from work tasks.

P4 lays ground to the user perspective employed in the later phases of the research, and provides insights into the potential of self-tracking devices and quantified feedback as well as ethical considerations to be taken into account when adopting self-tracking solutions in factories. Based on the expert evaluation and ethics assessment, a self-tracking device suitable to a factory context needs to be *unobtrusive* during wear and provide *reliable* data through *discrete feedback* and *encouraging suggestions*. In addition to possible immediate feedback, *longer-term trend data* is expected to be useful to enable personal reflection and positive behavioural changes.

4.2.2 P5: Designing a worker feedback dashboard

P5 presents the research process and outcome of a Worker Feedback Dashboard solution that presents automatically tracked well-being and work performance metrics to factory floor workers. Design of the solution was influenced by user interviews and observations as well as central principles of Quantified Self approach, which were ingredients for four UX goals and consequently, four design implications derived from them. In this thesis, we refer to these design implications as design guidelines, to enhance readability through consistency with Study 1, and to devote the term 'design implications' to the design guidance gained from the field study results of the usage of the solutions.

Fourteen interviews of factory workers revealed that the initial reactions towards tracking personal metrics at work were mixed, but mainly negative, as the interviewees associated self-tracking with receiving negative feedback. Typical feedback that they currently received was reported in negative measures and showed the general statistics of the machine flow. Therefore, we expected more personal and encouraging information to have more potential to be beneficial and interesting to factory floor workers.

Based on the results of the user interviews, nature of factory floor work and the central principles of Quantified Self approach, user experience (UX) goals were set for design. The four UX goals for designing a Worker Feedback Dashboard prototype were 1) *Being empowered and encouraged*, 2) *Getting personal feedback*, 3) *Getting meaningful insight* and 4) *Being undisturbed*. These UX goals were interpreted to four design guidelines: 1) *Keep positive (but truthful)*, 2) *Give personal feedback*, 3) *Enable personal*

reflection and 4) *Do not disturb the worker*. The design guidelines guided the design to highlight positive aspects and achievements of the workday, to show development of personal competences, to provide trend data and a possibility for self-reporting to support self-reflection and to show only summaries of data instead of real-time notifications not to distract the user from work tasks. The UX goals and design guidelines are in line with the results of P4, pointing out for example recognising of positive moments and achievements as well as aiming at unobtrusive use and discrete feedback.

In addition to the process leading to the design guidelines, P5 presents an overview of the first prototype of Worker Feedback Dashboard and results of co-design sessions in which it was introduced to factory workers. The concept evoked mainly positive feedback, but also the need of consideration of ethical aspects throughout the design and in adoption of the solution was strengthened. P5 provides initial understanding of the acceptability of self-tracking concepts in a factory context. The contributions to the HCI community include the preliminary insights of user acceptance, design guidelines and the suggested design elements for quantified feedback applications. It encourages future research related to user perspective, design alternatives and ethical issues related to quantification of workers, in a factory context and beyond.

4.2.3 P6: Field study of the worker feedback dashboard solution: factory workers' experiences and design implications

P6 presents the results of a field study of Worker Feedback Dashboard, the solution for providing quantified feedback to factory floor workers, introduced in P5. Ten machine operators of a highly automated manufacturing machine used the solution for 2-3 months. We studied the user experience, user acceptance, perceived benefits and concerns about the solution use through UX questionnaires, interviews and application log data. Before the results of the field study, P6 presents the purpose and content of the solution, aiming at providing factory floor workers data-driven near real-time feedback of metrics related to their well-being and work performance.

The results of the field study revealed that the factory floor workers used the application actively, evaluated the user experience positively and perceived various benefits from using the solution. The results verify also the relevance and success of four UX goals presented in P5: 1) Being empowered and encouraged, 2) Getting personal feedback, 3) Getting meaningful insight and 4) Being undisturbed. The

feedback of the application was perceived as personal and encouraging; it helped the participants see their work accomplishments and motivated them for better performance, as it concretized their efforts. As the application was mainly used during breaks or after the workday, the participants did not find the use disturbing their work. The participants considered the feedback mainly meaningful, but the aspect of getting meaningful insight could be enhanced.

The participants evaluated the solution unquestionable in the questionnaire and did not raise major ethical concerns related to it. However, they assumed that not all workers would accept the solution, as they could see it as a way to control them. Instead of privacy or data security, the participants' main concerns were related to the relevance and purpose of the application: whether relevant metrics are quantified and whether qualitative aspects of work are still acknowledged.

Based on the results, we highlight three design implications for the design of data-driven worker feedback applications. These are summarized from the worker point of view as: 1) *Give me meaningful overviews*, 2) *Guide me to act based on the feedback* and 3) *Do not underestimate the unquantified*. The design implications suggest means for facilitating discovering of personally meaningful information as well as making positive behavioural changes. The third design implication encourages defining the scope and purpose of quantification carefully, not to give an impression of underestimating the unquantified aspects of one's work and narrowing down the versatility of it. In addition, the results encourage customising the production metrics for the workplaces and involving workers in that, as we learned that the work goals and the relevance of metrics vary, even though the workers would operate the exactly same machine. The contributions of P6 include understanding of potential benefits and concerns related to quantified feedback as well as design implications to be taken into account when designing quantified worker solutions. The results encourage the members of HCI community to design research on solutions employing quantification, and to ensuring consideration of ethics and unquantified aspects of work in design and adoption of new solutions.

5 RESULTS

This chapter presents the results of the thesis in three parts to answer each of the three research questions. Section 5.1 responds to RQ1, related to Study 1: *What are the central design elements for fostering positive stress through a digital solution in the context of entrepreneurial work?* The section first describes the aim of the design research process and main insights of the background study: the entrepreneurs' means to achieve positive stress, which formed the core content elements of the digital solution. Then, the section presents the defined guidelines for design and finally, design elements illustrated with figures of the user interface of the resulted digital solution.

Section 5.2 responds to RQ2, related to Study 2: *What are the central design elements for providing quantified feedback through a digital solution in the context of factory floor work?* The section first describes the aim of the design research process and main insights of the background study: design and ethics-related considerations related to potential and acceptability of quantified feedback in a factory context. As Study 2 focuses on employing sensitive health and performance related data in a work setting, ethics considerations ground the design of the solution. After this, the section presents the defined user experience goals based on the background study and the design guidelines and design elements derived from them, illustrated with figures of the user interface of the resulting digital solution.

Section 5.3 responds to RQ3: *What design recommendations can be identified for digital solutions that support well-being at the changing workplace?* The section first presents design implications of the field studies in which the solutions presented in Sections 5.1 and 5.2 are used by target group users as a part of their work and life for 1,5-3 months. These implications are synthetized to the design guidelines of the design phase of the studies, presented as a part of Sections 5.1 and 5.2. This consolidates the results of the thesis to five design recommendations, which give guidance to practitioners of HCI community and other audiences for designing digital solutions that support well-being at the changing workplace.

5.1 Design elements for a digital solution for fostering positive stress

This section responds to RQ1: What are the central design elements for fostering positive stress through a digital solution in the context of entrepreneurial work? The design elements synthetize the gained new knowledge of entrepreneurs' means to achieve positive stress and the defined design guidelines to make the design appropriate and engaging for its users.

Section 5.1.1 describes entrepreneurs' means to foster positive stress. These means form the core content elements of the resulting digital solution, presented as six *toolsets* consisting of digital *tools* incorporating the means. After that, Section 5.1.2 describes the design guidelines to guide the design as well as design elements derived from the guidelines. Section 5.1.3 illustrates how the design guidelines and elements were realized in the resulting digital service. Finally, Section 5.1.4 gives a brief summary of the design elements.

5.1.1 Main insights of the background study: Means to foster positive stress

The aim of the design research process of Study 1 was to design a digital solution for fostering positive stress in the context of entrepreneurial work (P1-P3). As entrepreneurial work may subject entrepreneurs to heavy workloads and high levels of stress (Palmer, 1971; Langan-Fox & Roth, 1995), effective stress management is important for them. However, many entrepreneurs have skills and psychological capital that help them to face stress (Frese, 2009; Baron et al., 2016), and thus, they can provide a lot to learn to other entrepreneurs or employees. Our aim was both to learn from entrepreneurs their means to manage stress, particularly to facilitate positive stress experiences, and based on the gained knowledge design a digital solution that would support its users in finding new resources for work and well-being through the approach of positive stress.

Twenty-one interviews and a follow-up study consisting of a eustress diary, physiological measurements and follow-up interviews revealed that all participating entrepreneurs recognized the phenomenon of positive stress, i.e. eustress, and considered it beneficial for their work and well-being (P2, P1). It helped them to get best out of themselves, to achieve intended results on schedule and feel energetic but focused when working. Eustress was experienced, for example, when giving a

presentation, attending to an important meeting or when completing deliveries in a tight schedule. Feelings of eustress included starting to feel confident during a challenge, being in control of the situation and seeing gradual results of one's work. The entrepreneurs perceived feeling eustress as "a preferred state" (Zimmerman et al., 2007), a state worth striving for, which strengthened our goal to design a digital service to develop skills and practices for fostering positive stress.

Based on an analysis of the entrepreneurs' ways of working leading to eustress experiences, areas of co-creation and collaboration, planning and scheduling, togetherness and shared success, means for mental preparing and ways to recover were identified as areas that could be facilitated by technology (P1). The themes were refined after a new analysis that included also the entrepreneurs' ways of thinking that helped them to feel and stimulate eustress in their daily lives. The following results describe the identified six thematic areas consisted of the means to foster eustress and the resulting *Toolsets* comprising of these means (P2, P1).

First, the entrepreneurs' eustress experiences were facilitated by self-reflection of one's thoughts, feelings and actions. When the entrepreneurs described their eustress experiences, the descriptions included reflective practices, such as putting things into perspective, changing one's point of view and harnessing a feeling of trust in the future as well as trust in one's abilities. The reflective practices forms the first toolset of the resulting digital solution: *Self-reflection and changing the mind-set* (see a detailed description about this toolset in Tikkamäki et al., 2016).

Another aspect that the entrepreneurs associated with their eustress experiences were the daily practices that helped them to manage their work. For example, ways to prioritize and schedule work, share it with others, concretize it and divide it into smaller pieces facilitated eustress experiences. The practices to manage work form the second toolset: *Organizing work*.

Third, the entrepreneurs had various means to create pressure for boosting oneself to accomplish tasks or to learn new skills. The most typical way to create pressure for accomplishing a task was to set a deadline for it. A deadline helped also in accomplishing a task at a sufficient level to avoid making an overly perfect outcome. Creating pressure in cases of little or no external pressure forms the third toolset: *Stimulating positive pressure*.

Fourth, not only positive pressure but also harnessing of positive aspects of one's work increased the feelings of eustress. The entrepreneurs harnessed the feeling of joy at work by seeking out meaningful tasks, by building a positive work environment and by enjoying and sharing positive moments, successes and efforts toward a goal.

The ways to recognize and strengthen the positive aspects in one's work form the fourth toolset: *Harnessing a feeling of joy*.

Fifth, preparing for challenging situations and focusing on essential when facing a challenge, alleviated negative stress and enabled eustress experiences. The entrepreneurs had various means to prepare for challenges, such as mentally walking through them beforehand, making lists for clarifying their goals or creating an energetic or focused mind-set for facing the challenge. These practices form the fifth toolset: *Mental preparation*.

Sixth, most entrepreneurs recognized the importance of recovery between work challenges – even though they would have been perceived as positive. They had generated their own practices to detach from work, slow the pace and release mental pressure, such as physical exercise or going outdoors. They also ensured having a sufficient number of breaks while working and paid attention to the amount of sleep. Still, it was typical to continue the work after office hours, which makes it more difficult to reserve enough time for recovery. Ways to recover form the sixth and final toolset: *Recovery*.

The toolsets of the resulting digital solution consist of the described different practices or strategies, *Tools*, summarized in Table 4. The toolsets and tools form the core content elements for a digital solution to help users to achieve, increase or maintain the preferred state of positive stress, and recover from it when needed.

Table 4. Toolsets and tools for fostering positive stress.

Toolset	Tools for fostering positive stress
1. Self-reflection and changing the mind-set	Self-reflection of thoughts, feelings and actions; Shifting toward a positive point of view; Gaining perspective; Fostering trust in oneself and the future; Regulating personal resources; Sharing and sparring
2. Organizing work	Planning and scheduling; Concretizing tasks and goals; Working together; Breaking routines
3. Stimulating positive pressure	Creating challenges; Generating time pressure; Seeking out challenging situations
4. Harnessing joy	Seeking out meaningful tasks; Building a positive environment; Enjoying and sharing success
5. Mental preparation	Focusing on the essential; Preparing for challenges
6. Recovery	Taking breaks; Detaching from work; Slowing the pace; Releasing pressure; Fostering physical and mental well-being; Ensuring sufficient sleep

5.1.2 From design guidelines to central design elements

The field data and insights of three expert workshops leaded us to designing a holistic, modular digital solution to inform users of the phenomenon of positive

stress and to provide various tools to foster it for their individual needs (P2). To guide the design process, five design guidelines were defined, based on the field data, literature and the expert workshops (P2). The person based intervention approach (Yardley et al., 2015) and Persuasive systems design model (Oinas-Kukkonen & Harjumaa, 2009) were consulted as design frameworks to inform the guidelines. The defined design guidelines are *1) Minimizing user effort* to facilitate effortless adoption and use of the tool in typically tight schedules of entrepreneurs*, 2) Providing freedom to discover* to meet the personal needs for new means to support eustress, *3) Enabling follow-up of progress* to support awareness of one's development, *4) Enabling learning from peers* to provide insights from peers that the entrepreneurs may lack and *5) Supporting of integration of skills into daily life* to support new practices becoming habits. This section describes how the central design elements were created based on the design guidelines, to support adoption of the means of fostering positive stress, compiled in the core design elements of *toolsets and tools*, presented in the previous section.

The first design guideline, Minimizing user effort, guided creating of design elements that support tunnelling the user through the program, providing personalized suggestions, dividing content into standard-format and bite-size pieces and reminding of use. Tunnelling was supported by creating an *introduction* module for providing guidance to use the service. Personalized suggestions were designed to be given through *a screening questionnaire* that would help the user to start from the toolsets identified as most useful. To simplify use, the content was designed to be divided into modules with identical structure. In addition, *reminders* of the usage of the solution as well as yet-to-be completed tasks were designed.

The second design guideline, Providing freedom to discover, guided the design to support non-restriction of choice, enabling users to select the time and pace for using the solution, the order of walking through the toolsets, the toolsets and tools to practice and tasks to complete. Particularly the toolset Self-reflection and changing the mind-set as well as *reflection exercises* related to each tool encourage discovering personally meaningful insights.

The third design guideline, Enabling follow-up of progress, was followed on two levels in design: by designing ways to maintain user's awareness of the progress in completing the toolsets and tools of the solution as well as providing understanding of the overall progress of the development of skills facilitating eustress experiences. The latter was designed to be supported with an *end questionnaire*, which provides feedback of the progress in eustress skills gained during the use of the service.

The fourth design guideline, Enabling learning from peers, crystallizes the essence of our digital solution: to share practices that other entrepreneurs associate to eustress experiences to give inspiration, encouragement and practical tools for others. Examples of peer experiences were considered especially important for entrepreneurs who often work independently or may lack a work community. The voice of entrepreneurs was designed to be conveyed through examples collected from their descriptions of eustress, which would be used as a central content to demonstrate different means to foster eustress. Expressing the insights through *quotations illustrating peer experiences* was assumed to make the solution more authentic, engaging and realistic, by connecting the tools to the daily practices of real people.

The fifth and final design guideline, Supporting of integration of skills into daily life, guided the design to include elements that support practicing the skills also off-line as well as linking them to the user's work and life. Besides reflection exercises, practicing of skills was designed to be supported through *off-line exercises,* which encourage the users to rehearse the skills in their daily life. Furthermore, the users would be provided with links to selected *3rd-party applications* related to each toolset.

The design guidelines guided the design of the design elements, modules and content of the digital solution for fostering positive stress. The design guidelines, the underlying user needs and the resulting design elements are summarized in Table 5.

Table 5. Design for fostering positive stress: guidelines, design rationale based on underlying user needs and design elements realizing the guidelines for a digital solution.

Design guideline	Rationale	Design elements
Minimizing user effort	Focusing on work goals, optimizing the use of time	Introduction, screening questionnaire, reminders
Providing freedom to discover	Finding tools suitable for own work and life	Multiple toolsets and tools, reflection exercises
Enabling follow-up of progress	Staying aware of one's development	Progress indicators, end questionnaire
Enabling learning from peers	Gaining peer support	Quotations illustrating peer experiences
Supporting the integration of skills into daily life	Integrating new skills into routines, enabling positive behaviour changes	Reflection exercises, off-line exercises, 3rd-party applications

5.1.3 Resulting digital solution: Eustress Toolbox

The design process from gaining understanding of the entrepreneurs' means to achieve positive stress to defining and following the design guidelines and generating design elements to support them, eventually led to an iterative design of Eustress

Toolbox, an online service for fostering positive stress (P2, P3). In the following, the design elements are described in more detail by design guidelines and illustrated as part of the final solution in Figures 3-5.

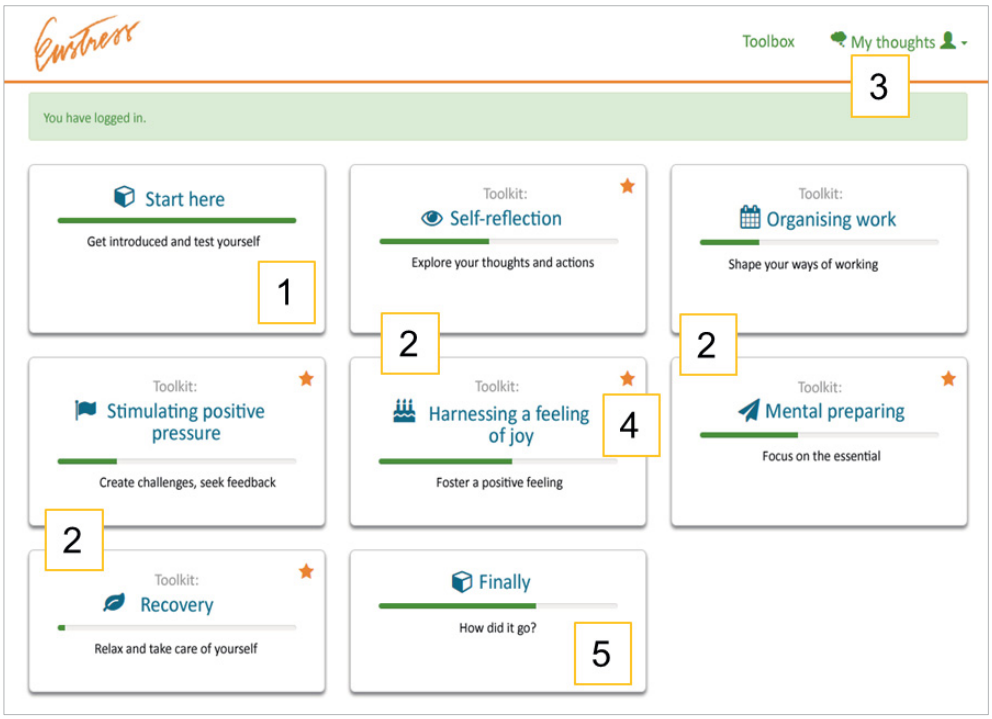

Figure 3. Main view of the Eustress Toolbox online service with numbers 1-5 indicating five design elements: 1) Introduction and screening questionnaire for identifying the most useful toolsets, 2) Six toolsets, 3) Dedicated place for responses to the reflection exercises, 4) Star indicator for recommendation of a toolset, based on a screening questionnaire and 5) End questionnaire.

The first design guideline, Minimizing user effort, is realized in particular in the introduction sections of the service. The introduction of the toolbox (Start here section, no. 1 in Figure 3) guides the user in the use of the service in general, and offers a screening questionnaire for identifying the most useful toolsets. The screening questionnaire consists of 21 statements related to eustress skills, drawn from the findings presented in Section 5.1.1. The toolsets that are identified as the most useful for the user are marked with stars to guide the user to focus primarily on them (no. 4 in Figure 3). The effortless use is also supported by the identical structure of the toolsets and easy access between the parts of the service (e.g. no. 2 in Figure 5).

Besides the possibility to freely select toolsets and tools, the second design guideline, Providing freedom to discover, is realized, in providing reflection exercises related to each tool (Think section, no. 3 in Figure 5) and collecting the user's responses to these exercises to a dedicated section for further reflection (My thoughts section, no. 3 in Figure 3). In addition, the guideline is supported through providing alternative ways to proceed in the service, either sequentially completing all sub modules or selectively, walking through a part of the content (no. 4 in Figure 5).

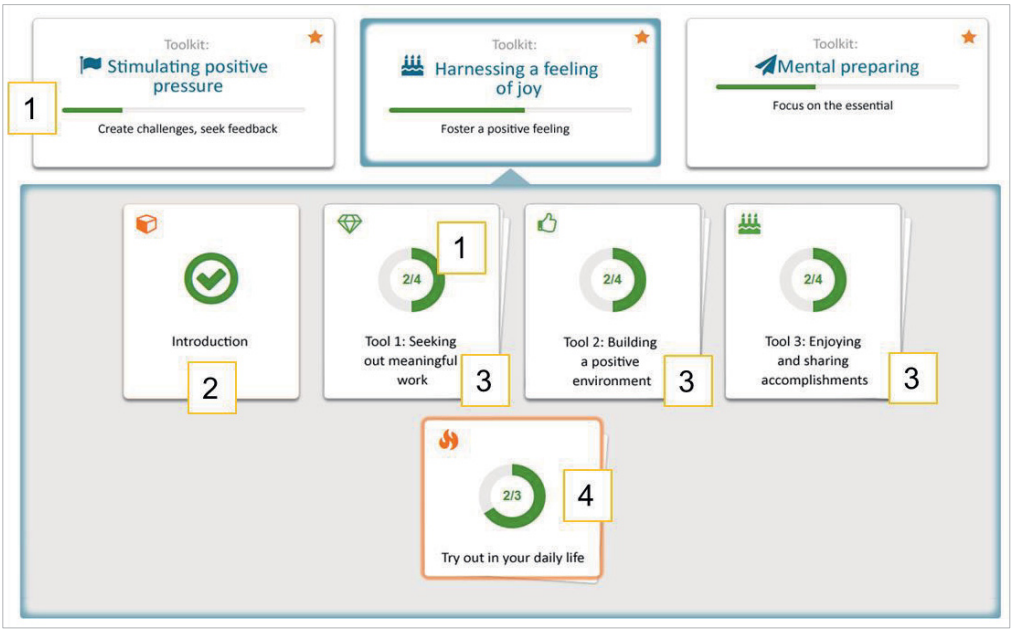

Figure 4. Main view of a toolset with numbers 1-4 indicating four design elements: 1) Progress indicators for completing a toolset and tools, 2) Introduction to give short description of the toolset, 3) Tools and 4) Section for trying out the tools in practice, including off-line exercises and 3rd party applications.

The third design guideline, Enabling follow-up of progress is realized by presenting progress indicators of completion of each toolset and the modules within a toolset (no. 1 in Figure 4). In addition, after three weeks of use of the service, an ending module is activated (Finally section, no. 5 in Figure 3). The module contains a follow-up questionnaire, which repeats the screening questionnaire and visually summarizes the user's progress related to eustress skills by providing a comparison to the status of the screening questionnaire.

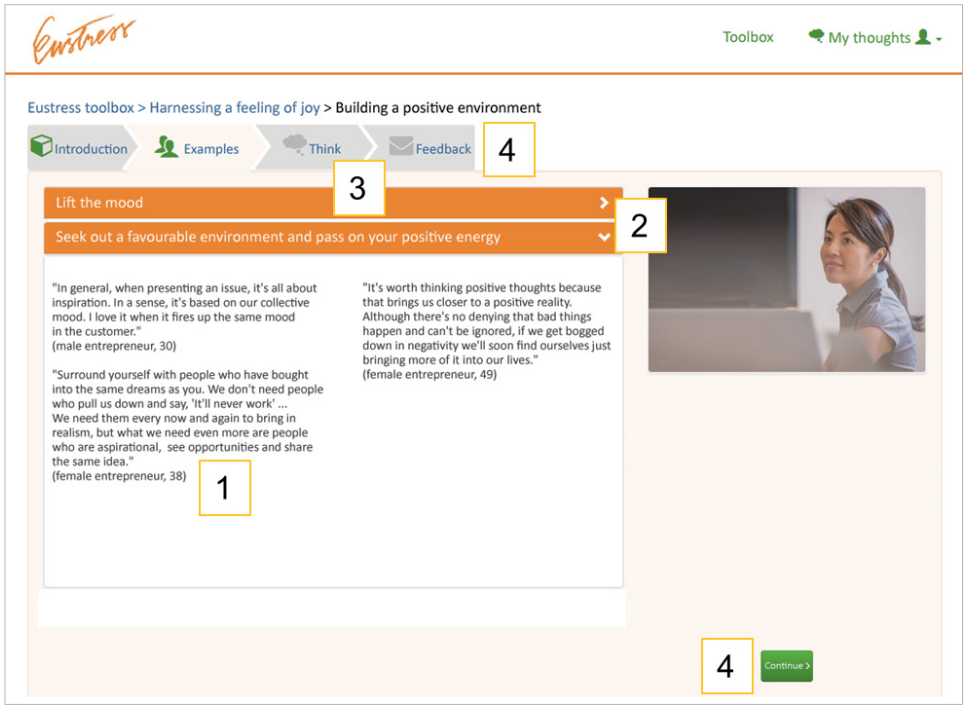

Figure 5. Example of a view with quotations illustrating peer experiences with numbers 1-4 indicating four design elements: 1) Entrepreneur quotes related to a tool, 2) Easy access to quotations of related tools, 3) Reflection exercises, and 4) Alternative ways to proceed: a sequential or selective approach. Photo by Jeremy Bishop on Unplash.

The fourth design guideline, Enabling learning from peers, is realized in the quotations of entrepreneurs, which form the central content of each eustress tool (no. 1 in Figure 5). The gender and age of the entrepreneurs are shown with the quotations, to add authenticity, still protecting the identity of the entrepreneurs. The photos used are from online photo services.

The fifth and final design guideline, Supporting the integration of the skills into daily life, is supported by the design elements for trying the tools in practice (Try out in your daily life section, no. 4 in Figure 4). Each toolset includes 2-3 offline-exercise options, to be selected to complete during the following week. Typically, the off-line exercises encourage the user to rehearse a certain practice during a course of one week, for example by proposing one moment of recovery for each day of the week. Furthermore, links to selected 3rd party applications are provided to give the users additional means to foster the selected areas of eustress.

5.1.4 Summary: Central design elements for fostering positive stress

The six themes derived from the qualitative study with entrepreneurs (P2, P1) form the core content elements, i.e. *toolsets*, comprising of skills and practices, i.e. *tools*, to foster eustress. The toolsets are 1) *Self-reflection and changing the mind-set*, 2) *Organizing work*, 3) *Stimulating positive pressure*, 4) *Harnessing a feeling of joy*, 5) *Mental preparation,* and 6) *Recovery*.

To guide designing a digital solution to foster positive stress, five design guidelines were created: *1) Minimizing user effort, 2) Providing freedom to discover, 3) Enabling follow-up of progress, 4) Enabling learning from peers,* and *5) Supporting of integration of skills into daily life*. In our design outcome, these guidelines were supported with multiple design elements, of which the most central are *a screening questionnaire, reflection exercises, off-line exercises, 3rd-party applications*, and *quotations from peers*.

5.2 Design elements for a digital solution providing quantified feedback

This section responds to RQ2, related to Study 2: *What are the central design elements for providing quantified feedback through a digital solution in the context of factory floor work?* The design elements are consolidated through a synthesis of the field data, ethical considerations and the principles of the approach of Quantified Self.

Section 5.2.1 describes the main insights of the background study of Study 2: the aim of the design process, encouraging factory workers through data-driven feedback, as well as design and ethics related considerations related to the potential and acceptability of quantified feedback in a factory context. As Study 2 focuses on employing sensitive health and performance related data in a work setting, ethics considerations ground the design of the solution. Section 5.2.2 presents the UX goals and design guidelines derived from the goals, as well as the central design elements created based on the guidelines. Section 5.2.3 illustrates how the design guidelines and elements were realized in the resulting digital service. Finally, the design elements are summarized in Section 5.2.4.

5.2.1 Main insights of the background study: Potential and acceptability of providing quantified feedback to factory floor workers

The aim of the design research process of Study 2 was to support factory floor workers in increasing their awareness of factors influencing their well-being and work performance as well as their development in work tasks. This is especially important in the future factory work, due to the expectation of the work changing towards more autonomous, including opportunities for self-development, and requiring more decision-making and problem solving skills (Gorecky at al., 2014). The concept of providing quantified feedback to factory workers originates from the Quantified Self approach, which promotes self-knowledge and self-improvements through data acquired with technology, such as wearables and mobile applications.

Thirteen interviews of factory workers as well as the expert evaluation and ethics assessment of wearable self-tracking devices provided insights into the potential and acceptability of providing quantified feedback in a factory context (P4, P5). When the idea of quantified feedback through self-tracking at work was first introduced to factory workers, they had mixed but mostly negative reactions towards it, as they associated it with receiving negative feedback. However, when perceptions to the first prototype of the digital solution with initial design elements were collected from the potential users, the concept was perceived more positively, as mainly interesting and valuable. Even though we explored the idea of self-tracking with a relatively small number of factory workers, the initial feedback was promising. Especially *encouraging and personal feedback* could be interesting and beneficial to factory floor workers, as the factory workers felt that they do not get much positive feedback on their efforts and that the provided statistical feedback of production is mainly targeted to the management, not for the machine operators. If quantified feedback would be designed in an appropriate and ethically sound way fitting to the factory context and aiming at encouraging and empowering feedback, it could be seen as "a preferred state" (Zimmerman et al., 2007), giving users insights of their productivity and well-being, without sacrificing one another.

To be able to design the quantified feedback in an appropriate and ethically sound way, an expert evaluation and ethics assessment of wearable self-tracking devices for a factory context were conducted (P4). Based on the expert evaluation, wrist devices measuring activity, heart rate and sleep were evaluated as suitable in a factory context due to their *data accuracy* and *unobtrusiveness* of use. In addition to possible immediate feedback, *longer-term trend data* would enable personal reflection and positive behavioural changes.

Table 6 summarizes the main findings of the ethics assessment, related to ten ethical values drawn from two frameworks of ethical guidelines and values (Ikonen et al., 2009; Nihan, 2015). The table includes impacts on design and adoption at workplace, as ethical values are relevant for both. The impacts may also intertwine. For example, a goal of conveying a clear purpose of self-tracking and quantified feedback may be supported with appropriate design and with clear communication at the workplace.

Table 6. Ethical values (Ikonen et al., 2009; Nihan, 2015), their rationale related to providing quantified worker feedback and the impact on design or adoption at a workplace. The values identified as most important are bolded.

Ethical value	Rationale	Impact on design or adoption at workplace
Privacy	Crucial as the data is personal and sensitive in nature	Feedback shown only for the user
Autonomy	Particularly important in the context of work; one should not be afraid of negative consequences if opting out	Voluntariness of use, ability to define/restrict the collected data, gentle guidance
Integrity and dignity	Important for any technology, the purpose of quantification needs to be clearly defined	Discreet feedback, Recognition of positive moments and trends, gentle guidance
Reliability	Ensuring trust in the usage purpose of the data as well as the reliability of measurements	Transparent process of collecting and using the data, accuracy of the data
E-inclusion	Including all volunteer workers	Design for all, e.g. not too complicated functionality
Benefit to society (and the workers)	Targeting to true benefit and empowerment instead of new concerns and mental load	Clear purpose and communication of self-tracking
Health and safety	Typically the main objective for self-tracking at work	Gentle guidance to healthier choices, no disturbance to work tasks
Responsibility	Ensuring workers' well-being and safety, preventing misuse	Data security, no disturbance to work tasks
Justice	Quantification should convey a feeling of justice	See the impacts related to Reliability and E-inclusion
Social interactions	Important to consider: e.g. potential social pressure for sharing data	Communication of the purpose of feedback and e.g. respecting of privacy

Even though the ethics assessment revealed a variety of ethical issues, it emphasized particularly the importance of *privacy* and *autonomy* of users as well as their *health and safety*. The findings related to these aspects suggest that the *feedback of the digital solution would be shown only for the user* to ensure privacy of the sensitive data, the application would provide *gentle guidance to encourage* positive behaviour change and it would cause *no disturbance for work tasks*. In addition, the user should be able to define the collected data and voluntariness of usage should be guaranteed. Privacy and autonomy need

particular attention in design, as they require balancing with the benefit for the workers. For example, to support self-reflection and finding new discoveries of oneself and one's work, collecting a rich variety of personal data may be useful. However, to ensure privacy of users, unnecessary data should not be collected. Balancing is needed also in defining whether only the worker can see the provided data or could some information, for example anonymous summaries, be used in a wider scope to develop work practices at the workplace.

Based on the results, a self-tracking device suitable to a factory context needs to be *unobtrusive* during wear and provide *reliable* and *encouraging* feedback in a *discreet* way. Besides the identified ethical issues, the ethics assessment guided the design team to consider ethics throughout the design process. Ethics, together with field results, requirements of factory context and the principles of Quantified Self approach influenced definition of the user experience goals, which are presented in the following section.

5.2.2 From UX goals to central design elements

The field data as well as the insights of the expert evaluation and the ethics assessment of wearable self-tracking devices leaded us to designing a digital solution that provides feedback to factory floor workers related to their well-being and work performance, and connections between these. To guide the design process, four user experience (UX) goals were defined, based on the gained insights and the principles of Quantified Self approach (P5). The defined UX goals are *1) Being empowered and encouraged* to emphasize the aimed impact of worker feedback*, 2) Getting personal feedback* to enable awareness of one's development in work tasks, *3) Getting meaningful insight* to support self-discoveries, and *4) Being undisturbed* to ensure full concentration on work tasks.

The first UX goal, Being empowered and encouraged, was interpreted to Design guideline 1: *Keep positive (but truthful)*. This guideline guided creating of design elements that encourage users by highlighting positive aspects, progress and achievements of the workday, still giving truthful feedback. This was supported by selecting the solution to include *positive production metrics* instead of typically used negative measures, such as the machine idle time or the number of failures. In addition, encouragement was designed to be provided by *indications of positive progress* of the metrics.

The second UX goal, Getting personal feedback, was turned to Design guideline 2: *Give personal feedback*. It guided the design to include *personal production metrics* that the user could have an impact on, which would allow seeing one's development in work tasks. All the collected data and provided feedback was defined as personal, leading to a design decision of all data being accessible only for the user, not to be shared with the employer or the management.

The third UX goal, Getting meaningful insight, is based on the vision of Quantified Self approach that meaningful insights require personal reflection on the data. Thus, this UX goal was interpreted to Design guideline 3: *Enable personal reflection*. Personal reflection was designed to be encouraged by triggering personal assessment of the workday or by providing different types of data to offer the user an opportunity to find meaningful connections or trends. This was designed to be supported by three design elements: enabling *self-reporting*, seeing longer-term trends via *Trend view* as well as *combining of well-being data and production data*.

The fourth UX goal, Being undisturbed, was turned to Design guideline 4: *Do not disturb the worker*. It guided the design to include only elements that would not disturb the worker during the work tasks. No real-time information or notifications were designed and only *summary-type of feedback* was provided. The main view was designed in a way that it can be accessed quickly, for example during a break at work.

The four design guidelines guided the design of the content and design elements of the digital solution for providing quantified worker feedback. Table 7 summarizes the UX goals, design guidelines, their rationale and the resulting design elements.

Table 7. Design for quantified feedback: UX goals, design guidelines, their design rationale, and design elements realizing the guidelines for a digital solution.

UX goal	Design guideline	Rationale	Design elements
Being empowered and encouraged	Keep positive (but truthful)	Empowerment and encouragement through positive feedback; supports the feeling of achievement	Positive production metrics, positive progress indicator of a metric
Getting personal feedback	Give personal feedback	Enabling positive behaviour changes, showing development in work tasks	Well-being metrics, personal production metrics
Getting meaningful insight	Enable personal reflection	Providing new insights, such as connections between own well-being and work performance	Self-reporting section, combining well-being and production metrics, trend view
Being undisturbed	Do not disturb the worker	Factory work requires attentive monitoring of machinery and quick reaction to problems	Summary-type of feedback (no real-time information or notifications)

5.2.3 Resulting digital solution: Worker Feedback Dashboard

The design process from gaining understanding of the potential and acceptability of the quantified feedback in the factory context to defining UX goals and design guidelines and generating design elements to support them, eventually led to an iterative design of Worker Feedback Dashboard, a smart phone optimized web application for providing data-driven feedback for machine operators in a factory (P4, P5, P6). The application shows the user well-being metrics, tracked with an activity tracker, and production metrics of the work shift, tracked from the production line. Figures 6 and 7 illustrate the structure and functionality of the application and particularly provide examples of the design elements supporting the UX goals. Each design element realizes one or more design guidelines derived from the UX goals.

The first design guideline, Keep positive (but truthful), is realized on two levels in design: in the selection of production metrics and in indicating positive progress of the metrics. The selected production metrics include the utilization rate of the machine and the longest continuous machine-running period during the work shift as well as the average recovery time after failures. The focus of the feedback was shifted from the machine idle time and number of errors to more positive metrics (Machine running and Resolved failures, no. 3 in Figure 6), to be encouraging for the workers. Still, the metrics mirror the main work objectives of the machine operators: running production without interruptions and quick solving of problems. Positive progress of a production metric, compared to five previous work shifts, is indicated with a star indication (no. 4 in Figure 6).

The second design guideline, Give personal feedback, is realized in all feedback provided by the application: well-being metrics being personal in nature and work performance metrics summarizing the production metrics during the worker's own work shifts (no. 1 in Figure 6). All the production metrics are such that the user has a possibility to have an impact on them. The first prototype included also a number of produced orders and items as production metrics, to increase a sense of achievement, but they were removed from the final design, as the workers felt them irrelevant, as they cannot influence them.

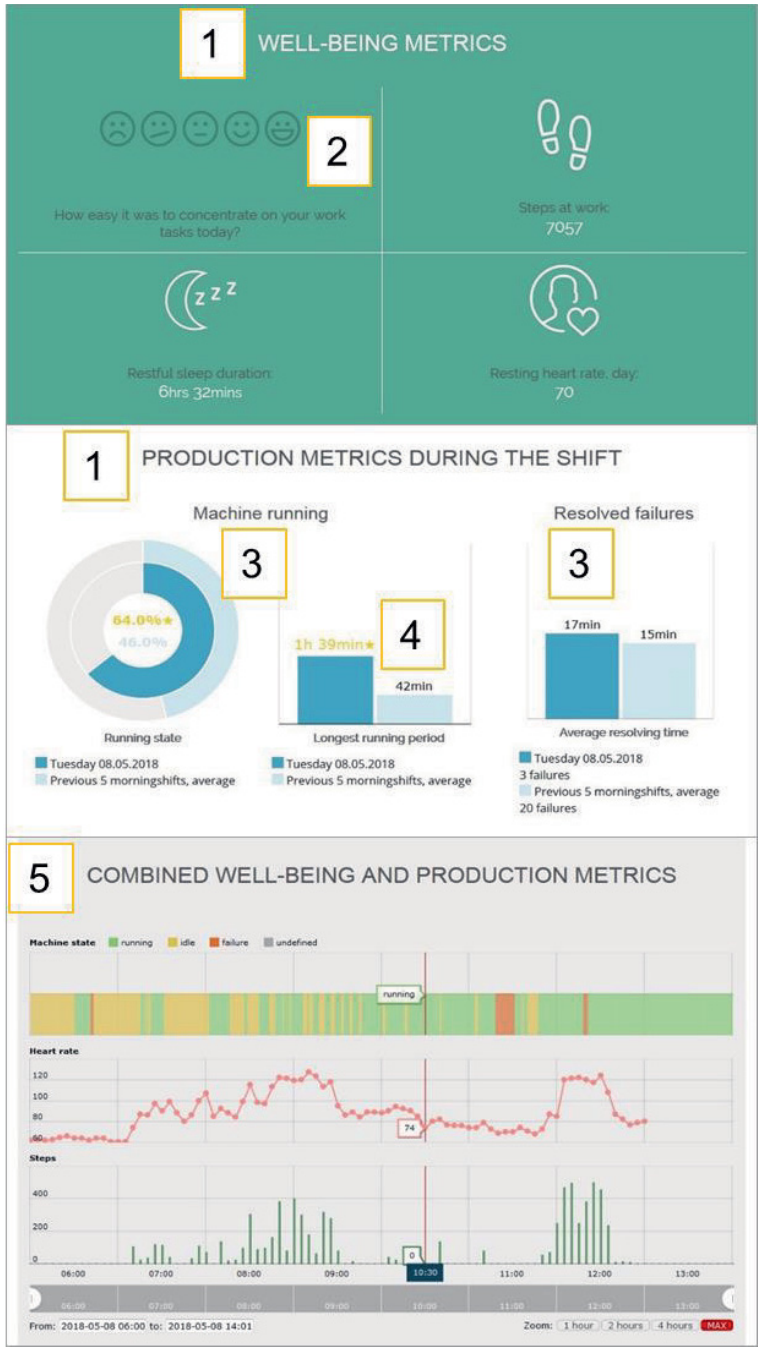

Figure 6. The metrics of the main view of Worker Feedback Dashboard with numbers 1-5 indicating five design elements: 1) Personal well-being and production metrics, 2) Self-reporting section, 3) Positive production metrics of machine running time and resolved failures, 4) Positive progress indicator, and 5) Graph combining well-being and production metrics.

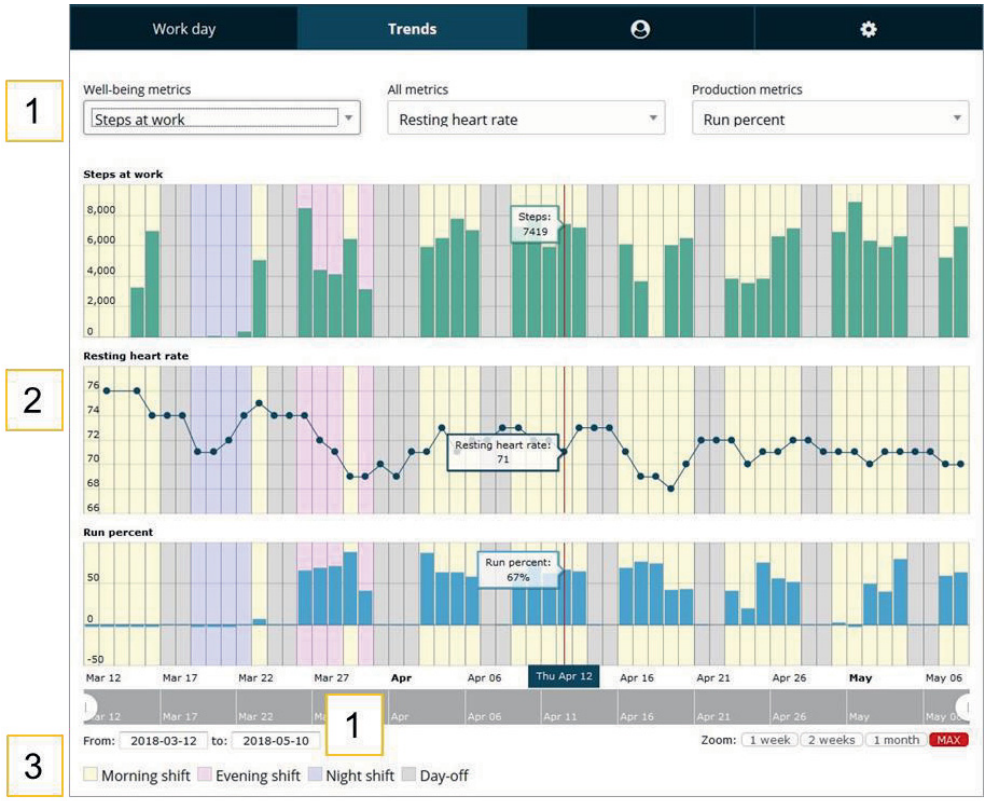

Figure 7. Trend view of the Worker Feedback Dashboard with numbers 1-3 indicating three design elements: 1) Selection for the metrics and the timescale, 2) Three metrics shown simultaneously, and 3) Type of the work shift.

The third design guideline, Enable personal reflection, is realized through three design elements: a self-reporting section, a time-series graph and a trend view. In the self-reporting section (no. 2 in Figure 6), the user is asked to report the perceived concentration level each day, to encourage engagement with the application and assessment of one's mental state. In line with the user feedback, the self-reported aspect was changed from mood to the level of concentration, to make the assessment more clearly connected to the work performance. A time series graph supports self-reflection of the workday by providing detailed information combining the most central production metric to two well-being metrics: heart rate and steps (no. 5 in Figure 6). The trend view enables seeing evolvement of metrics and discovering connections between metrics (no. 2 in Figure 7) according to the user selection of the metrics and the timeline (no. 1 in Figure 7). In the trend view, personal reflection is further supported by presenting the different types of work shifts with different colours in the background of the graphs (no. 3 in Figure 7).

The fourth design guideline, do not disturb the worker, is realized in the overall design, enabling quick checking of a certain metric or quick browsing of the main view. The well-being metrics from the activity wristband and the production metrics from the production line are retrieved in every twenty minutes. The lack of real-time information has the benefit of not attracting the user to check the data while working.

5.2.4 Summary: Central design elements for providing quantified feedback

The insights derived during the design process (P4, P5) were crystallized as UX goals that can be used as guidance for the design of digital solutions for providing quantified feedback for factory workers. The UX goals are summarized as 1) *Being empowered and encouraged,* 2) *Getting personal feedback* 3) *Getting meaningful insight,* and 4) *Being undisturbed* and interpreted to four design guidelines, accordingly: 1) *Keep positive (but truthful)*, 2) *Give personal feedback*, 3) *Enable personal reflection*, and 4) *Do not disturb the worker*. In our design outcome, these design guidelines are supported with multiple design elements, of which the most central are *well-being metrics, personal and positive production metrics, combined view of the well-being and production metrics, a self-reporting section, a trend view* and *indications highlighting positive progress.*

5.3 Design recommendations

This section responds to RQ3: *What design recommendations can be identified for digital solutions that support well-being at the changing workplace?* Section 5.3.1 first presents seven design implications identified through field studies of the Eustress Toolbox and Worker Feedback Dashboard solutions, presented in Sections 5.1.3 and 5.2.3. Section 5.3.2 consolidates these design implications as well as the design guidelines, presented in Sections 5.1.2 and 5.2.2, to form more generic design recommendations for the design of digital solutions that support well-being at the changing workplace. Even though the studies address entrepreneurship and factory floor work in particular, the recommendations are applicable to other fields and occupations, particularly ones that are changing, for example, due to increasing digitalization and automation, and thus require self-leadership and self-reflection skills from workers. Design recommendations are summarized in Section 5.3.3.

5.3.1 Design implications based on the field studies of Eustress Toolbox and Worker Feedback Dashboard

The user experience, user acceptance and perceived benefits of Eustress Toolbox and Worker Feedback Dashboard were studied through field studies. In the field study of Eustress Toolbox (P3), twenty-two entrepreneurs or people having an entrepreneur-type job used the Eustress Toolbox web application for approximately six weeks. In the field study of the Worker Feedback Dashboard solution (P6), ten factory floor workers from three factories used the smart-phone optimized web application accompanied with a self-tracking device for two to three months. The users experienced the content of both solutions interesting, and they perceived benefits of use, such as finding new possibilities to have an impact on one's work, recognising one's accomplishments, adopting new reflective practices or paying more attention to recovery on free time (P3, P6).

When rating the design elements of the Eustress Toolbox, the participants of the field study considered especially the off-line and reflection exercises, quotations of peers and the screening questionnaire useful. Off-line exercises were rated as the most useful feature of the service, as they provided concrete tools to practice new skills in the daily life. Reflection exercises helped users to identify their own practices and the quotes were considered as eye opening, because of the new perspectives they offered. The usage activity of the service was lower than expected, which may be partly due to lack of reminder features that were designed and implemented, but due to a technical reason, the service did not send them at all during the field study. However, almost all the participants wanted to continue using the service after the field study. During the field study, the participants' negative stress decreased significantly, as measured by the perceived stress scale, and the participants reported that their positive stress experiences had increased. The impacts on stress should still be considered as preliminary, as they may have been caused also by other factors than using the Eustress Toolbox. For example, participating in the study as such may have led to paying more attention in one's stress experiences.

During the field study of Worker Feedback Dashboard, the participants used the application actively and typically checked the application once or twice a workday, during breaks or after the work shift. All the five aspects of the evaluation framework for Operator 4.0 solutions (Kaasinen et al., 2018), including usability, user experience, user acceptance, safety and ethics were evaluated positively. The users were especially interested in the metric of the amount of restful sleep that was rated very interesting by most of the users and interesting by all. The users showed interest

also towards the number of steps taken during the work shift, resting heart rate, utilization rate of the machine and the graph of combined well-being and productivity measures. The metrics of the longest run of the machine and the recovery time from failures were not regarded as relevant by all, even though some considered them as interesting and encouraging. Similarly, most users found the trend data interesting but not all, possibly because it was not located in the main view and thus the use could be easily forgot. The self-reporting section was rated as least interesting, possibly because it does not provide data-driven, new information and because the trend information was not actively followed, which could have made this metric more insightful.

Based on the user experience and users' development ideas related to the use of Eustress Toolbox, four design implications are proposed to support adoption and engagement with a digital solution, especially in an entrepreneurial work context (P3). Although the design implications are linked particularly to the context of entrepreneurship, they can also be applied to employees, especially ones, whose work would benefit from the entrepreneurial mind-set and work practices.

The first design implication, *Make me put it into practice! – Integrate into the daily hassle of entrepreneurs* emphasizes the need to integrate the use of the solution and rehearsal of the new skills to the daily life of the users. When using Eustress Toolbox, self-reflection exercises and off-line exercises supported this, but the integration could have been further supported by mobile optimisation of the application, use of reminders and designing content for versatile usage situations, for example audio exercises for situations when reading is not an option.

The second design implication, *Guide me! – Provide personal guidance while maintaining a possibility to explore*, emphasizes the need for balance between offering personalized guidance and allowing free exploration of the content. The needs may vary between users, but also between the usage sessions of one user. The users considered the screening questions as useful for guidance, yet further guidance could be given based on the completed modules or the achieved skills.

The third design implication, *Recognize me! – Recognize the user's progress and accomplishments in a meaningful way* emphasizes the need for encouraging feedback, which concerns progress in using the tool as well as progress in learning the new skills. A meaningful way of giving recognition can include, for example, a summary of skills learned, a recommendation for additional content or a mindfulness exercise to enhance recovery.

The fourth design implication, *Show me what the others do! – Support implicit learning from peer entrepreneurs* emphasizes the importance of peer support that may be

especially important for entrepreneurs who often lack a work community. The central content of the Eustress Toolbox, the quotes illustrating the beneficial ways of thinking and working of other entrepreneurs were perceived as inspiring and insightful. The aspect of peer support could be further strengthened by providing an opportunity for actual interaction with peers.

The field study of the use of Worker Feedback Dashboard resulted in proposal of three design implications for the design of data-driven feedback applications (P6). The design implications are applicable to any digital solutions for quantifying the worker, also beyond the factory context. As these design implications complement the four design implications of Study 1, already presented, these are listed as the design implications 5-7.

The fifth design implication, *Give me meaningful overviews,* emphasizes the importance of giving data-driven information or feedback as a personally meaningful overview that supports finding the relevant information at a glance. Meaningfulness can be increased, for example, by highlighting new trends or by enabling customisation of shown data, based on user preferences or work priorities.

The sixth design implication, *Guide me to act based on the feedback*, highlights the need to put the knowledge into practice to enable positive behaviour changes. This may be supported by behaviour tips, exercises or the possibility to set personal goals. In addition, all the previously presented design implications may foster positive behaviour changes; integration of a new tool or skill into daily practices, personal guidance as well as encouragement to act through recognition, peer support or discovery of new connections through insightful overviews of data all support positive behaviour change.

The seventh design implication, *Do not underestimate the unquantified*, reminds the designer that also unquantified aspects of work may include very meaningful work tasks or objectives, which should not be overlooked, even though a digital solution would concentrate on the aspects that can be quantified. Quantified feedback should provide tools for self-reflection and support the worker's intrinsic motivation for considering well-being or improving work performance, but it should not aim at the complete coverage of all aspects of work or conveying that the quantified objectives would be more important than the unquantified.

The results of the field studies support the design guidelines that were defined in the design phase of the digital solutions. These seven design implications either refine the design guidelines or highlight new design aspects. For example, a design guideline 'Enable follow-up of progress' was refined to a richer format: 'Recognize the user's progress and accomplishments in a meaningful way', while the seventh

design implication 'Do not underestimate the unqualified' raised a new issue that was not explicitly considered when designing the Worker Feedback Dashboard solution.

5.3.2 Synthesis: Design recommendations for supporting well-being at the changing workplace

The design guidelines, presented in Sections 5.1.2 and 5.2.2, as well as design implications drawn from the field studies, presented in the previous section, form a synthesis of design recommendations for supporting well-being at the changing workplace. Figure 8 illustrates the process of creating the research recommendations based on the design guidelines of the design phase and design implications of the evaluation phase of the studies.

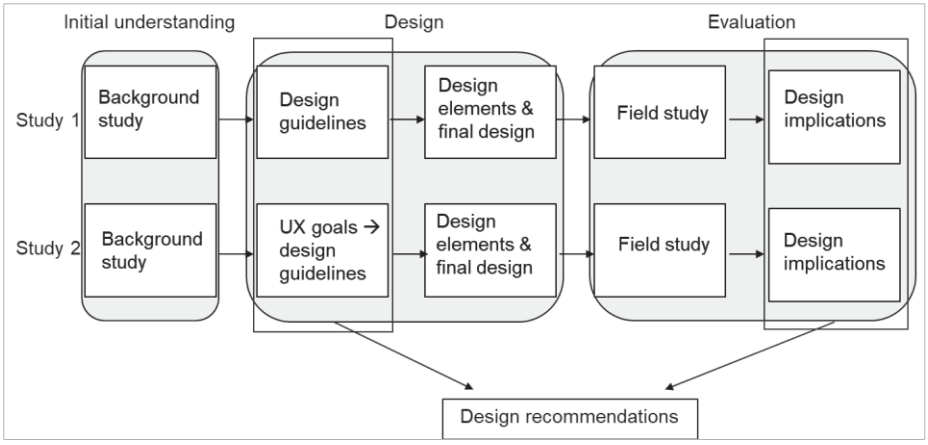

Figure 8. Rationale for the synthesis: Design recommendations derived from the design guidelines of Design phase and design implications of Evaluation phase of Studies 1 and 2.

In Study 1, the term design guidelines was used to refer to the guiding principles for design while in Study 2, respectively, user experience goals were defined first to guide design and then interpreted to design guidelines. These results were combined to the design implications derived from the field studies of the evaluation phase. The design guidelines and design implications were then grouped according to their affinity, resulting to five design recommendations. Table 8 lists the design recommendations and the related design guidelines and implications of the design and evaluation phase of the studies. The names of the original guidelines and implications are slightly modified to shorten and generalize them, and the design implication 'Provide

personal guidance while maintaining a possibility to explore' is divided into two parts.

Table 8. Design recommendations for digital solutions that support well-being at the changing workplace, synthetizing the design guidelines of Design phase and design implications of Evaluation phase of the studies (P2-P3; P5-P6).

#	Design recommendation	Related design guideline of Design phase	Related design implication of Evaluation phase
1	Provide encouragement and recognition	Enable follow-up of progress; Keep positive (but truthful), Give personal feedback	Recognize me – recognize the user's progress and accomplishments in a meaningful way
2	Enable self-reflection	Provide freedom to discover, Enable personal reflection	Give me meaningful overviews; Maintain a possibility to explore
3	Support focusing on the essential	Minimize user effort; Do not disturb working	Provide personal guidance; Do not underestimate the unquantified
4	Integrate to daily practices	Support the integration of skills into daily life	Make me put it into practice; Guide me to act based on the knowledge
5	Inspire and inform through peer experiences	Enable learning from peers	Show me what the others do – support implicit learning from peers

The first design recommendation, *Provide encouragement and recognition*, emphasizes the opportunity to support well-being through empowering the users of a solution to acknowledge their strengths, efforts and accomplishments. The recommendation can be followed, for example, by supporting the users of a digital tool by concretizing their efforts by the means of quantification or giving feedback of their progress in using the tool, learning new skills or developing in work tasks.

The second recommendation, *Enable self-reflection*, suggests employing design elements that support discovering meaningful insights through personal reflection. Self-reflection can be encouraged by a more open or personalized design approach: by offering various kinds of data or knowledge for making new connections and self-discoveries or more straightforwardly, by offering meaningful overviews of data or knowledge to support new insights. Supporting both approaches would serve users with different needs and preferences or the use of a tool in different situations.

The third design recommendation, *Support focusing on the essential*, reminds the designer that using a digital tool is not the main task of the user. The digital tool should support completing work tasks, but it should not disturb working. Thus, the use should be effortless and guided, and the tool should fit to the work context and needs of its users. The design should aim at respecting the aspects of work that are meaningful to the user. Even though the tool would focus on one approach to support well-being, it should not overlook the other sides. For example, when designing a tool for fostering positive stress the designer should not overlook the

impacts of negative stress or when designing a tool for providing quantified feedback, the designer should not underestimate the unquantified aspects of work.

The fourth design recommendation, *Integrate to daily practices*, emphasizes the importance of integrating the usage of a tool or new skills learned through the tool to daily life of the user. Several design elements, such as exercises or elements supporting different usage situations, support integration to daily practices and thus forming of habits and enabling of positive behavioral changes.

The fifth and final design recommendation, *Inspire and inform through peer experiences,* highlights the opportunity of learning from peers or conveying a sense of fellowship through design. This may be especially important in autonomous work where support from work community is not always available. The experiences of peers are not effective for conveying only practical tools and tips but also ways of thinking that are easier to identify with than general recommendations or research results.

5.3.3 Summary: Design recommendations for digital solutions that support well-being at the changing workplace

Table 9 concludes Results chapter by summarizing the design recommendations that support well-being at the changing workplace. To concretize the recommendations, the table gives examples of design elements that support their implementation.

Table 9. Design recommendations for digital solutions that support well-being at the changing workplace, their design rationale and examples of design elements realizing the recommendations.

Design recommendation	Rationale	Examples of design elements
Provide encouragement and recognition	Empowering users through acknowledging their efforts and progress	Positive indications of progress and achievements
Enable self-reflection	Enabling personal reflection through different approaches	User-selectable content and data supporting own discoveries; overviews capturing potentially meaningful insights
Support focusing on the essential	Supporting completing work tasks without disturbing the user; guiding to focus on the essential when using a digital tool	Summaries of information without real-time indications; personal guidance for identifying useful content
Integrate to daily practices	Facilitating integration of usage of the solution and practicing of new skills into daily life	Offline exercises, reminders, versatile content for different usage situations (e.g. audio content)
Inspire and inform through peer experiences	Conveying a sense of fellowship and real-life examples	Practical tips from other users, commenting and other interacting possibilities

All five design recommendations support designing of digital solutions that help facing challenges of the changing working life. Changes may induce stress and uncertainty of one's competences, which could be alleviated with design that encourages the user, enables self-reflection, focuses on the essential and is integrated to daily practices. In addition, peer experiences can offer inspiration and practical insights, particularly in autonomous work.

6 DISCUSSION AND CONCLUSIONS

This chapter discusses the scientific and practical contributions of the thesis, ethical considerations, trustworthiness and limitations of the research and opportunities for future research. Finally, the chapter concludes the thesis.

6.1 Contributions of the research

The contributions of this research benefit both the HCI research and practice communities. Due to the integrated and intertwined nature of the scientific and practical contributions, the scientific contributions have also practical implications.

6.1.1 Scientific contributions

This doctoral thesis contributes primarily to the field of HCI, by providing understanding of design elements and recommendations for well-being at work, through two design research studies, focusing on fostering of positive stress, particularly in an entrepreneurial context, and encouraging quantification of a worker, in a factory context. This work contributes to HCI by widening the prevalent approaches of design for well-being by proposing new approaches to focus on the positive aspects of work and by providing empirical understanding of user groups that are at the forefront in facing the changes in working life. The contributions of both studies extend beyond the original work contexts, to the fields and occupations that are changing, for example, due to increasing digitalization and automation, and thus require self-leadership and self-reflection from workers.

Through Study 1, this research provides new knowledge of the less studied positive side of stress. It adds to the current, mainly conceptual, knowledge empirical understanding of the phenomenon of positive stress and ways to foster it in everyday life and work. While the earlier research suggests means for leaders to encourage eustress experiences of the employees (Hargrove et al., 2013), the contribution of this research is in the focus on entrepreneurial work and thus the shift to self-

leadership and self-reflection, identifying tools for empowering the workers themselves to find ways for enhancing their well-being. The contribution for design research are the guidelines and design elements for fostering positive stress, which are illustrated through the created design artefact.

Study 2 increases the understanding of self-tracking by adopting the approach of Quantified Self into a factory context, and focusing on the perspectives of user experience and design as well as ethics. It widens the current understanding of self-tracking at work that has typically been studied in office context and responds to a research gap of focusing on the user experience of workers (Chung et al., 2017). The results provide also new knowledge to the theme of future factory work and more specifically, to the scientific literature of Operator 4.0. (Romero et al., 2016). With means of design research, the results, illustrated through the created design artefact, provide understanding of design guidelines and elements that have potential in providing the benefits and overcoming barriers related to self-tracking at work identified in prior research.

The main contribution to design research is crystallized as the synthesis of the results of the thesis into five design recommendations for digital solutions that support well-being at the changing workplace. In line with the results of Study 1 and Study 2, the recommendations emphasize the role of the worker in the discovery of insights and work practices suitable to oneself, thus enabling generating and reinforcing job resources and personal resources for work, which predict work engagement (Bakker & Demerouti, 2007). While theories and frameworks related to positive design and design for well-being focus on providing meaningful experiences for the user (Hassenzahl, 2010), enhancing personal experiences (Riva et al., 2012) or supporting satisfying of psychological needs (Peters et al., 2018), the approach and recommendations of this work aim at empowering the worker through supporting self-leadership and self-reflection. By supporting the worker in identifying personal and job-related aspects influencing one's well-being, the design has potential to strengthen the user's resources to face the challenges of the changing workplace and even proactively have an impact on them.

The design research and the resulting design recommendations of this thesis are in line with Positive design framework (Desmet & Pohlmeyer, 2013). Both share a human-centred perspective, a holistic approach to design and the focus on opportunities. Desmet and Pohlmeyer (2013) define five characteristics of positive design: design for possibilities, balance between present and future benefits, personal fit, active user involvement and long-term effects. The results of this thesis contribute most to the part of active user involvement by giving design guidance that

facilitates the user to discover insights and work practices suitable for oneself and thus requiring engagement of the user. The work of this thesis adds to their proposal of user involvement a perspective of design as empowering the user of technology through encouraging self-leadership and self-reflection as well as design examples that convey an interpretation of active user involvement for one's own well-being in a concrete format. Emphasis on active user involvement proposes also one response to a design research challenge raised by Desmet and Pohlmeyer (2013) to find ways to "empower people to flourish without being prescriptive" (p. 15). When the purpose of design is to engage the user to identify beneficial ways of thinking and working rather than persuasion as such, the risk of manipulation through design is smaller.

As Persuasive systems design model (Oinas-Kukkonen & Harjumaa, 2009) was consulted in the early stage of our design research, also the resulted design recommendations have common elements with the principles of the model. For example, the persuasive principles of self-monitoring, rehearsal, praise, rewards and real-world feel are incorporated in our recommendations of enabling self-reflection, providing encouragement and recognition, supporting integration to daily practices and emphasis on peer experiences. The value of our design recommendations is to focus particularly on design for the changing working life where self-leadership and self-reflection skills are increasingly required and to empower the user to discover and experiment practices suitable for oneself.

Prior research has presented a range of design principles and considerations that are supported by our design recommendations. For example, integration to daily practices has been identified as a common challenge in persuasive systems (e.g. Consolvo et al., 2009; Ahtinen et al., 2013; Stawarz et al., 2015) and thus should be paid particular attention in design. As another example, our design recommendation of enabling self-reflection encourages supporting reflective practice, which has come to focus in HCI relatively recently (Baumer, et al., 2014). Our design recommendation encourages supporting self-reflection both with an open and a personalized approach: by providing possibilities to explore and by providing insightful overviews of data. More prominently, an open approach has been proposed to support reflective practice, by means of providing time and space to explore (e.g. Hallnäs & Redström, 2001), but recent research has proposed also design principles for self-reflection through glanceable information (Gouveia et al., 2015), for which insightful overviews are particularly important.

6.1.2 Practical contributions

The practical contributions of this thesis lie in presenting the design process of the two studies in a practical way by describing the design research phases, design guidelines, design elements and design implications in a manner that provides pragmatic understanding to the practitioners of the HCI community. This responds to the call by Zimmerman et al. (2010) to provide more examples and rigorous documentation of the Research through Design approach in practice. It responds also to the call by Vermeeren et al. (2016) for more research on the process of UX design in practice, such as knowledge of how design decisions are made and how they lead to the final design. In addition, Desmet and Pohlmeyer (2013) have called for focus on hand-on methods for designers, in particular for the early stages of the design process. Another practical contribution of this work is to base the proposed design recommendations on insights gathered throughout the design process of the digital solutions. They are synthetized from design guidelines of the design phase as well as design implications of the evaluation phase, which provided understanding of the user experience and acceptance of the solutions by studying their long-term usage as a part of the real daily work and life of the users.

The design research studies of this thesis present concrete demonstrations of the design process that starts from a more open or defined objective, proceeds to gathering initial understanding by integrating various methods and perspectives, employs the gained insights to create UX goals and design guidelines, advances to generating design elements and finally, studies the long-term user experience of the design in the field. Even though the overall design research approach and the main phases of the human-centric design process are the same in the two design research cases, different data collection methods have been employed and different aspects emphasized in the two cases. This gives realistic understanding of the design processes in practice that are shaped by the target and area of design, background and skills of the practitioners involved and the joined creative process. As the design research process in Study 1 employs the approaches of health interventions and HCI by studying both initial effectivity as well as user experience and design implications, it provides an example of how these approaches can complement each other – a need that has been pointed out in the literature (Klasnja et al., 2011; Poole 2013).

The design research of this thesis proposes an empirical, experience based alternative for a more closely theory-based design research approaches. Even though theory-based frameworks were consulted during our design process, the experiences and perspective of potential users were the main influencer to the design outcomes.

The eustress experiences of entrepreneurs form the central content of our Eustress Toolbox solution, and the perspective and perceptions of factory floor workers were vital when designing the Worker Feedback Dashboard solution. Our aim was to maintain the human-centricity throughout the design process, by interpreting insights of field data to design guidelines, converting them to design elements of the design outcome, and finally studying the user acceptance, user experience and the perceived benefits through field studies. Description of this process, illustrations through design and the concluding design recommendations provide a pragmatic contribution to support designers in designing for well-being at the changing workplace.

6.2 Ethical considerations

Considering ethics is vital when designing new solutions for fostering well-being at work, to ensure that the consequences are favorable from the perspectives of all stakeholders concerned. As Desmet and Pohlmeyer (2013) have pointed out, awareness of potential ethical considerations of design is important, even though the goal of the design would be honorable. To support this, ethics should be embedded in the everyday activities of practitioners (Gray et al., 2018) and attention should be paid to ethical issues throughout the design process (Niemelä et al., 2014), from the early stages of design to adopting the new solutions at workplaces. Workers and other relevant stakeholders should be involved in the process. Ethical considerations are particularly relevant in the context of this thesis, as introducing new solutions to support well-being at the changing workplace raises a range of ethical issues, for example, related to the purpose of new technologies, voluntariness of use and privacy of workers.

When applying the results related to fostering positive stress, it is important to acknowledge that adopting new practices for stress management requires one's intrinsic interest. Solutions that foster positive stress cannot be used as a means to increase stressful work among employees, even though stress would be perceived as positive. By promoting the positive side of stress, it is important not to underestimate the harmful consequences of negative stress or claim that all stressors could be perceived as positive. Instead, the aim of the research is to promote a holistic stress approach that recognizes the positive aspects of stress and may work as a resource to turn the interpretation of some stressors towards more positive, hence enhancing one's well-being.

When applying the results related to providing quantified worker feedback, it is important to pay attention to the relevance and purpose of the feedback. The purpose of self-tracking needs to be clearly defined and communicated to the work community. As self-tracking data is sensitive and personal in nature, privacy of it should be guaranteed. The results of the thesis support the earlier notions by Lupton (2016) as well as Moore and Piwek (2016), who have emphasized that special attention should be paid to the true voluntariness of self-tracking, as in a work context the user may feel social pressure to participate or be afraid of negative consequences if opting out. It is also important to ensure that self-tracking does not distract the worker's attention from work tasks, particularly in safety-critical work contexts, such as factories. In addition, quantification of work should not give an impression of underestimating the non-quantified aspects of work. If the purpose of quantification of a worker is extended beyond personal self-tracking, for example, to convey anonymous summaries of bigger samples to the employer, the workers should be aware of it and a neutral agent, such as an occupational health representative, should convey the information. The same service provider could then help workers in interpretation of their biometric data if needed.

6.3 Trustworthiness and limitations of the research

The research approach of the thesis was mainly qualitative, aiming at generating understanding instead of explaining (Stenbacka, 2001). Several concepts have been suggested for assessing the quality of qualitative research, instead of or to redefine the concepts established in quantitative research. First, the quality of the research of the thesis is discussed through concepts proposed to evaluate *trustworthiness* of qualitative research: *credibility, transferability, dependability* and *confirmability*, parallel to internal validity, external validity, reliability and objectivity, widely used in quantitative research (Lincoln & Guba, 1985). Then, the research is assessed through evaluation criteria suggested for studies applying Research through Design approach.

The research of the thesis aimed at credibility mainly through *data triangulation*, referring to engaging multiple research methods to increase validity, reliability and richness of the data (Golafshani, 2003). For example, when gathering initial understanding of positive stress, data was gained through thematic interviews that were complemented and validated through eustress diaries, physiological methods and follow-up interviews. In addition, the data was collected mainly in real-life

settings and with semi-structured methods, allowing the participants to focus on issues relevant to them.

Transferability refers to the possibility to transfer the results to other contexts. In our research, the studies were conducted among entrepreneurs and factory workers, and thus, the results are applicable especially to entrepreneurial work and modern factory floor work. However, the design recommendations are generalized in a way that they are relevant also to other work contexts, in particular fields and occupations that require self-leadership and self-reflection from workers. Although altogether 70 participants were involved in the studies, which is a considerable number in qualitative research, the number of participants is still the main limitation of the research, and quantitative studies are needed to validate these explorative results.

Dependability and confirmability can be pursued through appropriate sampling and rigorous documentation of the research. In our research, random sampling could not be utilized. In Study 1, recruitment was done mainly through entrepreneur email lists, and in Study 2, workers with a specific work role were recruited from three pre-defined factories. In study 1, most participants were interested in the concept of positive stress, which was considered important for their commitment towards the study. In study 2, the participants represent only a portion of factory floor workers, yet an important one, as their role was regarded as representing the vision of future factory floor workers, due to high automation of their work task. The study samples cannot be considered fully representative, but they included diversity and the sampling method enabled richness of data as well as commitment of participants. In all research phases, at least two researchers were involved in the analysis of the data and the research process was rigorously documented.

According to Zimmerman et al. (2007), the traditional evaluation criteria of research, such as reliability, repeatability and validity, are not applicable to studies following the Research through Design approach. Thus, they set four criteria for evaluating the quality of design research contribution. First, the *process* criterion entails detailed documentation of the research process as well as providing a rationale for selection of the research methods. Second, the *invention* criterion refers to demonstration of how the contribution advances the state of the art in the research community. Instead of validity, Zimmerman et al. state *relevance* as the third criterion, referring to articulating the motivation of the research, "the preferred state" that the design aims at achieving. Fourth, *extensibility* refers to the ability to build on resulting outcomes of the research within the research community.

According to these critical lenses, our research makes both scientific and practical contributions to the HCI community. First, it gives detailed information of the

research process and the rationale for selection of research methods. In terms of invention, it makes a novel integration of research and design outcomes to address the specific research questions and contexts, and situates the work through a comprehensive literature review. In terms of relevance, it provides clear motivation for the research based on the societal changes in working life. It intends to support well-being of workers – contributing to a preferred state where the workers would have appropriate and engaging tools to support them to work effectively while ensuring personal well-being. Finally, to enhance extensibility, it describes the research and design outcomes in the form of design recommendations, which facilitate leveraging the gained knowledge.

6.4 Opportunities for future research

The research of this thesis increases understanding of the area of designing for well-being at work, yet it also suggests opportunities for further research. As the research approach was mainly qualitative, quantitative studies would validate the research findings.

The gained knowledge of Study 1 provides a foundation for a nascent understanding of eustress at work, which may be beneficial for future theorising and refinement of the concept, as well as for empirical studies in different work contexts. In particular, future design research could apply the means to foster positive stress to other digital solutions or non-digital interventions. In general, further research that focuses on or includes the perspective of positive stress would be beneficial to foster holistic and preventive understanding of stress. In addition, combining the approaches of HCI and health interventions in future research would provide further understanding of design elements and implications that support the goals of different types of interventions.

The knowledge provided in Study 2 increases understanding of the factory floor workers of the future, referred to as Operator 4.0, highlighting the expected change in the nature of their work. As our research focuses on the perspective of self-tracking and quantified feedback, research focusing on other aspects related to the factory floor context of the future would be beneficial for understanding the impacts of the change from the worker perspective. In addition, it would be interesting to see future design research on solutions for providing meaningful and encouraging worker feedback also in other work contexts. The field would benefit from further design research that would reveal design practices, strategies or elements to support

gaining the benefits and overcoming the barriers related to self-tracking, in work and leisure contexts.

The main contribution of the thesis, five research recommendations for design for well-being at the changing workplace, open an opportunity to apply them in practical design work and to refine them to highlight relevant design considerations to different target users, work contexts or application areas. Ethical considerations presented provide potential aspects to be considered in the future design research, even if they may not provide a comprehensive list of potential ethical issues. As relevant ethical questions are dependent on the factors specific to each design research case, it is important that designers engage with finding a suitable, proactive approach for ethics-awareness and relevant ethical issues in each design case, considering the purpose of design, target users and stakeholders, context of use and other design-relevant aspects.

6.5 Conclusions

This doctoral thesis presents two design research studies aiming at enhancing well-being at the changing workplace. They approach well-being from different novel and positive perspectives: by fostering the positive side of stress in the context of entrepreneurial work and by providing encouraging quantified feedback in the factory floor context. The results provide empirical knowledge of the less studied positive side of stress and particularly of the means to foster it in daily work and life. The results provide also understanding of the potential of applying Quantified Self approach to a modern factory context to provide encouraging feedback for factory floor workers on their well-being and work performance. The research contributes to HCI by widening the prevalent approaches of design for well-being and focusing on support for facing the demands of the changing working life. It provides empirical understanding of user groups that are at the forefront in facing the changes in working life and still have received less attention in HCI research.

The thesis highlights the importance of describing the design process, design guidelines and design implications in a manner that provides pragmatic understanding to the practitioners of the HCI community. In addition, the research encourages considering ethics throughout the design process. The studies provide understanding of design guidelines, design elements and design implications relevant for both design cases, and a synthesis of the insights, leading to five design recommendations: *1) Provide encouragement and recognition, 2) Enable self-reflection, 3)*

Support focusing on the essential, 4) Integrate to daily practices, and *5) Inspire and inform through peer experiences*. The design recommendations guide HCI practitioners in endeavors for designing for well-being at work. The results are applicable particularly for fields and occupations that face changes, for example, due to increasing digitalization and automation, and thus require self-leadership and self-reflection skills from workers. Beyond the field of HCI, the results of the thesis provide design-related understanding to other specialists focusing on well-being at work.

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PUBLICATIONS

PUBLICATION I

The potential of technology in facilitating positive stress experiences

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The Potential of Technology in Facilitating Positive Stress Experiences

Päivi Heikkilä
VTT Technical Research Centre
Finland
paivi.heikkila@vtt.fi

Mari Ainasoja
University of Tampere
Finland
mari.ainasoja@uta.fi

Virpi Oksman
VTT Technical Research Centre
Finland
virpi.oksman@vtt.fi

ABSTRACT
The positive side of stress, eustress, has remained an understudied area in psychology, health technology and HCI. Based on 21 qualitative interviews with entrepreneurs on their positive stress experiences, we aim at providing implications for technology-supported service design. First, we shed light on the current role of technology in experiencing positive stress in the everyday work-related situations of entrepreneurs. Second, the potential of technology is assessed by analysing entrepreneurs' mind-sets and the ways of working which they perceive as enablers for eustress and which could be facilitated by novel technological solutions. Our findings show that the potential of technology for supporting eustress includes areas such as co-creation and collaboration, planning and scheduling, togetherness and shared success, the means for mental preparing and ways to recover.

Author Keywords
Positive stress, eustress, potential of technology, entrepreneurs, digital services, human-driven design

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g. HCI): Miscellaneous.

INTRODUCTION

Recent scientific papers focusing on stress management and technological solutions typically start with impressive figures demonstrating health problems and cost estimations related to stress [e.g. 18,17,7,1]. Considering this widely agreed impact of stress on workplaces and society, ensuring rich and multidisciplinary research of this phenomenon is important.

Our aim is to contribute to HCI, cognitive ergonomics and stress management research by focusing on the positive side of stress, eustress, which has clearly received less attention in the scholarly literature than negative stress, distress. Even though the beneficial side of stress has been recognised a few decades ago [20,28,29], the research has concentrated on the negative aspects of stress, and only few studies have been conducted or theories constructed focusing on or including eustress. The emphasis of this research has been on conceptual papers, and empirical papers have concentrated on limited contexts so far (e.g. hospital nurses and ministers of religion). Several authors have concluded calling for further research and a clearer elaboration of eustress, especially in work life settings. [30,14,10].

We aim at increasing understanding of the phenomenon of positive stress by studying work-related eustress experiences of entrepreneurs. In this study, the term entrepreneur refers to small business owners or self-employed workers. Although entrepreneurs represent different domains and are far from a homogeneous group, high stress levels, unique sources of occupational stress and also positive effects of positive stress have been been identified among them [see an overview in 11]. Compared to employees, entrepreneurs have more freedom in deciding their working time and ways of working. Thus, they probably have more opportunities to influence eustress experiences as well. However, this freedom also creates a need for balancing one's time to achieve the intended results efficiently.

This research is a part of a larger project on eustress, which aims at increasing personal and workplace well-being, innovativeness and ways of finding new resources for daily work. In addition, we aim at contributing to the field of HCI and cognitive ergonomics by studying the use and potential of technology from a new perspective, eustress, which we believe to be beneficial and worth aspiring to.

In this paper, we aim to shed light on the understudied area of eustress and especially the connection between eustress and technology, which has not been covered in the existing studies. Our research questions are:

1) What is the current role of technology in experiencing positive stress in the everyday work-related situations of entrepreneurs?
2) What is the potential of technology in facilitating positive stress experiences?

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The structure of the paper is as follows: First, we introduce the concept of eustress and the idea of savouring eustress. Second, we present research findings on the effectiveness of web-based and mobile health interventions, and third, examples of mobile applications related to stress management. After introducing our research approach and method, we present our findings. The first part of the findings responds to research question 1, and the second part widens the focus to research question 2. Finally, we present our conclusions and suggest directions for future research.

RELATED WORK

Concept of Eustress

The term eustress was first introduced by Hans Selye [28], who divided the concept of stress into distress and eustress, based on the initiator of stress – either negative stressors or positive emotions. Later [29], he emphasised the different reactions to stress: "it is not only what happens to you, but how you react to it". Selye suggested that one can learn to react to stressors with positive emotions (e.g. gratitude, hope or good will), which is likely to maximize eustress and minimize distress. Already before Selye, the positive side of stress was explored from a more cognitive perspective by Richard Lazarus [20]. He suggested that the cognitive response to stress experience can also be a positive one, leading to a feeling of fulfilment or other positive feelings. Lazarus and Folkman [21] emphasised that the individual's resources and ability to cope define the stress experience. Cox et al. [5] have clarified further the role and significance of individual differences in psychological processes when coping with stress.

Based on the work of Lazarus and Selye, the current understanding of eustress emphasises the individual interpretation of stressors. The stressor type itself does not lead to eustress or distress, but the person may perceive the stressor as a negative threat or a positive challenge [9]. According to Simmons and Nelson [30], eustress and distress are seen as distinct qualitative constructs, not the two ends of the same continuum. The responses to stressors can be either positive or negative, and they can take the form of psychological states and emotions, attitudes and behaviours.

Interestingly, Simmons and Nelson do not only focus on coping with distress, but emphasise the meaning of savouring eustress. Savouring the positive literally means enjoying it with anticipation or dwelling on it with satisfaction or delight [24]. Hargrove et al. [13] propose three means for leaders to encourage eustress in their employees. They can help employees to savour eustress by offering them meaningful work, encouraging mindfulness at the workplace and supporting employees in understanding their capacity to meet challenge stressors. Also, the match between a person's skills and the demands of the task is seen as critical.

Even though eustress may lead to many positive outcomes, an individual's inability to cope or excess of eustress can lead to exhaustion [5,13]. It is important to recoup and recover also from positive stress. Adequate daily recovery is essential for staying healthy and energetic both at work and during leisure time [6]. For example, mindfulness and self-regulation skills can support a detachment from work stressors and a focus on leisure time activities [31].

Efficacy of Web-based and Mobile Stress Management Interventions

The actions, techniques and interventions for managing stress, or positive stress, for example in work life settings, are affected by both the characteristics of the stressors (e.g. amount, timing, source, control) and by individual' interpretations of them [10]. Occupational stress management training sessions are traditionally guided by an instructor and taught face-to-face to a group of people. However, the search for more cost-effective and non-stigmatizing, easy access mental health interventions has increased the interest in web and mobile health interventions.

In work life stress management context, the evidence in web-based interventions is promising, but not yet comprehensive [17,16]. The few studies already studying the potential of web-based stress management interventions [16,8, 2,4,12,15] have given varying results. Some studies have reported positive results in web-based stress management intervention compared to a control group [2,15] or compared to conventional care alone [12]. On the other hand, Eisen et al. reported that in their trial, computer-based relaxation techniques led to significant reductions in immediately-reported stress, but the effect was lower than in in-person format and the training session suffered from a higher attrition rate [8]. Also, another randomized controlled trial finds out that a web-based programme was no more effective than print material in reducing stress, although it worked better in e.g. dietary changes [4].

Ly et al. evaluated the efficacy of a smartphone-administered stress management intervention based on acceptance and commitment therapy [18]. Their application had similarities with the idea of positive stress: it contained, for example, modules and practices for recognizing stressful thoughts that do not necessarily reflect reality. The intervention tested had a moderate effect on stress in a randomized controlled trial and the authors conclude that the results are promising.

Also, an ongoing study by Heber et al. shows promising results in perceived stress levels with web-based stress management with responsive web design usable also by mobile devices [17,16]. This training puts emphasis on emotion regulation, and because of that, resonates at least on some level with the concept of positive stress.

While few studies exist already about stress management interventions facilitated with technology, no studies so far, at least to our knowledge, have examined the potential of technology in facilitating positive stress experiences in particular. However, despite some challenges and the small number of scientific studies, the effectiveness of technolo-

gy-aided stress management interventions is promising. Naturally, the benefits and efficacy depend heavily on the design of mobile and web-based solutions.

Examples of Mobile Experiments and Applications Supporting Stress Management

Based on existing research on health interventions and design experiments, it seems that stimulating positive stress, as well as reducing negative stress, can be supported by digital services or applications. Promising results have been achieved for example in piloting the Oiva application [1] and Mood Map application [23]. Both applications focus on reducing stress, but base themselves on cognitive processes which could support experiencing eustress as well. Using wearable sensors and utilising physiological data are other interesting design directions applied e.g. by Sanches et al. [27] and MacLean et al. [22]. Still another design direction is applied by Paredes et al., who have experimented with repurposing popular web applications as stress management interventions [26]. The following sections summarize the findings and conclusions related to these experiments.

The Oiva application was developed for prevention and management of work-related stress, and its usage, impact and user experiences were studied in a one-month field study with fifteen office workers [1]. The application is based on acceptance and commitment therapy methods, and includes 45 exercises divided into four themes (Mindfulness, Healthy Mind, Values and Actions, Healthy Body). The pilot study showed active use and good acceptance of the application and positive effects on well-being. The authors conclude that engaging mobile applications may provide benefits for personal mental well-being.

The Mood Map application was developed for increasing self-awareness and supporting coping with stress, and it was tested in a one-month field study with eight participants who had reported significant stress [23]. Participants were prompted to report their moods several times a day using a two dimensional scale (valence-arousal) and single-dimensional scales of anger, anxiety, happiness and sadness. Despite the limitations related to the small sample size and the fact that users did not use their own mobile phone, the study showed promising signals of increased emotional awareness and self-regulation. The authors even conclude that mobile applications hold promise for delivering state-of-the-art psychotherapies in a non-stigmatizing way to people who would not otherwise have access to therapy.

Sanches et al. designed a biofeedback mobile service for everyday stress management, and iteratively tested different visual user interfaces by using the system themselves [27]. Through their experiments and exploration, they learned that the design should allow room for users' own interpretations and reflections on the physiological stress reactions instead of trying to offer a ready-made diagnosis of stress.

MacLean et al. tested their design MoodWings: a wearable butterfly that mirrors a user's real-time stress through wing motion [22]. MoodWings was tested in a simulated driving environment to discover whether the participants using it were more aware of their stress and consequently, were able drive more safely. The results showed that the solution increased their awareness of stress and performance, but interestingly, it also acted as a stressor itself, regardless of whether it mirrored low or high arousal. In general, the users were enthusiastic about the potential of the system, but it caused stressful distraction in the driving context.

Paredes et al. experimented with a rather different approach to stress management, which they call crowd therapy [26]. Through a mobile application, they explored whether popular web applications could work as stress management interventions. The idea was that different individuals could benefit from different applications based on their personalities and current needs. Based on experiments with 20 participants, the approach could be beneficial, as it increased self-awareness of stress and provided new, simple ways to deal with stress. However, in a similar way as with the MoodWings experiment [22], one third of the users perceived using the application itself as a source of stress.

Kaipainen has studied the real-world use of health-promoting online and mobile applications, and discovered that the applications can contribute to improved well-being and behavioural changes as long as they are simple, attractive and easy to integrate into everyday life. Applications should be designed to support small concrete actions with immediate benefits, encourage self-reflection and provide guidance while maintaining freedom of choice. [19]

According to prior studies and experiments, relieving stress via technology can be based on several, rather versatile, factors. Technology can increase an awareness of stress (also too much!), trigger stress-relieving exercises and enhance self-regulation skills. Although prior experiments have not focused particularly on eustress, the results of the studies also provide useful insights for other kinds of well-being solutions, including the facilitation of eustress.

RESEARCH APPROACH AND METHOD

Research Approach

This research is the first part of a human-driven design process, in which the design starts from the field and everyday life of people without any technology, devices or services to be tested [25]. Our research approach is selected to provide new and relevant knowledge of the research subject, but also to increase the participants' awareness and engagement related to the themes of the study. To ensure versatile perspectives on the subject, we have adopted a multidisciplinary approach, combining an understanding of user experience, social sciences, business and technology.

Participants

The 21 interviewees were all Finnish entrepreneurs, 11 males and 10 females. Their age range was from 30 to 52, the majority being in their thirties or forties. Most of them

had a small company with fewer than 10 employees. The entrepreneurs represented different fields: ten of them worked in education or consulting and eleven in other fields, such as the building industry and software design. The sample included relatively new entrepreneurs – twelve of them had worked as an entrepreneur for less than five years. Many had worked as an employee before, and indicated that becoming an entrepreneur was a part of a bigger life change for them. Almost all of the interviewees were from the Tampere area, but the sample also included two entrepreneurs from the capital area of Finland.

Entrepreneurs were invited to participate in the study through different channels, such as entrepreneur email lists, and thus the participation was voluntary and mainly based on one's interest in the research area.

Method

This research was carried out by conducting 21 semi-structured entrepreneur interviews focusing on the participants' personal experiences of positive stress. The 2-hour face-to-face interviews were conducted at the entrepreneur's workplace or another quiet place. Although working context offers valuable insights of the working environment, conducting the interviews without disturbance at a location convenient for interviewees was prioritized. The interviews were carried out by two researchers.

Due to the exploratory nature of our research, the interviews consisted of broad and open themes around every day experiences, not focusing only on the use of technology as such. The aim was that participants had an opportunity to bring up aspects that are meaningful to them and the role and potential of technology would emerge from these descriptions. The interviews proceeded in three phases. First, the participants were asked to walk through their personal history as an entrepreneur and describe their daily life. Second, participants retraced at least one experience of positive stress and elaborated their emotions, behaviour and attitudes related to this experience and the factors they see as relevant for achieving such experiences. Third, just in the last part of the interview, questions explicitly explored the role of technology in these experiences.

The transcripted interview data was thematically analysed. The coding followed the steps defined by Braun and Clarke [3] and the analysis proceeded as follows:

1. **Familiarization with data.** The transcribed data was first read through as a whole. The main content of each interview was discussed in the multidisciplinary research team to build mutual understanding of the data to form a basis for analysis.
2. **Generating initial codes.** All data was then systematically coded. Initial coding was data-driven, analysed without a preformulated framework from the literature. In the first phase, all the data, including comments or experiences related to technology use, was coded.
3. **Searching for themes among codes.** Codes related to technology were next sorted into two themes: current technology use supporting eustress experiences and current technology use hindering eustress experiences. Inside these themes, the quotations were thematically grouped according to their affinity.
4. **Reviewing themes.** The closer review of the themes revealed that the coding covered well the current role of technology in eustress experiences, but did not sufficiently reflect the potential of technology. For this reason, all the data was coded again in order to identify the current ways of working which facilitate eustress and have the potential to be aided by technology. The data-driven analysis led into 5 sub-themes describing the potential uses of technology in facilitating eustress: co-creation and collaboration, planning and scheduling, togetherness and shared success, means for mental preparing and ways to recover.
5. **Defining and naming themes, and producing the final report.** Finally, all themes were written down with descriptions. Quotations were chosen to illustrate entrepreneurs' experiences and the current or potential role of technology.

FINDINGS

Among the interviewed entrepreneurs, positive stress was perceived to be an unfamiliar term, but the phenomenon was recognised by everyone. They all recalled situations in which eustress played an important role, such as giving a presentation, leading an important workshop or writing a critical document under time pressure. Some even thought that eustress is the reason for being an entrepreneur, leading one to enjoy the work and the work to feel rewarding. Most of the entrepreneurs did not mention technology when they were asked to recall a recent eustress experience. Through a more thorough elaboration, however, technology was identified to be one of the barriers or enablers for experiencing eustress, similarly to the working environment, social interaction and the content of one's work.

In the next sections, we first describe the current role of technology in the everyday working contexts of entrepreneurs. Second, we present themes which were perceived by the entrepreneurs as being important for experiencing eustress, and through them, discuss the potential role of technology in facilitating eustress experiences.

Role of Technology in Experiencing Positive Stress

Among the entrepreneurs interviewed, the role of technology evoked both positive and negative comments and experiences. The positive aspects are presented first.

Technology as a Facilitator for Positive Stress Experiences

Technology was seen to create or enhance a feeling of control through reachability, joint scheduling and communication tools – also when working remotely. Communication

tools that support instant, positive, dynamic and dialogic discussion around work tasks were seen as useful and motivating – enabling a shared understanding of the challenges and progress of the ongoing work. At its best, technology may facilitate eustress by conveying a feeling of presence or supporting the impression of working in the same space even though the participants were in different locations.

"When I have coached managers, it [well-designed video conferencing system] has been great, totally amazing. The table in Helsinki looks exactly the same as the table here; it looks through the screen as though we were around the same table. I couldn't believe that those people are in Helsinki (laughs), not here in Tampere." Female, 49.

Technological tools help in building and maintaining a contact network, following or sharing work-related news, receiving feedback or recognition and digitally demonstrating or distributing one's work. The entrepreneurs interviewed felt that all these aspects may lead to the feeling of eustress – by making it easier to be in contact with relevant partners, to stay updated, inspired and tuned in to news and have a digital channel for sharing one's efforts and success. Although digital sharing does not directly guarantee recognition of one's work, it increases the opportunities for receiving feedback and making new connections.

"If someone does something to my posting, like shares it or likes it, it always feels rewarding. If you share a blog post and share it and someone likes it, it doesn't mean that other people see it or consume it, but you get it out into the world" Male, 31.

Technology as an Obstacle to Experiencing Eustress

Besides the positive aspects of technology use, technology was also seen as an obstacle to experiencing eustress. Non-functioning, slow or too complicated technology was seen to hinder the experience of eustress or cause frustration increasing distress. If technology does not work properly, it distracts one's concentration from the main tasks, and if it is perceived too complicated, it requires learning, which is often felt to be time-consuming or unappealing in general.

"I'm totally hopeless with technology, I hate gadgets. I couldn't bother less; I never read manuals. Then I wonder why they don't work. When I have my summer holiday, I always plan that I would study the use of something. As if I will. And I hate it, because if I would, it would all be easier." Female, 52.

In addition to more functional problems, some entrepreneurs were also anxious about the increasing role and number of technological tools and channels, which may lead to excessive refinement of one's work or extend one's work to leisure time. It is easy to stay connected to work also in one's free time, which brings both benefits and harm. When the work is always within reach, recovery and relaxation requires more effort and determination.

"It is difficult to switch off; you are connected to the work all the time. You should detach at least for a moment, do something else. It's unfortunate that I'm quite a slave to my phone and tablet and laptop." Male, 40.

The endless amount of information, news and opportunities may also create a feeling of inadequacy.

"You notice that there is so much going on in the world, that you feel inadequate. There is always someone who tweets and someone who has done something and who publishes something. It's endless. If you try to keep up, it makes you stressed – negatively, not positively." Female, 39

To summarize, the perceived role of current technology use is twofold, facilitating eustress by enhancing the flexibility and fluency of working, but also preventing eustress by poor functionality or excessive and exhausting pervasiveness, which blurs the borders between work and leisure time – impeding detachment from work. Current technology use patterns and the attitudes towards using it show that technology may be a channel for facilitating eustress, but currently the impact is often the opposite.

The findings suggest that eustress could be supported both by the appropriate design of technological tools in general and by offering novel tools for facilitating experiences, mind-sets or ways of working which may lead to eustress. The following section concentrates on these aspects.

Potential of Technology in Facilitating Positive Stress

When describing their eustress experiences, the entrepreneurs seldom mentioned technology as a part of these. However, technology may serve as an enabler to create an appropriate mindset or ways of working which lead to eustress. In the sections following, the future potential of technology is assessed through the themes which rise from the interviews: co-creation and collaboration, planning and scheduling, togetherness and shared success, the means for mental preparation and ways to recover.

Co-creation and Collaboration

According to the entrepreneur interviews, the experience of eustress is often generated through collaboration and co-creation between colleagues, partners or customers. For example, an active workshop or a demanding negotiation is a typical situation involving eustress due to meaningful objectives of a meeting or the insecurity of the course of it – embedded in the nature of social activities. In these kinds of working contexts, technology was perceived to be a potential means for enhancing presence between participants and for providing the concrete tools for collaboration.

Technology was seen as potential in enhancing focusing on a shared goal, providing the tools for testing or demonstrating ideas and helping instant or automatic recording of results. It was seen as an important facilitator for remote working – to enable seeing and hearing others, co-creating a shared document, and in general, to replicate a feeling of working together. The potential was also seen in sharing relevant information – instead of detached bits and pieces.

"I see email, Facebook, Twitter, LinkedIn and such as separate tools, used unconnected from the really meaningful stuff. Technology should support presenting the staff with the relevant things,

that make people committed and help create states of excitement together." Male, 41.

Planning and Scheduling

The occurrence of eustress was seen to require achievable but tight enough scheduling, ways to monitor progress and triggering oneself to complete relevant tasks. To facilitate planning and scheduling, the entrepreneurs had their personal means to list and prioritize tasks, schedule their own and joint activities and chop their tasks into smaller parts. Especially chopping the tasks seemed to be an effective means of generating eustress, as it does not only increase one's feeling of control, but also gives a feeling of small success any time a task is accomplished and can be crossed off from the list. Breaking one's tasks into smaller pieces is one way to make planned or completed work visible – an ambiguous objective can be changed to concrete actions, such as emails, phone calls, meetings and documents.

"You need to see the overall picture and break it up into smaller pieces…. I may have twenty emails and three to react, which takes half an hour. I list it down, and it makes me feel effective when I can cross it off." Female, 38.

In scheduling, eustress was facilitated by deadlines and reserving enough time for non-work activities. Some entrepreneurs also consciously planned peaks to their schedule to enable periods of eustress and recovery after them.

"I have made a sort of rhythm for my work. There are peaks with lots of travelling, which I can do three or four times a year…. At peaks, I feel really effective, and by all means, then I enjoy the most." Male, 52.

In many situations, non-digital tools, such as post-it-notes and manual calendars, were preferred, due to their concreteness. Digital tools for planning and scheduling should aim at supporting similar instantness to help e.g. in chopping up tasks. Still, tangibility and the possibility to make digital into non-digital are important aims to make digital tools more versatile, more easily adopted and suitable to be used in hands-on work.

Togetherness and Shared Success

Entrepreneurs highlighted the importance of acknowledging the achieved results, good progress and positive feedback inside the team as one building block of positive stress. It is also important for entrepreneurs without a team, but sharing success brings it to a new level. It gives new energy to the whole team and makes everyone's efforts feel worthwhile. In addition to recognising the achievements, recognising the unrewarding but necessary work behind it may be even more appreciated within the team, make everyone strive for the same goals and raise the spirits among co-workers.

"I launched a sort of shovel prize … Most of us don't really do anything with the shovel as we live in the city centre, but the thing is that you can have it besides your desk. Everyone knows that the one who has the shovel has done something really unrewarding, which has brought money and got things going on, but definitely hasn't been enjoyable." Female, 39.

Recognising others' achievements and successful collaboration is not only important when celebrating it, but these shared experiences may help in achieving a can-do attitude in other challenging situations. Thus, the role of technology in eustress could lie in sharing, but also in reminding the team to recall the feelings of good moments.

Means for Mental Preparing

To facilitate eustress, one of the most central factors is to achieve the correct kind of mindset to respond to new challenges. Depending on the situation, it may happen through reassuring and relaxation, but also through recapturing a good, energetic mood. Many of the entrepreneurs mentally walked through an upcoming demanding situation beforehand, imagined difficult steps and some even went through the worst scenario – to make the actual situation feel much easier. A similar walk through could also be conducted by making material for the situation or writing the key points, outline or details down beforehand.

"I may do 59 power points, that I don't use at the event at all, none of them. But they make me feel that I'm prepared … I do the stress journey beforehand and feel afraid. But when I'm presenting I may feel all right." Female, 52.

Most entrepreneurs had their means of relieving tension before an important meeting, training or presentation, but some also orientated to challenging work by striving for a positive and energetic mindset. This may happen through very versatile actions: mindfulness exercises, socializing, smiling, listing reasons to be grateful or by having a break. Humour and playful behaviour – in very different forms – were also perceived as effective facilitators for eustress.

"When we worked in the open space office I saw how fast you can travel with the office chair down the corridor. It was like I was a child again. It distracted me from the cause of the stress and made me feel good. And when feeling good, it is easier to continue with the challenge." Female, 39.

These entrepreneurs did not use any technological tools to support their mental preparation. However, technology could be helpful both in achieving an appropriate mindset and in offering practical tools for preparation.

Ways to Recover

Ways to recover and detach from work have become more and more challenging, as the obligations and uncompleted tasks can also easily be accessed outside the office. However, the importance of reserving time for recovery – also after positive stress - has been emphasised in prior studies [13,6]. Most of the entrepreneurs acknowledged the benefit of detachment and recovery, although some had difficulties in reserving enough time for it in practice.

Most of the entrepreneurs had proven methods for recovery: physical exercise, social contacts, leisure activities and a sufficient number of breaks were seen as key methods to recover. Still, it was typical to continue work after office hours and do mental preparation – intentionally or uncon-

sciously – during leisure time. Even though technology was appraised as it enables flexible working methods, hours and place, working tools should be designed to also enable blocking work issues and being unavailable when wanted.

DISCUSSION

According to the findings of this study, positive stress is a phenomenon which offers interesting application possibilities for digital service design. The findings suggest that experiencing eustress could be supported 1) by an appropriate design of technological tools in general, and 2) by offering new kinds of tools to facilitate experiences, mind-sets or ways of working which may lead to eustress.

Based on the interviews with the entrepreneurs, the current technology they have in use does not play a major role in facilitating eustress. It seems to have a significant role, however, in removing the barriers to experiencing eustress, supporting concentration on the essential and enabling flexible ways for co-operation. Still, the potential of technology may be notably bigger and can be extended to several other areas central for experiencing eustress.

As technology-aided stress management interventions have mainly shown promising results [17,16,2,12,15], the study of new opportunities for positive stress management seems worthwhile. In addition to new solutions, the development of applications facilitating eustress could utilize some features tested already in the earlier research. The features of recognizing stressful thoughts in the study by Ly et al. [18], emotion regulation in Heber et al. [17, 16], self-awareness exercises of Mood Map [23] and stress recovery themes in Oiva [1] are all relevant also in the context of eustress.

This study works as a starting point to explore the potential connection of eustress and technology. Our intention is to continue the work by studying the phenomenon further and using the insights of this study in co-designing digital service ideas or solutions, which would support experiencing positive stress or create opportunities for such experiences. In the next study phase, we will study eustress experiences when they occur. Apart from self-reporting, the study phase includes physiological measurements.

Both the strengths and limitations of this study lie in the focus on entrepreneurs, which provided solid benefits for this research, but as a special group they do not necessarily reflect the experiences of the average employee. Although the experiences of entrepreneurs give valuable insights, qualitative research focusing on other user groups, such as employees, students or unemployed people would also be interesting in the future.

Based on our experience, approaching stress from the positive angle has been both inspiring and productive. Furthermore, the participants highlighted that the session served as a welcome moment for self-reflection. As we aim at co-design activities in the later phases of the project, increasing the participants' awareness, interest and engagement related to the themes of the study is a promising start.

CONCLUSION

This article provides understanding on the current and potential role of technology in experiencing positive stress in the daily work of entrepreneurs. The findings show that the current role of technology is twofold: supporting eustress by enhancing the flexibility and fluency of working, but also preventing eustress by the poor functionality or excessive pervasiveness of technology. The role could be shifted from preventing eustress to supporting it by the appropriate design of technological tools. However, the potential role of technology also extends to several other areas central to experiencing eustress: co-creation and collaboration, planning and scheduling, togetherness and shared success, the means for mental preparation and ways to recover. The insights related to these themes can be used as guidance for designing new tools to facilitate eustress in particular (e.g. enhancing self-regulation skills) or developing tools in general to better support eustress experiences.

This study is the first step in our attempts to understand the potential of technology in facilitating experiences of positive stress. It helps us to focus our co-design activities around potential themes, and contributes to the field of HCI and cognitive ergonomics by offering a new perspective in designing for positive emotions and well-being.

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PUBLICATION II

Designing a eustress toolbox: From entrepreneur experiences to an online service

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DESIGNING A EUSTRESS TOOLBOX: FROM ENTREPRENEUR EXPERIENCES TO AN ONLINE SERVICE

Päivi Heikkilä
VTT Technical Research Centre of Finland
Finland

Elina Mattila
VTT Technical Research Centre of Finland
Finland

Mari Ainasoja
University of Tampere
Finland

Abstract: *Stress is typically seen as a negative phenomenon. However, the positive side of stress (i.e., eustress) has the potential to improve well-being, productivity, and innovativeness, thus increasing individuals' daily resources at work. Focusing on eustress could enhance work engagement by turning some of the negatively perceived stressors into positive challenges. We explored this possibility by interviewing 21 Finnish entrepreneurs from various fields regarding their experiences of eustress. Nine of the interviewed entrepreneurs also recorded a eustress diary. Based on thematic analysis of the interview data, six main themes supporting eustress were identified: (a) Self-reflection toward changing the mindset, (b) Organizing work, (c) Stimulating positive pressure, (d) Harnessing a feeling of joy, (e) Mental preparation, and (f) Recovery. A Web-based service, the Eustress Toolbox, was designed to support practicing eustress skills related to the six main themes within the daily lives of the entrepreneurs.*

Keywords: *eustress, positive stress, work engagement, digital services, human-centered design, entrepreneur interviews, qualitative research.*

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INTRODUCTION

Stress has been defined as a psychological and physiological state resulting from an imbalance between demands and resources (Lazarus & Folkman, 1984). This term typically refers to negative stress (*distress*), which occurs when an individual perceives that the demands of an external situation (i.e., stressors causing stress) are beyond his or her perceived ability to cope with them (Lazarus, 1966). However, the responses to stressors can also be positive because a stressor can be perceived either as a negative threat or as a positive challenge (Le Fevre, Kolt, & Matheny, 2006).

Positive stress, also known as *eustress*, has gained rather minor attention in the fields of and research in psychology, health technology, and human–computer interaction (HCI). Even though the positive side of stress is not a new concept (Lazarus, 1966; Selye, 1974), relatively few studies focus on eustress (see, e.g., Le Fevre et al., 2006; Simmons & Nelson, 2007) compared to the overall number of stress studies. In this paper, eustress means a positive response to stressors (Le Fevre et al., 2006; Simmons & Nelson, 2007). Although negative stress is a significant issue and causes serious health problems (Chandola, Brunner, & Marmot, 2006; Kivimäki et al., 2006), approaching stress only from this perspective may ignore a remarkable resource for well-being, innovativeness, and productivity.

In this paper, we concentrate on entrepreneurs' experiences of eustress. The term entrepreneur refers to small business owners or self-employed workers. Managing distress and savoring eustress is especially important for entrepreneurs. Entrepreneurship comes with stressful conditions, such as heavy workloads and a high need for achievement (Harris, Saltstone, & Fraboni, 1999; Langan-Fox & Roth, 1995), along with a personal commitment to the company and the risk of failure (Greenhaus & Callanan 1994). A lower degree of structure, predictability, and support are characteristic as well of the entrepreneur's work (Greenhaus & Callanan, 1994).

Despite the stressors of entrepreneurial work, not all entrepreneurs are reporting higher levels of negative stress compared to organizationally employed people (Baron, Franklin, & Hmieleski, 2016; Rahim, 1996). Cardon and Patel (2015) elaborated that the attitude toward stress, and thus the self-evaluation of it, might differ because the effect of stress on one's income can be positive, even while stress can impact negatively one's physical health. Baron et al. (2016) stated that psychological capital, coping, and effective stress management are critical factors influencing the stress experience and, potentially, the survival of companies. In addition to approaching stress from the perspective of managing distress, we believe that learning to savor eustress can support these factors and thus, positively affect one's overall well-being.

Entrepreneurs often have the freedom to arrange their working schedules and ways of working. This freedom creates the possibility and need for balancing one's time (both at work and in personal life) to achieve the intended results efficiently and to ensure time for recovery from work. We chose to concentrate on entrepreneurs' experiences of eustress at work because the line between work and free time is not always clear in the daily lives of entrepreneurs.

The objective of this research was to increase knowledge of the positive side of stress and the entrepreneurs' ways of fostering it and, based on the qualitative data, present a Web-based service prototype to stimulate eustress in the daily work of entrepreneurs. Overall, we aimed at contributing to the design for well-being and the positive approach to design, which

are growing research interests in the field of HCI (Calvo & Peters, 2014; Desmet & Hassenzahl, 2012; Desmet, Pohlmeyer & Forlizzi, 2013).

The research questions that guided the various aspects of our study are

1. What ways of thinking and working help entrepreneurs to identify and feel eustress (i.e., positive stress)?
2. How could a Web-based service be designed to support entrepreneurs in developing eustress skills in their daily lives?

Based on the findings related to Research Questions 1 and 2, we present the resulting Eustress Toolbox, with the aim of providing practical information on eustress and the means to achieve it. Focusing on the positive side of stress builds understanding of one's well-being at work and may empower people to view stress from the beneficial perspective. We expect the results to be useful for practitioners and other members of the HCI community who are interested in the new approaches and studies related to digital services fostering holistic well-being in general and supporting the opportunity to experience eustress in particular.

The paper first presents related research on eustress and digital services designed to enhance well-being. We then elaborate on how eustress relates to other positive work-related concepts, and work engagement in particular. Second, our design process, methods, and participants are described. The results describe briefly the central findings related to entrepreneurs' experiences of fostering eustress (see more on experiences related to technology in Heikkilä, Ainasoja, & Oksman, 2015) and focus more on introducing the Eustress Toolbox. We conclude this paper with discussion of the findings and suggestions for future research.

RELATED RESEARCH

In this section, we present related work on eustress and digital services developed for supporting well-being. Relevant design frameworks also are introduced. The related work on eustress provides background understanding of the concept and its relationship to more familiar positive work-related concepts, and work engagement in particular. The sections related to digital services supporting well-being and design frameworks connect the related research more tightly to HCI and relevant design principles and recommendations.

Eustress: Stress as a Resource

The positive side of stress was recognized already a few decades ago (Lazarus, 1966; Selye, 1974). The term eustress was introduced by Hans Selye (1974), who distinguished two sides of stress: the harmful side (distress), caused by negative stressors, and the beneficial side (eustress) that include positive emotions. He suggested that one can learn to react to stressors with positive emotions, such as gratitude, hope, or good will, which is likely to maximize eustress and minimize distress. Even before Selye, Richard Lazarus (1966) proposed that the cognitive response to stressors can also be positive, leading to positive emotions, such as a feeling of fulfillment.

Despite these early notions, the theories of stress have approached stress primarily as a negative phenomenon or have focused on the negative impacts of stress when studying the

application of these theories. The various theories of work stress have emphasized, for example, the relationship between job demands and job control (the demand–control model; Karasek & Theorell, 1990), the imbalance between perceived efforts and rewards at work (the effort–reward imbalance model; Siegrist, 1996), or the processes of appraisal and coping (the cognitive stress theory; Lazarus & Folkman, 1984). The latter belongs to the transactional theories of stress that acknowledge the role of cognitive and emotional processes in stress experiences. More specifically, Lazarus and Folkman (1984) emphasized that the individual's resources and ability to cope define the stress experience.

The current definitions of eustress are based mainly on the transactional stress theories, which emphasize the individual interpretation of stressors. In other words, individual responses to stressors can be positive or negative: A stressor can be perceived as a negative threat or a positive challenge (Le Fevre et al., 2006). Consequently, eustress is defined as a positive response to stressors and distress as a negative response to stressors (Le Fevre et al., 2006; Simmons & Nelson 2007). Thus, the stress response is determined by the perception of demand related to the stressors, but also by the perception of other contextual characteristics, such as the source, timing, and desirability of a stressor and one's perception of having control over it (Le Fevre et al., 2006). According to Simmons and Nelson (2007), eustress and distress are not the two ends of the same continuum, but rather distinct qualitative constructs. This means that a stressor may not only be interpreted either as positive or negative, but it may have both outcomes. Positive and negative responses to a stressor are complex and mixed, and they manifest themselves in different physiological, psychological, and behavioral indicators. However, the eustress experience is characterized with positive emotions, attitudes, and behaviors, such as a feeling of joy, contentment, or excitement, as well as perceiving the situation as meaningful, manageable, or engaging, to mention some of the indicators listed by Simmons and Nelson (2007).

In addition to minimizing distress, savoring eustress has been suggested as having the potential for increasing the well-being of an individual (Hargrove, Nelson, & Cooper, 2013; Simmons & Nelson, 2007). Hargrove et al. (2013) proposed three means for leaders to encourage eustress in their employees: offering meaningful work, encouraging mindfulness at the workplace, and supporting employees in understanding and embracing their capacity to meet challenging stressors. Moreover, they viewed the match between a person's skills and the demands of the task as critical. Because the means for approaching stressors are based on self-leadership, they can be assumed to suit entrepreneurs too.

Although experiencing eustress may enhance well-being, an excess of eustress can lead to exhaustion (Hargrove et al., 2013). Therefore, the need to recover from eustress is equally important. Recovery and detachment from work stressors of both kinds can be supported, for example, by developing mindfulness, acceptance, and self-regulation skills (Sonnentag & Fritz, 2015).

Although the terms eustress and positive stress are not often used as such in research, in recent approaches to stress the positive impacts that job conditions may have on well-being are recognized. For example, the job demands–resources model (Schaufeli & Bakker, 2004) stated that job demands can boost work engagement when sufficient resources are available. Experiencing demands such as high time pressure and/or a high workload has been viewed as having the potential to lead to the development of self-efficacy and resilience when adequate resources and recovery between exposures are available (Ilies, Aw, & Pluut, 2015).

Eustress is closely connected to more familiar positive work-related concepts, such as flow experience and work engagement. Experiencing eustress can culminate in flow (Hargrove et al., 2013), in which the individual is extremely focused on the work task (Csikszentmihalyi, 1990). Work engagement is defined as a positive, relatively stable, affective–motivational state of fulfillment at work (Schaufeli, Salanova, González-Romá, & Bakker, 2002). It refers to a persistent state that is not focused on any particular object, event, or individual (Schaufeli & Bakker, 2004). This distinguishes it from eustress or distress, which are seen as short-term responses to stressors (Fevre et al., 2006; Simmons and Nelson, 2007). However, the relationship of eustress and work engagement is not comprehensively elaborated in the literature. The definitions of eustress and work engagement are intertwined and may support each other in several ways. According to the holistic stress model (Simmons & Nelson, 2007), engagement is seen as one positive response to stressors among other attitude indicators, such as hope, meaningfulness, and manageability. On the other hand, the HRD (human resource development) eustress model (Hargrove, Becker, & Hargrove, 2015) presented engagement as one positive outcome of eustress.

In this paper, we focus on eustress, as it has the potential to empower people to view stress from a beneficial perspective. This, in turn, can potentially build personal resources and affect the more stable state of work engagement.

In the field of positive psychology, a shift toward recognizing the positive has been called for in many areas. Thus, eustress is seen as an interesting topic for research. As positive psychology researchers explore health as the presence of the positive—and not only as the absence of the negative (Seligman & Csikszentmihalyi, 2000)—then stress research is seen benefiting from a holistic view that includes eustress (Nelson & Cooper, 2005). Although the literature sheds light on eustress as a concept, more empirical research is needed to understand the everyday experiences of eustress and ways to achieve it. We believe that approaching stress also as a resource and learning to react to stressors in a positive way may be especially useful for preventing distress-related problems of entrepreneurs, who often have to cope with high time demands and pressure.

Well-being Through Digital Services

Digital services are being used increasingly to support health and well-being, including tackling mental health and stress symptoms. Due to limited resources, traditional public health and clinical interventions cannot provide early prevention and health promotion to all people with early-stage health or mental health concerns. Digital interventions provide a scalable means for distributing health promotion and well-being services to a wide range of people. They enable affordable, anonymous, and self-paced access to well-being services with increased fidelity in intervention delivery (Portnoy, Scott-Sheldon, Johnson, & Carey, 2008). Web-based health programs have been proven effective and many of them are as effective as face-to-face programs for a wide variety of health problems, including depression, anxiety disorders, smoking, and alcohol abuse (Cunningham, Gulliver, Farrer, Bennett, & Carron-Arthur, 2014).

Several Web-based programs have been developed for managing mental health symptoms and stress among employees (Stratton et al., 2017). For example, Hasson, Anderborg, Theorell, and Arnetz (2005) presented a Web-based program consisting of stress monitoring, cognitive

exercises, and a chat option for clients' stress management. They found that during the 6-month program, employees' ratings of their stress management ability, sleep quality, mental energy, concentration ability, and social support improved. In a study by van Straten, Cuijpers, and Smits (2008), a 4-week Web-based program for depression, anxiety, and work-related stress resulted in reduced symptoms of depression and anxiety, but less pronounced effects on stress.

In addition to Web-based programs, mobile applications can be utilized in delivering health promotion programs. Ahtinen et al. (2013) presented a mobile application for stress management based on acceptance and commitment therapy (ACT). The application used audio and text exercises to teach the users ACT-based skills, including mindfulness and acceptance. In a month-long pilot study with 15 users, increases in satisfaction with life and decreases in experienced stress were found. Ly, Asplund, and Andersson (2014) studied the effectiveness of an ACT-based stress management program delivered via a mobile application. The program consisted of six weekly modules containing short audio lectures, texts, and exercises on stress and the principles of ACT. In a randomized controlled trial with middle managers, the application was found to decrease stress and increase general health.

Additionally, positive psychology approaches are being incorporated into digital interventions aimed at improving psychological well-being. Ouweneel, Le Blanc, and Schaufeli, (2013) developed an online program intended to improve positive emotions, self-efficacy, and work engagement through happiness, goal-setting, and resource-building exercises. In a controlled trial, improvements in positive emotions and self-efficacy were found, but not in work engagement. However, additional analyses revealed improvements in work engagement among those who scored low at the beginning of the study. Luthans, Avey, and Patera (2008) developed a Web-based training program for increasing positive psychological capital, namely hope, self-efficacy, optimism, and resiliency. The program consisted of two 45-minute sessions that included videos, narrated PowerPoint presentations, and self-reflection exercises. A brief study found improvements in psychological capital in the intervention group compared to a control group. Mitchell Stanimirovic, Klein, and Vella-Brodrick (2009) developed a 3-week Web-based positive psychology intervention focusing on personal strengths. In their 3-month study, the intervention was compared to a problem-solving intervention and a placebo control; small but significant effects in well-being were found in the strengths intervention. The attrition in the study was high, with 34% of participants completing the strengths intervention but only 15.5% of participants completing the problem-solving intervention. The authors hypothesized that the difference in adherence to the interventions may have been caused by the fact that the strengths intervention focused on positive aspects whereas the problem-solving intervention focused on problems.

Despite active research in the fields of stress management and employee wellness, it seems that achieving large and sustained improvements in stress management and positive work-related skills, such as work engagement, are challenging. However, a large majority of studies so far have approached the issue from a negative perspective, and positive approaches have emerged only in recent years (e.g., Orsila, Luukkaala, Manka, & Nygård, 2011). Notably, to our knowledge, no Web-based interventions focusing specifically on eustress exist.

Finally, we consider digital services promising for supporting entrepreneurs as they are inexpensive to distribute, can be tailored to various needs, do not require appointments or occupational health care, and can be used independent of time and place. Combining Web and mobile technologies ensures that most users can find ways to incorporate the tools into

their daily lives. Digital services may also provide a feel of having a virtual community of peers, which entrepreneurs often lack.

Design Frameworks

The challenges of digital interventions include low uptake and high attrition rates that hinder the effectiveness of the interventions (Eysenbach 2005). To address these concerns, digital intervention designers have developed frameworks and guidelines to steer the development of new services. In particular, the need to identify and address end-user perspectives in intervention design has been acknowledged. Yardley Morrison, Bradbury, and Muller (2015) introduced the person-based approach to intervention development, which emphasizes understanding and incorporates the perspectives of the target users at every step of the design process, that is, adopting a human-centered approach in intervention design. The design process involves in-depth qualitative research with target-group users to develop guiding principles. The guiding principles state the key objectives of the intervention and outline the key features required to achieve each objective. A prototype is initially tested with end users to evaluate the acceptability, attractiveness, persuasiveness, ease of use, and feasibility of the prototype. After improvements, the prototype may be tested by asking users to use the intervention on their own, which enables them to try out behavioral changes.

Yardley et al. (2015) listed guiding principles that are common to many interventions, drawn from the self-determination theory. The principles address three key design objectives: (a) promoting user autonomy by providing user choice, when possible; (b) promoting user competence by providing a clear structure and guidance, examples, stories modeling overcoming barriers, graded goal-setting, minimizing conscious effort, and lifestyle disruption, when possible; and (c) promoting positive emotional experience and a sense of relatedness through several features. The features include using positive language; giving a rationale for advice; acknowledging and addressing concerns; ensuring all communications provide something interesting, enjoyable, relevant, and helpful to the user; providing immediately rewarding feedback; and following best practice to maximize accessibility, usability, and trust.

The persuasive systems design model (PSD; Oinas-Kukkonen & Harjumaa, 2009) is a framework for designing behaviorial-change-supporting technologies. The model divides persuasive features into four categories: (a) primary task support, which consists of seven techniques, including reduction of user effort, tunneling the user through a process, self-monitoring, and rehearsal, (b) dialogue support, which consists of seven techniques, including reminders, rewards, and suggestions, (c) system credibility support, which consists of eight techniques, including trustworthiness, surface credibility, and real-world feel, and (d) social support, which consists of seven techniques, including social learning, social facilitation, and recognition. Research suggests that persuasive features can increase adoption and engagement in Web-based interventions (Kelders, Kok, Ossebaard, & Van Gemert-Pijnen, 2012).

Both frameworks have several recommendations in common, that is, providing a clear structure and guidance through the program, minimizing conscious user effort, social modeling and learning from others, providing ways to monitor progress, and giving rewarding feedback. In addition, trust is emphasized in both frameworks, which is an important aspect to consider in health-related digital services. These recommendations were adopted as guiding principles in the design of the Eustress Toolbox.

DESIGN PROCESS AND METHODS

The design process of our study followed a human-centered design approach (International Organization for Standardization [ISO], 2010) and proceeded from a two-phased collection of user data to designing a prototype of the Eustress Toolbox Web service (see Figure 1). The collection and analysis of user data were conducted by four researchers of a multidisciplinary team having expertise in psychology, HCI, adult education, and business. We conducted our study with a qualitative approach to gain deeper understanding of the eustress experiences and ways to foster eustress in everyday work lives of entrepreneurs.

In the first phase of the study (entrepreneur interviews), 21 Finnish entrepreneurs were invited to participate through various channels, for example, entrepreneur e-mail lists. The volunteer participant candidates completed a short questionnaire that collected background information, designed explicitly to assure that the data represented diversity in gender, fields represented, and entrepreneurial experience. The study participants comprised 10 females and 11 males, aged 30 to 52 years. Most had a small company with fewer than 10 employees, and these companies were active in fields from consulting and education to building industry and software design. Three entrepreneurs had a larger company with 50–130 employees. The majority of the participants were relatively new entrepreneurs; 12 of them had worked as an entrepreneur for fewer than 5 years. Seven of the entrepreneurs had worked as an entrepreneur at least 10 years. All participants signed an informed consent for participating in the study.

We then interviewed the entrepreneurs in pairs to explore their personal experiences of eustress and their means for "feeding" and maintaining it in their daily lives. A semistructured interview protocol was selected as the research method to enable the participants' freedom in describing their experiences while maintaining a systematic process for the questions asked.

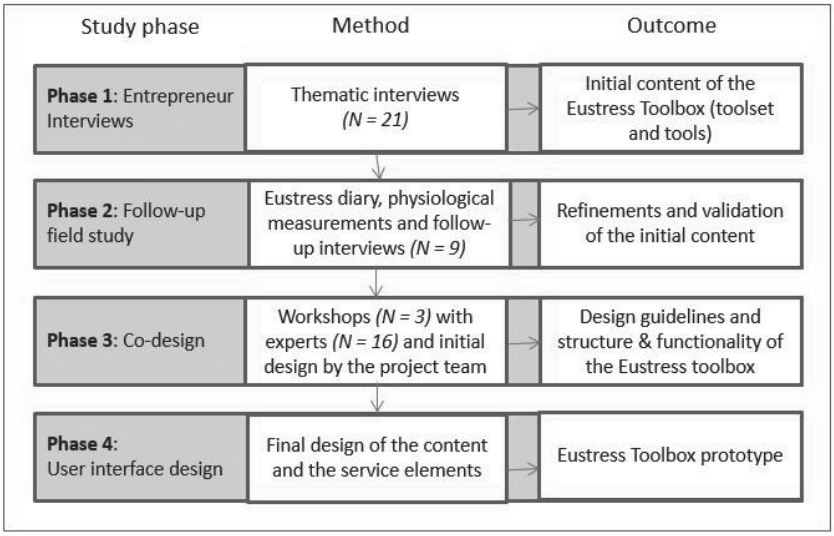

Figure 1. Design procedure describing the study methods and outcomes as Phases 1–4.

The interviews lasted 2 hours and were voice recorded. We conducted them face-to-face at the participant's workplace or other quiet place agreed upon with the participant. All interviews were conducted in Finnish; both the interviewers and the entrepreneurs were competent in the language. The quotes provided in this paper were translated from Finnish to English by a professional translator.

At the start of the interview, each participant was asked to describe his/her current work and daily life as an entrepreneur. The interviewer then briefly explained the term eustress as an experience that occurs when one "enjoys working because of or despite a feeling of pressure." Because eustress has various indicators, enjoyment was selected as a familiar and positive term to encompass positive feelings and attitudes. The interviewee was asked whether he/she has experienced it and whether he/she could recall recent experiences. The participant was asked to elaborate the recent eustress experiences and any feelings or behaviors before, during, and after them, as well as the causes for feeling pressure and enjoyment in the situation. Finally, the interviewer asked how often the entrepreneur experienced eustress, what triggers it, and whether he/she has developed or identified means to achieve it.

The researchers aimed to create rapport with the participants to support them in sharing their experiences freely. However, several means were used to minimize the researchers' impact on the data: The term eustress was explained with a similar description to all participants, the semistructured interview was used as a method instead of a more open approach, and the participants were encouraged to describe concrete examples of their experiences instead of general abstractions.

We analyzed the verbatim transcriptions of the interviews following the steps of thematic analysis defined by Braun and Clarke (2006). Each researcher first read through each interview transcription independently and then the complete body of transcriptions was discussed within the team for clarity of understanding. Then, we systematically coded the parts of the data in which entrepreneurs described the ways of stimulating eustress. The coding was not limited to specific questions; rather, codes were added every time the respondent described a way he/she stimulated eustress, no matter where that took place in the course of the interview. Based on the similarities, we grouped the codes into wider themes. This data-driven analysis led to six main themes that later became the toolsets of the Eustress Toolbox (described in Results section and Table 1). A review and further analysis of these themes produced 24 subthemes that were later employed as the tools in the toolsets and illustrated with entrepreneur quotations chosen from the data. Thus, the basis for the content of the Eustress Toolbox was formed from this first user data collection phase.

The second phase of the user data collection (follow-up field study) was organized with nine participants from the first phase to collect their near-real-time experiences on eustress over the course of a week. We offered the opportunity to participate in this phase of research to all participants, and all who were willing to invest time in participating were accepted. The methods for this phase were designed to support self-reflection of all stress experiences and were recorded daily. We created a subjective diary in a form of a paper booklet. It included a calendar view where the participants assessed the times of experiencing positive or negative stress, their overall feeling in the situation (smileys), and the causes of pressure and enjoyment in the situation. We asked participants to make more detailed notes of the moments in which they felt eustress (that is feeling enjoyment while feeling pressure) and to provide more detailed descriptions on two or three of these situations. In addition to filling in

Table 1. Toolsets, Underlying Needs, and Tools of the Eustress Toolbox Service Drawn from Interviews with Entrepreneurs, Experts, and the Literature.

Toolset	Needs	Tools
Self-reflection and changing the mindset	Need to identify own ways of thinking and working to be able to change them; Need to recognize the signals of stress (positive and negative)	-Self-reflecting on personal thoughts, feelings and actions -Changing the point of view towards the positive -Putting things into perspective -Fostering trust in oneself and the future -Regulating personal resources -Sharing and sparring
Organizing work	Need to manage work in a meaningful and effective way; Need to achieve clarity and avoid tedious routines	-Planning and scheduling -Concretizing tasks and goals -Working together -Breaking routines
Stimulating positive pressure	Need a boost when there is no external demand or pressure	-Creating challenges -Generating time pressure -Seeking out challenging situations
Harnessing a feeling of joy	Need for meaningful and rewarding work to feel happy and motivated	-Seeking out meaningful tasks -Building a positive environment -Enjoying and sharing successes
Mental preparation	Need to face a challenging situation	-Focusing on the essential -Preparing for challenges
Recovery	Need to recover and detach from work	-Taking breaks -Detaching from work -Easing the pace -Releasing pressure -Fostering physical and mental wellbeing -Ensuring sufficient sleep

the diary, the participants conducted a 3-day physiological heart rate variability measurement with the Firstbeat BodyGuard device,[1] which provided data on their physical well-being: stress, recovery, and sleep.

Because physical data on the participants was to be collected in this study phase, we applied for an ethical review from the Ethics Committee of the Tampere Region. The committee identified no barriers for conducting the study. The personal data was treated confidentially in all research phases and anonymized after the data collection.

The data comprising the diary notes and the heart rate variability measurement were elaborated with the nine second-phase entrepreneurs in a new semistructured interview. The goal was to gain deeper knowledge of eustress experiences and to help entrepreneurs learn to recognize these experiences and to interpret their behaviors. The data drawn from each diary and physiological study were addressed chronologically, and the participant was asked to elaborate his/her stress experiences as presented.

The data of the multiple steps in the second phase were used to gain timely and detailed experiences of eustress and to validate the results of the first study phase. When the second-phase data were thematically analyzed, the same six main themes identified in the first data set were present also in the second data set. However, the second-phase analysis allowed us to execute minor refinements to the descriptions and illustrating quotations of the subthemes. As a final step of the second data collection phase, we organized a workshop for all nine participants. In this workshop, these volunteer entrepreneurs shared their approaches to achieving eustress and had an opportunity to learn new approaches from their peers. Although a fruitful experience, the workshop participants did not reveal any new information to augment what had been collected already.

After the two-phased entrepreneur study, we organized three codesign workshops to identify potential design implications and to define a delivery channel for the results. Altogether 16 experts on health technology, well-being, and professional coaching attended the workshops, 4-6 experts at each workshop. In the 2-hour workshops, we first introduced to the experts the six main themes from the user data (with subthemes and illustrative quotations from entrepreneurs). These were presented on posters in the meeting room. After that, we asked each participant to mark down what he/she believed were the most important themes and challenging issues and to generate design implications related to the themes. After this individual task, the experts discussed the issues together within their group. The resulting material of the workshops was analyzed by the project team. The workshops strengthened the potential of the idea of a Eustress Toolbox service, as the participants regarded the data valuable in increasing knowledge of the positive side of stress. Moreover, they advocated for a holistic service, instead of several separate services concentrating on the six explicit themes. The data of the workshops guided the project team in focusing on the following aspects of the service: supporting entrepreneurial work, highlighting peer experiences, and providing means for reflecting and rehearsing new work practices and ways of thinking in one's daily life. Later, these aspects were emphasized in the design guidelines of the service.

In the final step in our research project, we designed the prototype of the Eustress Toolbox online service iteratively in joint workshops within the multidisciplinary project team. The design work started by defining design guidelines, which we formed by utilizing and reflecting upon the materials of both user study phases, the codesign workshops with experts, and the design frameworks described in the literature. We designed the elements and functionality of the eustress service prototype based on the identified guiding principles. The content of the toolsets and the explicit tools of the service were designed based on the entrepreneur experiences (i.e., the analyzed entrepreneur data). In addition, exercises related to the various themes of the toolbox were created. Furthermore, we identified and evaluated third-party mobile and Web applications related to the themes, and those that deemed most suitable to support the goals of the toolbox were included in the service.

The final service prototype was evaluated with four usability experts outside the project team. Based on their evaluations, minor modifications were made to the design.

RESULTS

The Results section is organized to present the results in the order of the study procedure, proceeding from the findings of the user studies to the design of the Eustress Toolbox. The objectives of this research were to provide understanding of the means that help entrepreneurs to recognize and feel eustress and, based on this knowledge, to design a service that introduces methods to stimulate eustress in one's daily life. In the following subsections, we first describe the role of eustress in the entrepreneurs' daily lives and their ways of thinking about and working to foster it; the implications for the Eustress Toolbox follow immediately. After this, we present the design of the Eustress Toolbox, a digital service designed based on entrepreneurs' experiences.

Entrepreneurs' Means of Fostering the Experiences of Eustress in Their Daily Lives, Leading to the Identified Eustress Toolsets

All participants recognized the phenomenon of eustress and considered it beneficial for their work and well-being. Eustress was perceived to be vital for achieving intended results on schedule, for getting the best out of oneself, and for working with a positive and energetic attitude. Eustress was experienced in different situations, but mostly before and during important meetings, such as customer negotiations or a presentation, or when completing important deliveries on a tight schedule. When experiencing eustress, the participants felt themselves enthusiastic and energetic but also able to concentrate and be present in the current moment. The participants reported that it was typical to feel the new stressors as negative at first but later to perceive them as more positive. Examples of eustress presented by participants included starting to feel more confident, being in control of the situation, or seeing the gradual results of one's work.

Based on the entrepreneurs' descriptions of eustress, several factors contributing to the experience could be identified. The following results describe the entrepreneurs' means to simulate eustress in their daily lives.

First, eustress experiences were facilitated by self-reflection on one's thoughts, feelings, and actions (see more about eustress and self-reflection in Tikkamäki, Heikkilä, & Ainasoja, 2016). For example, eustress experiences included descriptions of putting things into perspective, changing one's point of view, and harnessing a feeling of trust—trust in the future, in one's abilities, and the possibility of having an impact. One participant described her insight on the importance of having an impact on her own work in a following way *"You can have an impact on things. It is up to you whether you carry on without doing anything and just complain or whether you actually do something"* (Female, aged 39).

The tools for self-reflection formed the first toolset of the Eustress Toolbox: Self-reflection and Changing the Mind-set. The toolset provided various tools for and examples of the means to change one's point of view, put things into perspective, foster trust, regulate one's resources, and share with and/or bounce ideas off others who are members of the work community, peers, mentors, or close friends or family members.

Second, the entrepreneurs had several daily practices that helped them manage their work better or gain a feeling of things being in control. These methods included, for example, ways to prioritize and schedule work, divide it into smaller pieces, share the work with others, and

make the plans concrete and visible. One participant described the effect of writing a to-do list and making pending tasks visible: *"When you start to write down things, you can see what you need to do. It is no longer this enormous mush in your head that makes you [negatively] stressed"* (Male, aged 41).

The ways to manage and organize one's work formed the second toolset of the Eustress Toolbox: Organizing Work. Thus, the toolset includes tools for planning and scheduling tasks or projects, concretizing tasks and goals, working collaboratively, and breaking up tedious routines.

Third, the entrepreneurs had various means to challenge themselves and create pressure or a boost for accomplishing tasks. The most typical one was to set a deadline for a task. For others, it meant starting the work shortly before the deadline, rather than early, to enhance the effectiveness of one's work: "*If I start the task very early, I may do the things too well. If I start later, I do the task at a sufficient level and can forgive the hidden perfectionist in me"* (Male, aged 40).

The means for creating pressure helped to achieve eustress in cases of low or no external pressure. This practice formed the third toolset of the Eustress Toolbox: Stimulating Positive Pressure. The tools provided include ideas for challenging oneself.

Fourth, the feeling of eustress was increased not only by increasing the feeling of pressure but also by harnessing the positive aspects of one's work. The entrepreneurs harnessed the feeling of joy at work by seeking out meaningful tasks, by building a positive working environment, and by stopping to enjoy and share successes. They described situations where humor, playfulness, acknowledging past successes, and a positive work environment reduced negative stress and helped them in seeing the difficult tasks or parts of them as positive challenges. One participant described his attitude as follows: "*There's no need to act like a wet blanket, even when you're talking about major, work-related issues.... A little humor goes a long way*" (Male, aged 51).

The ways to see the positive aspects in one's work formed the fourth toolset of the Eustress Toolbox: Harnessing a Feeling of Joy. The tools within this toolset including means to recognize the meaningfulness of one's work, create rewarding and fun conditions for work, and cherish one's efforts and accomplishments.

Fifth, the entrepreneurs noted that facing the stress in challenging situations was alleviated by mentally preparing for the situation and, when within the situation, keeping one's mind focused and concentrated on the essential issues. For example, the entrepreneurs visualized the situations beforehand or made lists to clarify the goals in advance of important meetings. Identifying goals or preparing for tasks may not only relieve negative stress, but these processes simultaneously may help in focusing on the most relevant issues in the challenging situation. This process was described by one study participant in this way: *"I make wish lists and to-do lists even for short meetings. Then the things go into your unconsciousness and pop up while in the meeting"* (Male, aged 52).

The means to prepare for a challenging situation and focus on the essential when facing a challenge formed the fifth toolset of the Eustress Toolbox: Mental Preparation. The toolset includes two parts: Focusing on the essential and preparing for challenges.

Finally, most of the entrepreneurs recognized that recovery between work challenges—even positive ones—is extremely important. In the entrepreneur's world, it is typical for this need to be neglected and to work outside office hours as well. Because of this, it is important to

have reminders and routines for detaching from work. For many study participants, observing the scarcity of the moments of recovery in their well-being measurement was eye-opening.

As a result, many of them committed to new daily practices to increase the number of recouping moments. However, a number of the entrepreneurs had already found good practices to detach from work, for example, by doing something completely different from work tasks. This is characterized by the following comment:

> *When I start feeling that I only do one thing after another [without enjoyment], I take my dog with me and go into the forest. To detach from the ongoing thoughts, I listen to some hard-core rock from Spotify that I wouldn't listen to otherwise*. (Female, aged 42)

Suggestions on ways to recoup and recover from the challenges and timetables of entrepreneurial work formed the sixth toolset of the Eustress Toolbox. The Recovery tools include various means to detach from work both during the workday and on free time.

To summarize, we found six main sets of tools based on the thematic analysis that were used by the entrepreneurs to foster eustress in their daily lives. These were concretized within toolsets: (a) Self-reflection and Changing the Mind-set, (b) Organizing Work, (c) Stimulating Positive Pressure, (d) Harnessing a Feeling of Joy, (e) Mental Preparation, and (f) Recovery. Each toolset addresses different but equally important needs for managing one's work and life. For the Eustress Toolbox to be useful and easily applied, each toolset comprised a number of distinct strategies (i.e., tools). The needs and tools are listed in Table 1.

Eustress Toolbox

From the codesign workshops, it was recognized that the Eustress Toolbox should be provided as a holistic entity rather than as individual tools. To do this, while simultaneously catering to individual needs, an interactive, guided, and personalized approach was conceived. A digital delivery channel, specifically, a Web-based service, was chosen due to its easy availability to most entrepreneurs; its capability for easy integration into the daily lives of users; the potential for guiding, personalizing, and reminding usage; and the possibility to monitor progress and provide feedback.

To guide the design of the Eustress Toolbox, five design guidelines were derived based on insights from the entrepreneur interviews and expert workshops. The person-based approach (Yardley et al., 2015) and the PSD model (persuasive systems design; Oinas-Kukkonen & Harjumaa, 2009) were consulted as formal frameworks to inform the guidelines. The guidelines were

1. *Minimizing user effort*. This is accomplished by dividing the content into standard-format, bite-size pieces, tunneling the user through a program, providing personalized suggestions, and reminding of use. Because entrepreneurs generally struggle with balancing their time, it is crucial that the process for adopting and using new tools is as effortless as possible.
2. *Providing freedom to discover.* To meet varying needs for and triggers in stimulating eustress among entrepreneurs, a free choice among a wide range of techniques is essential. Thus, active discovery of personally suitable tools must be enabled and encouraged.

3. *Enabling follow-up of progress.* Both in the program usage and eustress skills facilitated, the system must allow progress indicators and provide feedback. This aligns with the idea of making planned or completed work visible, which was seen as helpful for optimizing one's time and achieving eustress.
4. *Enabling learning from peers.* Learning about and developing skills that encourage eustress in all aspects of one's professional and personal lives is enhanced when other entrepreneurs' experiences and techniques related to eustress are visible. Sharing and bouncing ideas off peers was perceived as especially important because entrepreneurs often work alone and lack support from colleagues.
5. *Supporting the integration of skills into daily life.* Integrating new skills into the everyday life and turning them into automatic habits requires self-reflection and rehearsal. The process can be supported by providing tools and exercises that enable analyzing how the new skills could fit into one's daily life and rehearsing them until they become habits.

The Eustress Toolbox was designed both to increase understanding of eustress and to help users to develop skills for stimulating eustress in their lives. The goals of the Toolbox were to (a) enable users to familiarize themselves with the phenomenon of eustress and the multiple means to stimulate it, (b) allow users to reflect on their current practices and subtly suggest areas for improvement, (c) guide users through a program of learning new skills, and (d) provide practical tools for integrating the skills into their daily lives.

The structure of the Toolbox was built around the six toolsets derived from the data-collection phase with entrepreneurs. In addition, introduction and ending modules were included (see Figure 2) to provide background information and a possibility to identify the most useful toolsets for oneself, and after using the Toolbox, see one's results in learning new skills. The user's progress was indicated as progress bars, representing the completion of each toolset, and presented on the main page of the Toolbox. To facilitate remembering to use the service, email reminders were sent if the service had not been used for a week.

In the following subsections, the modules of the Eustress Toolbox are presented. As the original service is in Finnish, the texts in the screenshots of the service were translated into English.

Introduction Module

The introduction module (denoted as Start Here) presents the phenomenon of eustress and the background of the Eustress Toolbox service. It also summarizes the structure of the service and provides guidance on how to use it. The introduction module contains a questionnaire for identifying the toolsets most useful to the individual. The questionnaire consists of 21 statements representing the various toolsets drawn from the qualitative interview data. After completing the questionnaire, the user receives a summary and recommendation on the potentially most useful toolsets, which are also denoted in the main view with orange stars (Figure 2).

Eustress Toolsets

Each toolset is constructed in an identical way and contains an introduction, 2–6 tools, and off-line titled "Try out in your daily life" (Figure 3). User progress is indicated also at this level by

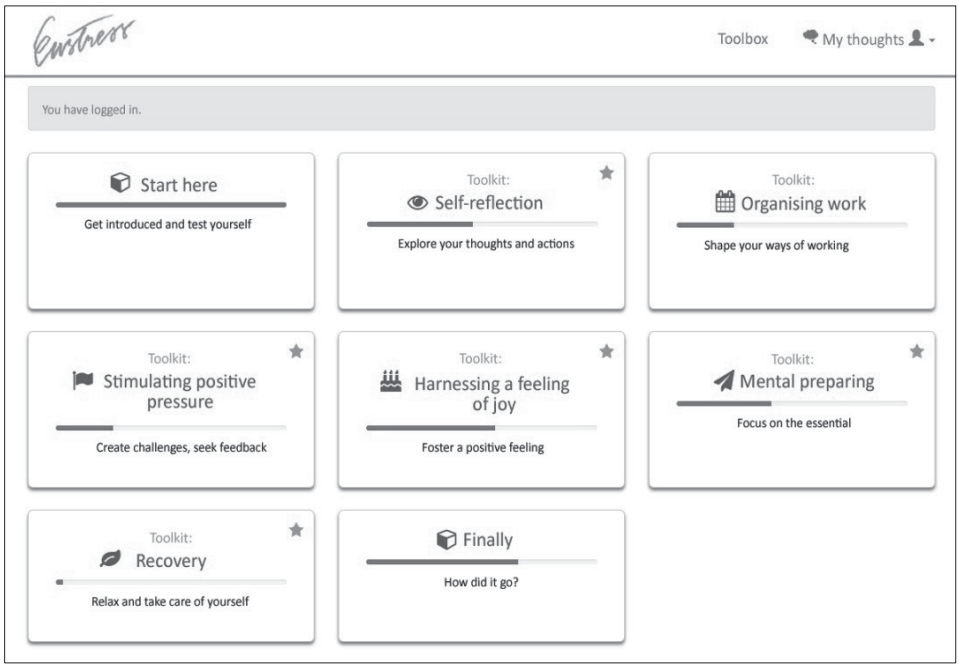

Figure 2. Main view of the Eustress Toolbox: introduction module, six toolsets, and ending module.

Figure 3. Main view of a toolset: access to introduction, three tools, and off-line exercises.

by round progress indicators, which display the number of steps completed in each tool. The indicators turn into check marks when all steps within a tool are completed.

Eustress Tools

All tools have an identical internal structure and consist of three steps: a description of the tool, entrepreneur quotations, and a reflection exercise. Furthermore, after completing each tool, the users can provide feedback to the researchers. The quotations from entrepreneurs who participated in the first phase of data gathering were used to illustrate real-world experiences related to the tool and to show the origin of the tool (see an example in Figure 4). This way of presenting the tools can make them feel more authentic and interesting, and also enable learning from peers according to design guideline 4.

The reflection exercises aim to help users identify their own practices and habits and to assess how the tools relate to their lives. This is done through one or more questions prompting self-reflection on the topics presented in the tool. A text box is provided for entering notes and reflections.

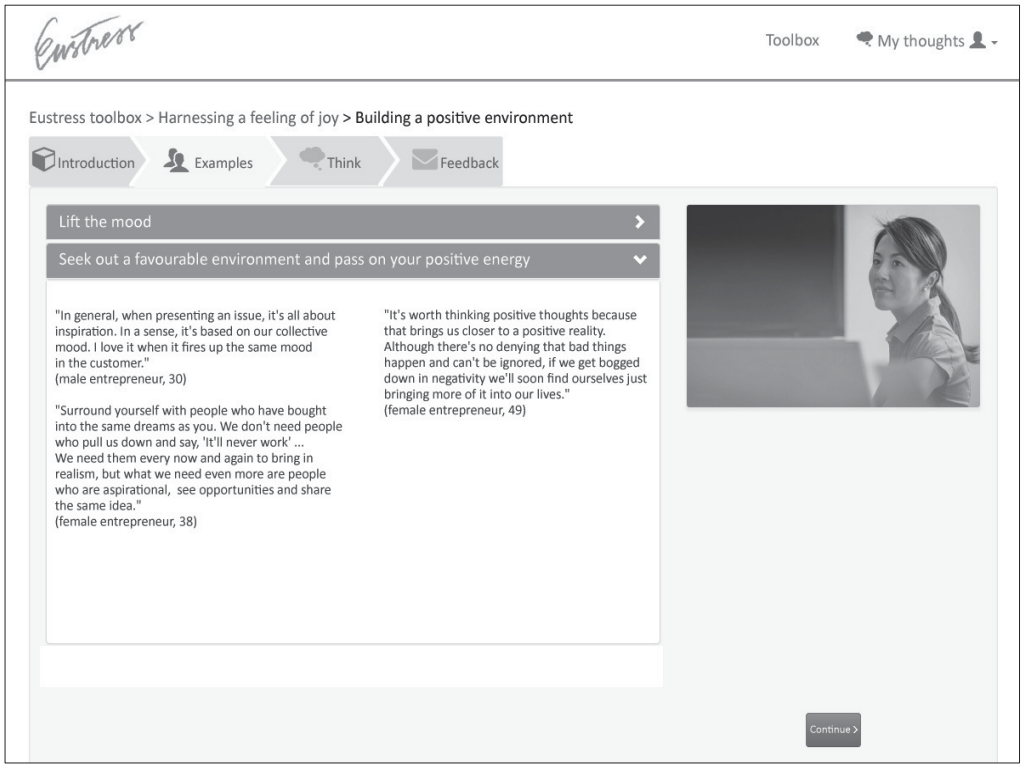

Figure 4. Example of contents of a tool: quotations from entrepreneurs who participated in the first phase of data gathering. Photo by Jeremy Bishop on Unsplash.

An example of a reflection exercise related to recalling successes asks the user to look back on one's successes at work:

> When have you felt the feeling of success in a challenging work situation? What did you do?
>
> Can you recall a situation where you succeeded even though you were afraid of failing? What did you learn?

The users can see only their own responses to the reflective exercises. Should they wish to revisit those comments, they can access them via the tools or via the main view (e.g., see the My Thoughts option; upper right of Figure 1).

Off-line Exercises and Eustress Applications

The last step of each toolset is an off-line exercise that aims to provide an opportunity for the users to rehearse the skills and, ultimately, to integrate them into their daily lives. The users are provided with 2 to 3 off-line exercise options and are asked to select one to complete during the following week. Off-line exercises consist of long activities, such as planning work tasks on a weekly basis or including a moment of recovery to each day of the week, and shorter exercises, such as having a meeting with oneself to analyze one's values or envisioning and trying out a new approach to a work assignment. Detailed instructions for completing the exercise are provided and the users may also write down their own plans for the exercise. The commitment and plans are then sent to their email as a reminder. Twenty-four hours after activating the exercise, a reflection form is enabled in the Toolbox, allowing the user to reflect on the exercise during or after the rehearsal period and to mark it as done after completing it.

An example of an exercise related to the toolset of Harnessing a Feeling of Joy challenges the user to lift his/her own mood and that of others:

> Praise Week
>
> On each day of the week, praise yourself or someone else for a job well done, an inspirational attitude, or a brave try. This can be about even small deeds and successes and is just one way to surprise others and create a positive buzz around you. Remember to choose yourself as a recipient of praise on at least one of the days!
>
> Answer the following questions after Praise Week: Did you remember to praise someone every day? What kinds of reactions resulted from praising others? Did you learn something during the week or begin to see anything in a new light?

As part of the off-line exercises, users also are provided with links to selected third-party mobile and Web applications related to the toolset. These applications aim to provide practical tools to foster eustress and give users additional means for integrating the skills into their daily lives and work. For example, in the first toolset (i.e., Self-reflection), a mindfulness-related application[2] is provided, and in the second toolset (Organizing Work), applications for listing, scheduling, and delegating tasks are included.[3]

Ending Module

The final module of the service contains an ending questionnaire that repeats the questionnaire presented in the introduction module. The ending questionnaire opens only 3 weeks after the first use session to ensure that users have had time to practice the skills before

repeating the questionnaire. After the users complete the questionnaire, graphical feedback summarizing the status of various eustress skills is provided along with a comparison to the screening questionnaire status. This feedback enables the users to reflect on what they have learned during the program and to see their progress in the skills related to the toolsets.

DISCUSSION

This paper sheds light on entrepreneurs' means to feel eustress in their daily lives and, based on this understanding, it presents the design process and implementation of an online service prototype, the Eustress Toolbox, for fostering eustress. We wanted to focus on the positive side of stress because research has been focused more typically on the negative aspects of stress. However, a positive view of stress may offer new tools for well-being (Simmons & Nelson, 2007). Although a positive approach has become a growing research and design approach in HCI (Calvo & Peters, 2014; Desmet & Hassenzahl, 2012; Desmet & al., 2013) and interventions fostering psychological well-being have emerged (Ahtinen et al., 2013; Luthans et al., 2008; Mitchell et al., 2009; Ouweneel et al., 2013), design studies and experiments have not focused on the positive side of stress. Our study provides new insights on this phenomenon, based on the experiences of Finnish entrepreneurs. It also proposes a new way to approach work engagement, that is, acknowledging the holistic nature of stress and potentially offering new tools to see some work stressors in a more positive light.

The ways of thinking and working that entrepreneur participants identified as helping them feel eustress were analyzed and grouped into six toolsets of the Eustress Toolbox: 1) Self-Reflection and Changing the Mind-set, 2) Organizing Work, 3) Stimulating Positive Pressure, 4) Harnessing a Feeling of Joy, 5) Mental Preparation, and 6) Recovery. These toolsets have similarities to methods proposed by Hargrove et al. (2013) to help managers encourage eustress among their employees. Hargrove et al. (2013) suggested that eustress experiences can be fostered by offering meaningful work, encouraging mindfulness in the workplace, and supporting employees in understanding their capacity to meet challenging stressors. According to our interviews with the entrepreneurs, the meaningfulness of the work was seen as a particularly important accelerator for eustress experiences. Thus, the first toolset in the Toolbox relates to self-reflection, providing tools that help users find meaning in their work or recognize the meaningful aspects of their work. Seeking out meaningful work is also a tool in the fourth toolset: Harnessing a Feeling of Joy. Our first and fifth toolsets (Self-Reflection and Mental Preparation) acknowledge the benefit of mindfulness. All toolsets can be seen to contribute to understanding or increasing one's capacity to meet challenging stressors through various means: increasing self-knowledge, enhancing the feeling of control of one's work, exposing oneself to challenges, stimulating positive affect, offering means to prepare for challenges, and reminding of the need to rest and recover before new challenges.

A Web-based service was chosen as the delivery channel of the Eustress Toolbox. Web-based services enable easy access, independent of the user's time and location, as well as self-paced use, an interactive and personalized approach to providing content, and the ability to design means to guide the user through a program. Another benefit is the possibility of reminding users of yet-to-be completed tasks and providing feedback on progress. The guidelines used for designing the Eustress Toolbox were (a) minimizing user effort, (b)

providing freedom to discover, (c) enabling follow-up of progress, (d) enabling learning from peers, and (e) supporting integration of skills into daily life. For this service, we considered learning from peers an especially important component as it may be more enlightening and motivational to hear about experiences from peers than from researchers. In the future, this aspect could be further strengthened by providing ways to communicate with other entrepreneurs, for example, by creating a discussion board or an associated Facebook group. Another crucial part of the service was to provide exercises and third-party applications that would support the integration of skills into the user's daily life. There are thousands of applications and services available related to well-being and work management, but finding and adopting them takes time, a commodity in short supply for most entrepreneurs. Integrating recommendations for services such as these may help to lower the threshold for adopting new practical tools. Reflection exercises were designed to help users identify their own practices and assess what each tool signifies for them, enabling the users to internalize the different concepts and skills related to eustress. The intention of the off-line exercises was to encourage practicing the skills in the real world and to help in integrating them into everyday routines.

Our design approach was in line with human-centered design approaches (ISO, 2010) and was related closely to the person-based approach applied by Yardley et al. (2015). Additionally, the PSD model (Oinas-Kukkonen & Harjumaa, 2009) was consulted to include features that would facilitate adoption and increase engagement with the service. Our design was based on the actual experiences of entrepreneurs rather than a specific psychological therapy, which is a typical base for many digital interventions. Moreover, our approach was empirical and experience-based with the goal to learn from the mind-sets and work practices of entrepreneurs, to find out their ways of fostering eustress, and to share the insights through a digital service. In the recent years, both theory-based digital well-being interventions and design experiments based on the empirical user data have increased, and our work is one attempt to foster a dialogue between these fields.

Despite the vast research on work stress, the complex relation between negative and positive stress is far from clear. Although the two sides of stress have been acknowledged already decades ago, stress usually is considered a negative phenomenon and termed as such, and this can result in challenges in studying the positive side of stress. The terms eustress and positive stress divided opinions also in our data, and some entrepreneurs expressed contradictory feelings about the terms, even though they recognized the phenomenon.

Additionally, the relationship of eustress and work engagement is still somewhat speculative and based on only a few linkages presented in earlier studies. As work engagement can be seen as a more stable state than eustress, it may contribute to a greater likelihood of experiencing eustress. Furthermore, the means to foster eustress may increase the attributes of work engagement—such as vigor, dedication, and absorption (Schaufeli et al., 2002)—especially if they are adopted as everyday tools and practices. However, more empirical research and further elaboration on the conceptual level is needed to bring clarity to the relationship between these two concepts. The relationship could be empirically clarified with quantitative research. For instance, surveying a representative sample of entrepreneurs could indicate whether people who experience higher work engagement also experience eustress more often or more intensively. Another option could be an experiment testing into whether practicing the means to foster eustress as a part of daily life also increases work engagement in

the long run. However, the implementation of such research is not straightforward, particularly because no validated measure of perceived eustress exists.

The Eustress Toolbox was created based on the experiences of Finnish entrepreneurs, and in its current form, it is targeted at entrepreneurs. Because entrepreneurs often have a need for effectiveness, the state of eustress can be seen as especially beneficial to them. Entrepreneurs also need to protect themselves from too long days and too intensive working in the goal of maintaining their well-being and mental resources. Further research is required in evaluating whether the current toolsets and processes are the most effective in assisting entrepreneurs in achieving these goals.

We believe the Eustress Toolbox might be beneficial for other user groups as well. As self-leadership skills are important in contemporary working life, the service may be beneficial for employees needing an entrepreneur-like mindset and skills. However, adopting the service requires voluntary interest from the user. Promoting ways to implement eustress by a supervisor involves ethical issues that need to be considered: The tool cannot be used as a means to increase stressful work among employees, no matter how positive that stress might be. By emphasizing the potential of stress as a positive resource, we do not want to deny the harmful effects of distress or to claim that all stressors could be perceived as positive. Instead, we aim at a more holistic view on stress by presenting the entrepreneurs' current practices to foster the positive side of it and explaining a service prototype that may help entrepreneurs in perceiving some stressors as more positive and by challenging their current ways of thinking and working.

The strengths and limitations of the research and design work relate to the user group studied. Entrepreneurs gave valuable insights on eustress, but naturally, the results cannot be straightforwardly generalized to other occupational groups. In the future, qualitative research on other user groups would provide interesting new knowledge. Also quantitative approaches will be needed to give a wider perspective on the subject and validate the results.

The Eustress Toolbox is a Web-based service prototype built for the purposes of this study and its wider utilization would require further developmental steps. In the next phase of the project, the content and implementation of the Eustress Toolbox will be evaluated among a new group of about 20 entrepreneurs and company employees doing entrepreneur-like work. This pilot will be used to study whether the content and design of the Eustress Toolbox are acceptable and useful to the users, as well as to inform us on further needs for development and design ideas. The potential of the Toolbox will be evaluated based on the user experiences, user acceptance, perceived benefits, and initial impacts on the users' well-being or stress experiences.

In the future, it would be interesting to study the use of Eustress Toolbox also with a larger group of users. It would allow us to study the use of the service in relation to work engagement. Specifically, it would be interesting to learn whether the work engagement of the users affects the use of the service and impacts of the benefits of the Eustress Toolbox or vice versa.

IMPLICATIONS FOR RESEARCH AND APPLICATION

This work contributes to the body of research related to eustress and work engagement in the field of HCI. On the theoretical level, the work enlightens the potential connections between

work engagement and the two sides of stress: eustress and distress. The empirical aspect of this research provides an understanding of the work practices of Finnish entrepreneurs and the ways of working that help entrepreneurs foster eustress in their daily lives. These findings present a basis for understanding the potential practical means of achieving eustress, especially in the context of entrepreneurial work. This knowledge provides a foundation for a nascent understanding of the concept of eustress in the work environment that may be beneficial to future theorizing and refinement of the concept, both within the work world and beyond.

Our research also contributes significantly to the research into the design of solutions to support individuals' development and implementation of eustress in their lives. The Eustress Toolbox, a novel online service, provides insights into eustress and offers users the opportunity to practice skills for stimulating eustress in their daily lives. Thus, our research and this article contribute to the field of HCI through a new perspective and a human-driven design example of how to enhance a positive state of mind and work engagement by means of a novel digital solution. Our Web-based service may help practitioners and other members of the HCI community to design engaging and useful services for well-being.

ENDNOTES

1. The devices employed to measure the physiological components of this study were provided by Firstbeat Technologies Ltd., Jyväskylä, Finland. The researchers were trained by the service provider to interpret the data that were collected during the study, and this process was completed in collaboration with each study participant.
2. Information on the Oiva application, developed by VTT Technical Research Centre of Finland and University of Jyväskylä, and currently owned by Headsted Ltd, can be found at http://oivamieli.fi/
3. The Trello application is produced by Fog Creek Software, Inc. and can be accessed at https://trello.com/home while the Wunderlist application, created by 6 Wunderkinder GmbH, can be obtained from https://www.wunderlist.com/home

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Authors' Note

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All correspondence should be addressed to
Päivi Heikkilä
VTT Technical Research Centre of Finland
P.O.Box 1300,
FI-33101 Tampere, Finland
paivi.heikkila@vtt.fi

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RESEARCH ARTICLE Open Access

Field study of a web service for stimulating the positive side of stress: entrepreneurs' experiences and design implications

Päivi Heikkilä[1*], Elina Mattila[1] and Mari Ainasoja[2]

Abstract

Background: Digital services have been found promising in managing different aspects of health, also stress. We developed a web service for cultivating the positive side of stress based on the stress experiences of entrepreneurs. In this paper, we present a field study conducted to evaluate the user acceptance and the user experience of the developed service.

Methods: Twenty-two participants, working as entrepreneurs or having an entrepreneurial-type job description, used the web service for 6 weeks. User experiences were collected from all participants with electronic questionnaires, and 10 participants were interviewed to gain deeper understanding and to formulate design implications. In addition, usage logs of the web service were analysed to assess how actively the participants used the service and a pre and post questionnaires on stress and work engagement were conducted to evaluate the preliminary effectiveness of the service.

Results: The usage activity of the service was relatively low, on average, the service was used on 3 days and a total of 101 min. During the usage period, the participants' negative stress measured by the perceived stress scale decreased and their self-reported positive stress experiences had increased. The participants considered the positive perspective to stress useful. In the Eustress Toolbox service, the users appreciated especially the off-line and reflection exercises, as well as the quotations from peers, but the design should have supported more active triggering to use the service.

Conclusions: Based on user experience, we propose four design implications: *Integrate the service into the daily hassle of entrepreneurs, Provide personal guidance while maintaining a possibility to explore, Recognise the user's progress and accomplishments in a meaningful way* and *Support implicit learning from peer entrepreneurs*.

Trial registration: ISRCTN14739582, Sept 3 2019, retrospectively registered.

Keywords: Human-centred design, Positive stress, Eustress, Well-being, Entrepreneurs, User experience

Background

Stress is a significant challenge in the working life. It causes serious health problems for individuals ([13, 27]) and has been associated with societal costs due to, for example, absenteeism and loss of productivity [11]. Entrepreneurial work may subject individuals to higher levels of stress due to the risks in business activities [40], a higher-than-average need for achievement [28], heavy workloads and a self-established role in the organization [19]. In Finland, employers are required by law to organize preventive occupational health services for their employees. However, for entrepreneurs and the self-employed, the arrangement of occupational health services is voluntary, often leading to a lack of preventive care [50].

On the other hand, many entrepreneurs have traits and skills that help them in the face of stress, such as high stress tolerance [12], a high internal locus of control [41], or high levels of psychological capital (a construct of self-efficacy, optimism, hope and resilience) [3]. According to a study by Cardon and Patel [5], self-employed people do experience greater stress

* Correspondence: paivi.heikkila@vtt.fi
[1]VTT Technical Research Centre of Finland LTD, P. O. Box 1300, FI-33101 Tampere, Finland
Full list of author information is available at the end of the article

than employees but as it has a positive effect on their income, they may have a less negative attitude to stress. Several studies confirm [3, 5, 48] that coping with and managing stress effectively are critical skills to entrepreneurs and for survival and success of their companies. These findings on successful entrepreneurs' strengths in managing stress indicate that other entrepreneurs and employees could learn from their ways of managing stress. The growing research interest in entrepreneurial mindset [21, 24, 35] and self-leadership [33, 37] imply that work in general has become increasingly entrepreneurial in nature.

The positive side of stress has been acknowledged already for several decades [29, 42], but this perspective is typically excluded from stress research and design experiments related to managing stress. The term eustress refers to the beneficial side of stress [42], or more exactly, to the positive response to stressors [46]. The term was introduced by Selye [42], who divided the stress concept into the positive and harmful sides of it: eustress and distress. This has paved the way to the current holistic understanding of stress, which emphasizes that the stressor type itself does not lead to eustress or distress, but a person may interpret a stressor as a positive challenge or a negative threat [30, 46] and that eustress and distress are not mutually exclusive [46]. The savouring of eustress has been suggested to have the potential to increase the well-being of an individual [18, 46]. The concept of work engagement is closely related to eustress, but where work engagement is seen as a relatively stable state, eustress is a short-term response to stressors [30, 46]. Work engagement may be conceptualized as one of the positive outcomes of experiencing eustress [17].

Digital interventions have increasingly been used for disseminating interventions for preventing stress-related problems and educating individuals on skills related to stress management. Several studies have reported promising stress-related outcomes with web-based programs and mobile applications (e.g. [2, 20, 32, 49, 51]). There are also examples of programs focusing on building positive resources such as personal strengths, positive emotions, self-efficacy, and happiness [31, 36, 39]. However, to the authors' knowledge, interventions focusing specifically on building skills to foster positive stress have not been reported. Furthermore, most studies have been conducted with organizationally employed people from workers to managers, and they may exclude some aspects relevant in the entrepreneurial context.

We have previously reported the development and implementation of a web-based program for practicing eustress-related skills, the Eustress Toolbox [23]. The program was developed by interviewing a group of entrepreneurs and analysing their personal experiences and techniques to foster eustress. In this paper, we present a field study conducted to evaluate the user experience of the Eustress Toolbox among a group of people working as entrepreneurs or having an entrepreneur-type work description. Our research objectives are to study the acceptance and usage of the Eustress Toolbox web service, and based on the findings, provide design implications to support the design of digital well-being services especially in the entrepreneurial context.

The specific research questions were:

(1) How is the Eustress Toolbox accepted and experienced by entrepreneurs and people doing entrepreneur-like work?
(2) Does the use of the service affect the users' experiences of stress and work engagement and are there perceived benefits from using the service?
(3) How should the service be developed and what design implications can be derived?

Methods

Eustress toolbox

The Eustress Toolbox is a prototype web service, which enables users to familiarize themselves with the phenomenon of positive stress and introduces different methods to stimulate eustress in one's daily life. The service is primarily targeted at entrepreneurs and people having an entrepreneur-like job. The aim of the Eustress Toolbox is to give inspiration and exercises to change one's ways of thinking and working in a way that would contribute to experiencing positive stress. The toolbox is designed for preventive, temporary and selective use: users can choose the parts that are useful for them and do the exercises from the selected parts. By providing the users knowledge of the phenomenon of eustress, quotes illustrating other entrepreneurs' experiences, reflection exercises and off-line exercises, they are guided and encouraged to increase positive stress in their daily work and life. The toolbox can be used with mobile devices, but it is not optimized for mobile use. The content is mainly in textual format.

The toolbox consists of 6 toolsets (thematic areas) and altogether 24 tools (ways of thinking and working) for stimulating eustress (Table 1). When starting to use the toolbox, the user is instructed to go through an introductory module that contains information and instructions for using the service as well as a screening questionnaire for identifying the most useful toolsets for the user. The screening questionnaire consists of 21 statements, drawn from the previously collected qualitative data. The toolsets that are identified as the most useful for the user are marked with stars, to guide the user to focus on them in particular. Each

Table 1 Toolsets and tools of the Eustress Toolbox

Toolset	Tools
Self-reflection and changing the mind-set	1) Self-reflection of thoughts, feelings and actions; 2) Shifting toward a positive point of view; 3) Gaining perspective; 4) Fostering trust in oneself and the future; 5) Regulating personal resources; 6) Sharing and sparring
Organizing work	1) Planning and scheduling; 2) Concretizing tasks and goals; 3) Working together; 4) Breaking routines
Stimulating positive pressure	1) Creating challenges; 2) Generating time pressure; 3) Seeking out challenging situations
Harnessing joy	1) Seeking out meaningful tasks; 2) Building a positive environment; 3) Enjoying and sharing success
Mental preparation	1) Focusing on the essential things; 2) Preparing for challenges
Recovery	1) Taking breaks; 2) Detaching from work; 3) Slowing the pace; 4) Releasing pressure; 5) Fostering physical and mental well-being; 6) Ensuring sufficient sleep

toolset contains an introduction, 2–6 tools and 2–3 off-line exercises for practicing the skills in everyday life as well as recommendations of third-party applications that would support learning the skills (Figs. 1 and 2, see Additional file 1 for more screenshots of the service). After using the service for 3 weeks, an ending module is activated. The module contains a follow-up questionnaire, which repeats the screening questionnaire and visually summarizes the users' progress related to the skills learnt in the toolbox.

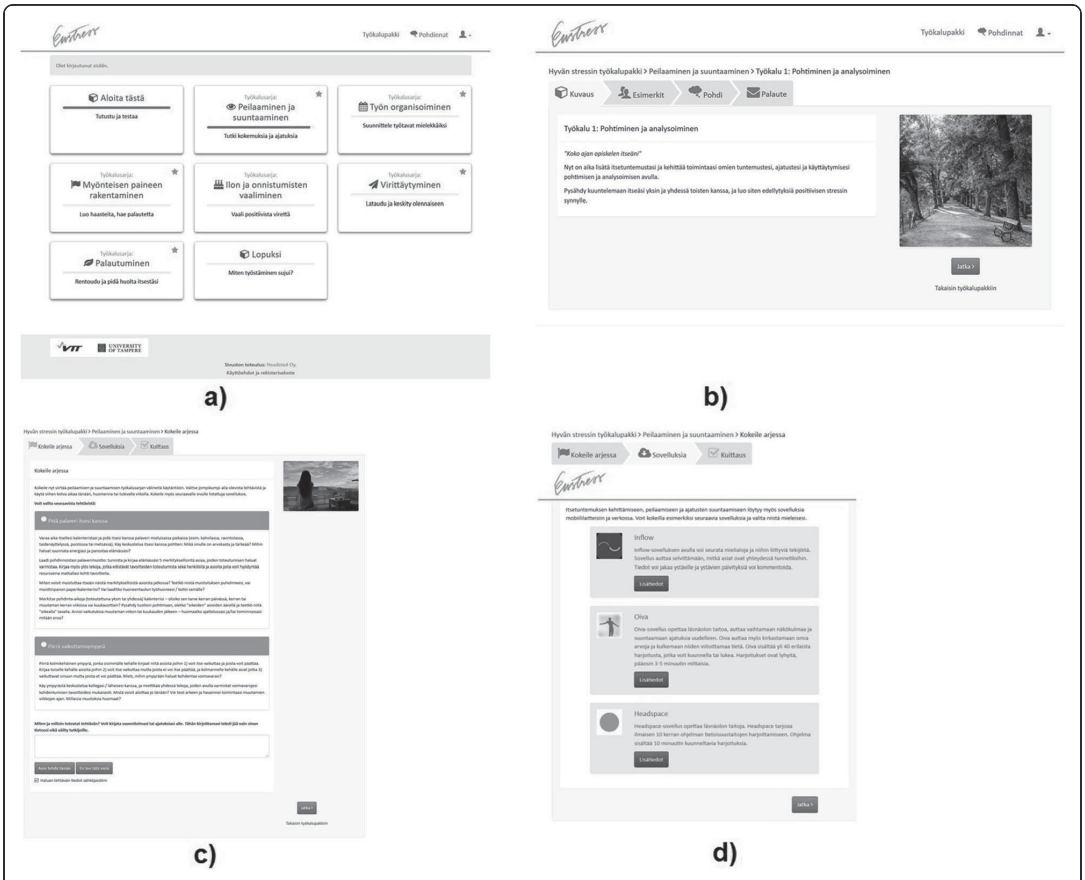

Fig. 1 Screenshots illustrating the user interface of the Eustress Toolbox (in the original language): **a** main view with introductory module, 6 toolsets and an ending module; **b** structure of one tool, including tabs for introduction, entrepreneur quotes, reflection exercises and feedback; **c** off-line exercise; and **d** links to third-party applications

Fig. 2 An example image of the Eustress Toolbox web service (translated to English). The structure of a toolset for harnessing a feeling of joy: an introduction, three tools and a section for trying out the tools in practice (including off-line exercises and 3rd party apps)

Field study

Twenty-two participants volunteered in the field study, 13 of them were entrepreneurs and 9 were employees having an entrepreneur-type job description. Most participants (18/22) were female and their average age was 40.3 years (SD 7.2, range: 26–52 years). The average time in the current occupation was 4.8 years (SD 4.7, range: 0.1–20 years). The participants were all Finnish and they were working in different fields, for example, providing training and consulting, well-being services, legal services or software design.

The participants were recruited to the study through email lists of local entrepreneur associations and word of mouth. The participants were required either to work as entrepreneurs in small companies (being self-employed or having their own business) or to have an entrepreneur-like job description, characterized by high levels of independence and responsibility. After the participants expressed their interest, they were emailed a link to an online recruitment questionnaire, which was used to confirm their eligibility and to collect background information.

Figure 3 illustrates the study procedures. After filling in the recruitment questionnaire, the participants responded to an online questionnaire on stress and work engagement (Stress 1). Stress was measured with the Perceived Stress Scale (PSS) [6], which includes 10 items and measures psychological stress, i.e. how stressful people perceive the situations in their lives and how uncontrollable and overloaded people have perceived their life during the past month. Work engagement was measured instead of eustress because there are no validated scales for measuring eustress and because work engagement is closely linked to the experience of eustress. Work engagement was measured with the 9-item version of the Utrecht Work Engagement scale (UWES-9, [43]), which measures vigour, dedication and absorption. The UWES scale may be considered a three-dimensional or a one-dimensional scale, and thus an overall score or sub-scores of the tree dimensions may be analysed.

All participants were invited to one of two group kick-off sessions. The 1.5-h session introduced the phenomenon of positive stress, the study procedures and the Eustress Toolbox. If a participant was unable to attend the face-to-face session, an individual phone introduction session was scheduled, and an informed consent form and the other introductory material sent by email. All participants signed a written informed consent form, and those who attended the phone

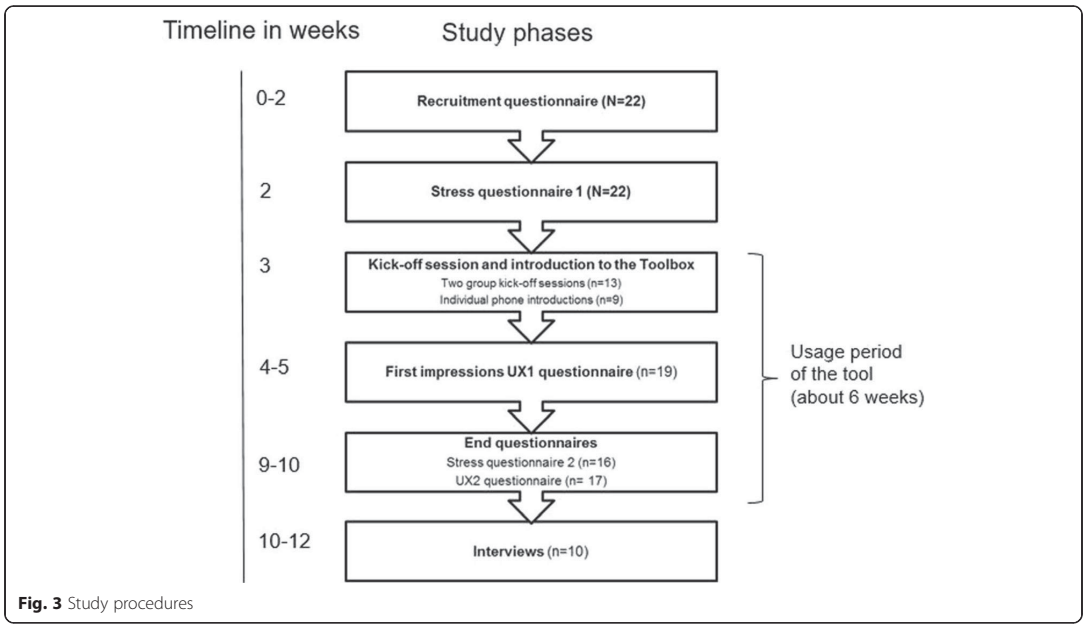

Fig. 3 Study procedures

introduction session mailed the signed form back to the researchers. An ethical review was not deemed necessary based on the guidelines of the Ethics committee of the Tampere region (https://www.tuni.fi/en/research/responsible-research/ethical-reviews-in-human-sciences), where the study was conducted. The participants were reimbursed with movie tickets; the participants attending to a final interview received four movie tickets each and other participants two movie tickets.

The participants used the Eustress Toolbox independently, as a part of their daily life, during an approximately six-week period. The choice of six-week duration and the use of introductory kick-off sessions are in line with the systematic review of Heber et al. [22], which shows that short-to-medium web-based stress interventions have been more effective than over 9 weeks long and that guided interventions have been more efficacious. The researchers monitored when participants logged in to the service and if a user did not log in within 2 days of the kick-off session, a reminder was sent. The maximum number of reminders prompting the user to login for the first time was three.

After 1 to 2 weeks of use (mean 7.3 days), the participants were sent an online user experience questionnaire on their first impressions on the service. The questionnaire (UX 1; see Additional file 2) consisted of 17 questions or groups of questions. One group of questions contained 13 statements related to the user acceptance of the service based on the Technology Acceptance Model for Mobile Services (TAMM) [26]. TAMM model was selected as a basis, as it is broader than the initial Technology Acceptance Model [9], including the dimension of trust and measuring perceived value instead of perceived usefulness. In addition, questions about the content of the service and usage activity were included. Eleven of the questions were voluntary open questions on the first impressions, expectations and use of the service in the daily life.

After about 6 weeks of use (mean 41.5 days), the users were sent two end questionnaires: the same stress and work engagement questionnaire as at baseline (Stress 2) and a final user experience questionnaire (UX 2; see Additional file 3). UX 2 consisted of 37 questions or groups of questions. The 13 TAMM-based statements were repeated, with slight modifications for longer use. Also questions about ways of using the tools, usefulness of different features and toolsets, experienced benefits related to stress and learning new skills, and desired additional features were included. In addition, 17 voluntary open questions allowed participants to elaborate on the topics of the questionnaire.

Furthermore, 10 volunteer participants were interviewed to deepen the data obtained with the questionnaires. The interviews concentrated on the users' prior knowledge on and experiences of positive stress, user experience with the Eustress Toolbox and the benefits and learning experiences gained from using the service

(see Additional file 4). The interviews were semi-structured, lasted 60–90 min and were audio recorded.

The Eustress Toolbox also automatically collected log files on usage, which included all user actions in the service as well as feedback collected in the service. For the reflection exercises and other private notes made in the service, only the number of characters was stored in the log, not the content.

Analysis

The PSS and UWES-9 questionnaires were scored according to their scoring manuals. An overall score for PSS was calculated, with possible scores ranging from 0 to 40. For UWES-9, both an overall score and sub-scale scores for vigour, dedication and absorption were calculated, with possible scores ranging from 0 to 6. The scores are reported as mean, standard deviation and minimum and maximum values. Changes in the scores from before to after using the service were analysed with paired comparisons using a Wilcoxon Signed Rank tests.

Log data were analysed to extract metrics for describing usage activity and ways of using the toolbox. We report usage metrics mainly for the six-week period after the first login. Usage metrics were calculated based on identified usage sessions. As the log file did not contain an explicit event marking the start or the end of a usage session, the rules for identifying a new session had to be created. To take into account possible breaks in usage sessions due to interruptions or completing off-line exercises, breaks of a maximum of 60 min were allowed, i.e. after a 60-min break, a new usage session was identified. Also other break lengths were tested, but based on visual inspection of the raw log file, 60 min seemed optimal. Completion of a tool was determined as having at least 5 events in a tool. Correlations between usage metrics and changes in stress ratings were studied using Spearman correlation.

Questionnaire data were analysed both quantitatively and qualitatively. The quantitative questions were analysed by calculating average scores of responses or numbers of participants responding in a certain way. For the TAMM-based questions, the average scores over the four TAMM dimensions (ease of adoption, ease of use, value and trust) were calculated. Scores of TAMM dimensions obtained from the UX1 and UX2 questionnaires were compared using the Wilcoxon Signed Rank test. Associations between perceived benefits related to positive and negative stress and usage metrics were studied using independent samples Mann-Whitney tests.

Only complete cases were analysed and reported in each type of quantitative data to avoid making assumptions on missing data. The statistical analyses were performed using the IBM SPSS Statistics Version 22 (IBM Corp, Armonk, NY, USA). Statistical significance threshold (α) was set at 0.05.

The qualitative questionnaire data and the interviews were analysed qualitatively by using the thematic coding method [15]. The coding was data-driven and done without reference to a preconceived framework. The codes were themed under the barriers of using the service, positive and negative user experience, perceived benefits, and development ideas proposed by the users. These themes were further analysed to find the key meanings and illustrative quotations.

Results

In this section, we present the results of the study by answering the three research questions. The first part focuses on acceptance and user experience of the service. The second part presents results related to experienced benefits of using the service: changes in stress experiences and perceived benefits. Third, users' development ideas and design implications are introduced.

The results will be presented based on the available data. The baseline questionnaire (Stress 1) and usage log files were available from all 22 participants. Nineteen participants responded to UX 1 questionnaire, 17 participants to UX 2, and 16 participants to the end questionnaire (Stress 2). Furthermore, 10 participants were interviewed.

Acceptance and user experience of the service

All participants took the Eustress Toolbox into use. Eleven participants (50%) were reminded at least once to take the service into use. The mean duration between the kick-off session and the first login to the service was 4.2 (SD 4.6, min 0.5, max 19) days. The service was used, on average, on 3 days (mean 3.5, SD 1.8, min 1, max 7) and the usage spanned over a period of 25 days (SD 13, min 1, max 42). The mean duration of a usage session was 33 min (SD 26, min 5.4, max 123) and the total duration of use was 101 min (SD 59, min 29, max 246). On average, the participants used 3 toolsets (SD 1.9, min 1, max 6) and completed 38% of the tools in the service (SD 22, min 4.2, max 92). The most popular toolsets were the first three: Self-reflection and changing the mindset, Organizing work, and Stimulating positive pressure, with more than half of the participants using them. Based on the log data and the interviews, a typical way to use the service was to select a toolset recommended in the screening questionnaire and go through all the content and exercises before starting a new toolset.

According to the interviews and open data in the questionnaires, the most significant barrier to service use was participants forgetting to use it. Although a reminder features had been specified and implemented,

due to a technical problem, the service did not send reminders during the field study period. The service was used rather occasionally, and thus it did not become a part of the users' regular routines. Most of the users used the service only during their free time; only one third of them used it also during work days. Based on the interviews, the participants using the service during work days found it easier to find the time for using it than the participants who had used it only on their free time.

The acceptance of the service was studied with ratings of the service as a whole and its different aspects. Data from the interviews and the open data of the questionnaires gave additional information on the user acceptance.

The overall score given to the service on a scale from 0 to 10 was 7.5 (SD 1.1) in the UX 1 questionnaire and 7.2 (SD 1.3) in the UX 2 questionnaire. The likelihood to recommend the service was in line with the overall score: 7.7 (SD 1.7) in the UX 1 questionnaire and 7.5 (SD 1.5) in UX 2 questionnaire. The user acceptance ratings according to the TAMM dimensions are presented in Fig. 4. Even though the user ratings were generally rather positive, the acceptance of the service had slightly decreased during the usage period. However, a Wilcoxon Signed Rank test showed that the only statistically significant decrease was seen in the Trust dimension ($Z = -2.81$, $P = 0.005$). Further analysis into the individual statements revealed that decline was mainly due to a third statement added in the dimension in UX2, namely "The service has fulfilled my expectations," which had an average score of 3.4.

On a scale of 1 to 5, the participants rated off-line exercises (average rating: 4.2, SD 0.83), screening questionnaire (4.0, SD 1.2), and reflection exercises (3.9, SD 0.75) as the most useful features of the service (see Fig. 5). Quotes from other entrepreneurs were also perceived as useful. Sixteen out of 17 participants intended to continue using the service after the study period, and because of that, most of the users had not responded to the follow-up questionnaire (which shows the change in one's eustress skills) of the service yet.

Off-line exercises were found to be especially useful, as they provided tools to integrate new skills into the daily life. They were commented to be small enough tasks, not requiring too big behavioural changes at a time, and to encourage the user to act – not just think about it.

> I got a feeling of hope that with small actions I can get things going forward. It was good that they (the exercises) weren't massive. Female, 50

Reflection exercises helped users identify their own practices and provided insights and inspiration on what the tools signified for them.

> I first thought that I wouldn't write down my thoughts as no-one else is going to read them. But when I did it, I realized that it makes you structure and understand and notice things better. It is not just some fuzzy stuff in your mind any more. Female, 34

The quotes from the entrepreneurs worked as a method to receive peer support and a way to obtain a new perspective or new ways of thinking.

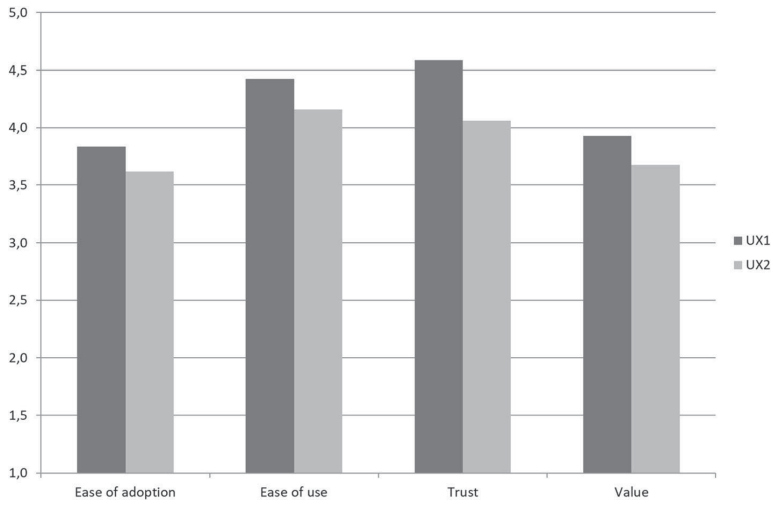

Fig. 4 User acceptance ratings of the service from the first impressions questionnaire (UX 1) and the end questionnaire (UX 2)

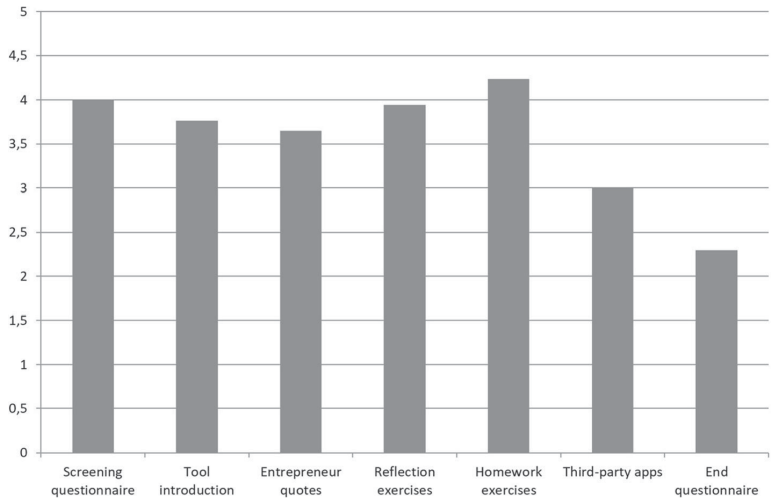

Fig. 5 Usefulness of features, average ratings on a scale of 1 to 5

> I liked to read the comments from real people, how they experience things. They wake you up, that you know, someone thinks like this and it makes her behave like this. It actually is the best information that everyone doesn't think the same way as you do. Male, 34

Organizing work (average rating: 3.3, SD 1.4) and Self-reflection and changing the mindset (3.3, SD 1.6) were rated as the most useful toolsets, which was also reflected in the usage data. In the interviews, self-reflection was experienced as an interesting and useful area that gave new viewpoints and compelled one to think about one's values and choices. The Organizing work toolset was perceived as giving practical tools to manage one's work, which are easy to adopt and have an impact on daily work.

According to the interviews, the content of the service was found to be interesting, but some considered the amount of information and exercises as overwhelming.

> It guides you to go through pretty large entities. If you want to get through everything, it takes quite a lot of time. And you may forget what you did the last time. It makes you feel a bit overwhelmed. Male, 35

The recommendations based on the screening questionnaire helped in finding relevant themes, but tunnelling to more personalized content inside the themes was desired. Although more guidance for proceeding in the service was desired, some valued the possibility to freely search for the content relevant to oneself.

> This left room for the right thing, the process that you need to go through yourself. It didn't force you to do this and this to get forward. Female, 42

Preliminary effects: changes in stress and perceived benefits

The participants' perceived changes in stress were studied by two methods: by a validated perceived stress score (PSS) in the stress questionnaire before and after the study period, as well as by self-reported estimation in the UX2 questionnaire, with a further possibility to openly describe the experienced changes. Among the 16 participants who responded to the Stress 2 questionnaire, PSS scores decreased during the six-week study period (mean change − 4.4, SD 5.9). A Wilcoxon Signed Rank test showed that the participants' stress score at the end was significantly lower than at the beginning ($Z = -2.47$, $P = 0.013$). Table 2 presents the PSS scores at the beginning and at the end of the study, and the changes calculated based on complete cases. The mean total UWES-9 score in the beginning was 4.9 (SD 0.82, 2.8–6.0), dedication sub-score was 4.9 (SD 1.1, 2.7–6.0), vigour sub-score was 4.7 (0.83, 2.7–6.0), and absorption sub-score was 5.0 (SD 0.78, 3.0–6.0). There were no significant changes during the study in any of the UWES-9 scores.

Table 2 Stress questionnaire scores as mean (SD, min-max)

Stress measure	Beginning	End	Change
PSS	15.1 (5.5, 6.0–22)	10.6 (4.2, 4.0–21)	−4.4 (5.9, −16–4) *

*$P < 0.05$, Wilcoxon Signed Rank test

The average percentage change in stress score was −21.5% from the baseline score. Half of the participants who responded to the end stress questionnaire (8/16) had a clinically important change in their stress score, characterized by at least a 28% change in the PSS score, as defined by Eskildsen et al. [10]. There were no significant correlations between usage metrics (amount of use and completed tools) and the change in the stress score or the UWES-9 scores.

In the UX2 questionnaire, almost all (14/17) participants reported experiencing changes in stress during the study. Eleven participants reported changes in positive stress and 11 in negative stress. Sixteen participants reported having learnt new skills related to positive stress by using the service. The most commonly reported skill was recalling and celebrating successful work (14/17 participants).

Self-evaluated changes in positive stress were significantly associated with usage metrics. The participants who reported that their positive stress experiences increased had used significantly more toolsets (median number of toolsets used 5, IQR 3–6 vs. 1.5, IQR 1–2.3; $Z = 2.86$, $P = 0.004$) and completed more tools (median completion percentage 38%, IQR 33–67% vs. 13%, IQR 13–32%; $Z = 2.83$, $P = 0.005$) than those who did not report benefits. No associations were found between self-reported decreases in negative stress and usage metrics.

In the UX2 questionnaire, the participants gave different examples of the beneficial effects of the service:

> By doing off-line exercises, I got to kick off a positive circle that things start going on and it gets you more enthusiastic. Female, 42

> I have figured out new ways to get feelings of success at work. Female, 50

> It has emphasized the importance of living in the moment. It has a great impact on stress and controlling it. Male, 34

The main benefits associated with the service usage were obtaining new insights and encouragement to try the skills in practice. For different participants the main insights were different: for example, finding new possibilities to have an impact on one's work, noticing how one could foster living in the moment or realizing that in some cases procrastinating may be a feasible way of working. Some of the participants had adopted new practices: for instance, listing the most important tasks for the week on Monday morning or "having a meeting with oneself" (one of the off-line exercises) once a week while practicing aqua jogging.

Development ideas and design implications

The participants proposed several design ideas; to overcome the current barriers, to integrate the service better into their life, and to make the service more engaging.

The most frequently stated improvement idea was the addition of reminders, which was requested by almost all participants (14/17) in the UX2 questionnaire and mentioned by all interviewees in the end interviews. Reminders were seen most useful if they had a direct link to the service and a concrete proposal for a new topic or exercise that might be useful for the user. Complementing usage with a physical handbook or a diary was also suggested. This might help in recalling the use of the service and support more versatile use contexts.

The service, in its current format, was not optimized for mobile use – using it when there is a convenient idle moment or a need for a more energetic or reassuring mind-set. The participants desired more instant access to the service and also a possibility to continue use from the previous state of the service. One participant compared the service to reading an e-book: the user should be guided back to the exact same spot that she last used. Some participants felt that opening the laptop and logging in required too much effort for a short use session. Instead, they wished the service was implemented as a stand-alone application, which would be easy to open.

More guidance was desired in proceeding inside the service. Desires were concretized as a personalized path, content appearing in the service in parts and a possibility to proceed in levels from beginner level to advanced use. In addition, the participants were missing clearer recognition of their achievements, as completing one toolset, for example, requires a considerable amount of time and effort. It was proposed that completing a toolset would be acknowledged by giving a summary of the content, proposing recommendations about what to do next or adding the toolset to a personal summary page of one's progress.

Some of the proposed development ideas were related to the features that were currently liked in the service. The participants wanted more auditory exercises, which were considered to be more relaxing and effortless than reading text. As some of the exercises would be useful to try or repeat later, users hoped for a means to mark them as their favourites or as to-do tasks.

When the participants were asked to ideate what would make the service more attractive or even worth paying for, the addition of social or communal elements and expert feedback or coaching were proposed. The presence of other users or experts could make the use more humane and fun.

> Even you researchers could have been more present in the service. You could see in the service that Pat (a

researcher) has a bad day today and she wants to use this tool to cheer herself up. Or today we have a bit better buns with the coffee at the office. You would see some personalities, and it wouldn't be just strict facts but something a bit more amusing. Female, 34

Also more advanced ways to analyse one's own stress state – physiologically or with questionnaires – were desired.

Based on the user experience and users' development ideas, the following key design implications were identified:

(1) Make me put it into practice! - integrate into the daily hassle of entrepreneurs
To make users utilize any service, it is crucial to support its everyday integration on practical level. This is especially important in the context of entrepreneurial work, as the daily work is often busy and fragmented. Regarding well-being information, it is typical to read it through, but often it does not lead into any changes in one's behaviour. In our service, off-line and reflection exercises were perceived as useful as they link the content to the users' life and supported applying it in the practice. Reminders and optimisation for mobile use would enhance the integration and enable more spontaneous usage. Another way to support integration is to offer versatile content for different usage situations. For instance, audio exercises are useful when reading is not an option. In addition, for some users, a physical or digital notebook or diary could further support practicing the new skills.

(2) Guide me! - provide personal guidance while maintaining a possibility to explore
Entrepreneurs may have very different needs regarding the service based on their prior knowledge, current work tasks and the work load, which may change frequently. For this reason, different users need different levels of guidance in using the service and the need may also vary between usage sessions. The Eustress Toolbox was designed to provide freedom to discover and empower the users to find the personally meaningful content. Even though the users valued the non-restriction of choice, they wanted more guidance in proceeding through the service. The design should offer guidance in a personally relevant way, for example, based on the screening questions or the achieved skills. In addition, the user's state of mind could be taken into account by providing clearer guidance for achieving more energy or calmness, depending on the situation at hand.

(3) Recognize me! - recognize the user's progress and accomplishments in a meaningful way
As the user puts time and effort into using the service, it is important to recognise the progress made walking through the material and rehearsing eustress skills. As entrepreneurs may lack feedback from a superior and colleagues, they may be especially motivated and delighted by the feedback given by the service. For example, completing a toolset should result in a meaningful recognition of the achievement, such as summarizing the content of the toolset and giving recommendations for additional content.

(4) Show me what the others do! - support implicit learning from peer entrepreneurs
Supporting learning from peers was one of the key design principles when designing the service. In the service, learning from peers was enabled by providing quotes from entrepreneurs who told about the ways of thinking and working that had helped them achieve eustress. The quotes were perceived as insightful and inspiring, while some participants also wished for actual interaction with peers to be included in the service. As entrepreneurs may lack support from colleagues and a feeling of belonging to a work community, a possibility to connect with peers or relate to their experiences is valuable.

Discussion

Earlier studies have reported entrepreneurs' special relationship with stress and underlined the importance of their stress management skills [3, 5, 41, 48]. This study investigated the feasibility of a new web service, the Eustress Toolbox, for stimulating the positive side of stress among entrepreneurs and people doing entrepreneur-like work. We aimed to study the user experience, user acceptance and preliminary effectiveness of the service, and identify the design implications that would make the service more attractive and integrate it better into entrepreneurial life.

User experience, user acceptance and design implications

The overall user experience of the Eustress Toolbox was rather positive – the content was found to be interesting and almost all the users wanted to continue using the service after the field study period. The reflection and off-line exercises as well as the screening questionnaire (giving personal recommendations about toolsets) were perceived as useful, as they helped linking the content to the users' life. Also the entrepreneur quotes were appreciated as they provided insights from the peer group and helped reflect on one's thoughts.

The Eustress Toolbox scored the highest in the perceived ease of use and trust dimensions, where the average of responses exceeded 4 out of 5 in both questionnaires. Research on the original TAM model has shown perceived ease of use to be an important determinant of perceived usefulness and attitude towards use [45]. Trust is a new dimension, which has been included in the TAMM model to capture issues encountered when using mobile services, such as trusting the service provider and ensuring the privacy of the user [25]. Same concerns apply to health and wellness related services, making trust an important determinant of intention to use the service.

Despite the positive overall experiences, most users did not feel able to incorporate the service into their daily routines and the acceptance of the service had slightly decreased during the usage period. Creating routines and habits is key to engaging users over the long-term, as it has been shown that habit explains up to 40% of continued use of online shops [14]. The results showed that the Eustress Toolbox did not meet the expectations of the users. The Eustress Toolbox was used, on average, on 3.5 days, 33 min at a time, and 101 min in total during the six-week study period. The users used about three of the six toolsets and completed 38% of the tools in the service. Although the minimum amount of usage required to achieve effects is not yet known, at least weekly usage was expected, and therefore the usage frequency was lower than expected. This may have been affected by the lack of reminders (due to a technical problem) and a lack of optimization for mobile use in our prototype version. In addition, the limited total usage can partly stem from the goals and design of the toolbox: the Eustress Toolbox was designed for selective use letting the users choose the toolsets they feel they need to practice. The screening questionnaire supported this by recommending potentially useful toolsets for the users. Furthermore, some exercises were designed to be done off-line, and the time spent with these exercises is not recorded in the log data. Compared to other studies, the usage rates observed were relatively low. For example, Hasson et al. [20] reported a median of 48 logins during a 6-month intervention. Asplund et al. [2] reported participants completing an average of 5.83 out of 8 weekly modules. Van Straten et al. [49] reported 55% of participants completing the whole 4-module intervention. A pooled analysis of three randomized controlled trials of an internet-based stress management program showed that users completed 4.4 to 5.7 of the 7 available modules during an intervention that was planned to take 4–7 weeks [51].

To support service use becoming a habit, reminders would be helpful to users when starting to use the service, but later on, habit formation could be better encouraged by supporting trigger events [47], such as using the service when starting the work day. To maintain the user's interest, it would also be useful to recognize the user's efforts and accomplishments in the service and support usage in versatile contexts. Moreover, supporting social interaction could make the service more engaging.

Based on the user experience and users' development ideas, four key design implications were identified. The implications are in line with the persuasive design principles of PSD Model [38], which was consulted already when designing the service. For example, providing quotes from peer entrepreneurs is one way to support social learning that is included also in PSD model, although the model describes it as learning from the other users. As the PSD model is wide and applicable in various contexts, prioritisation of the relevant features for a specific design may be difficult. The value of our design implications is to highlight the key issues that are relevant in the entrepreneurial context, to provide examples of implementing them and to present these issues in an intuitive way for HCI (human–computer interaction) practitioners. Each of the design implications supports the user in engaging with the system, which is especially important for facilitating experiences of positive stress, as the desire to achieve positive stress does not necessarily respond to a particular problem in one's life but requires self-leadership.

Our results are consistent with earlier studies and design recommendations that identify integration into everyday life to be a common challenge in persuasive systems [1, 8]. Our results also reinforce the significance of learning from peers. Supporting learning from peers is a design principle that could be utilized more in designing persuasive systems and motivating users regarding the potential significance and effects of using a system. The implication has similarities to the design principle of open-ended social awareness as suggested by Baumer et al. [4], which refers to encouraging healthy decisions implicitly by increasing awareness of the health-related activities and decisions of others.

Although the design implications are based on using this particular service, they may benefit also design of other services targeted to enhance well-being at work and especially well-being of entrepreneurs and people having an entrepreneur-like job.

Preliminary effects: changes in stress and perceived benefits

The participants' negative stress decreased significantly during the study, as measured with the Perceived Stress Scale. The average change was − 21.5% from the baseline score. In their recent study, Eskildsen et al. [10] defined that a decrease of 28% is required in order to consider

the change in PSS as clinically important. In our study, half of the participants responding to stress questionnaire 2 fulfilled this criterion. However, the participants in our study were not particularly stressed as their mean baseline PSS score of 15. corresponds to population averages of about 15 to 16 reported by Cohen and Janicki-Deverts [7], although it was slightly higher than entrepreneur average of 13.73 reported by Baron, Franklin and Hmieleski [3]. Thus, a large change in stress scores could not be expected. Also the UWES-9 score reflecting work engagement was at a high level, on average 4.9. In Finnish reference samples of altogether over 19,000 employees, the highest average work engagement scores of 4.83 were observed in senior managers [16]. We did not observe any changes in work engagement during the study, which is in line with the expectation that work engagement is a relatively stable state [44] and also with the study by Mauno et al. [34], where no changes in work engagement were seen during a 2-year follow-up of healthcare personnel.

More than half of the participants who responded to the second user experience questionnaire reported that they had experienced increases in positive stress and decreases in negative stress. The qualitative data may explain these evaluations; the users told that they had adopted new tools and practices especially for recognizing one's thoughts and actions, for organizing work, and for recalling and celebrating success. A longer-term follow-up study would be needed to discover whether the new practices will stay in use and whether the users will actively continue stimulating their positive stress experiences. It was found that experienced increases in positive stress were significantly associated with more active use of the Toolbox, i.e. using more toolsets and completing a higher percentage of the tools. However, changes in negative stress (either self-reported or measured with PSS) were not associated with the usage activity of the Toolbox. This may indicate that the Toolbox actually was more successful at increasing experienced positive stress than decreasing negative stress. However, the study setting does not enable confirming this finding.

It is possible that some of the reported changes have occurred due to increased awareness of eustress and not only due to using the service. However, there was a significant association between self-evaluated changes in positive stress and Toolbox usage and, in the second user experience questionnaire, several users attributed the positive changes to the Toobox and specific exercises, which provides some confidence in the assumption that the changes were indeed brought about by the use of the Toolbox.

The results are in line with earlier intervention studies in the field of stress. Earlier research has shown positive outcomes in managing negative stress with web-based programs [2, 20, 49]. Our results support this, add to the understanding of entrepreneurs as a user group and provide preliminary evidence that approaching stress from a positive perspective can be feasible in targeting entrepreneurial stress. The results regarding the effectiveness of using the service are preliminary due to the limitations in the study setting, such as the sample size and the lack of a control group. However, we believe that reporting this preliminary feasibility is valuable due to the following differences in comparison to earlier papers: 1) our prototype service was preventive and targeted to entrepreneurs with fairly low baseline stress scores, 2) the service is based on entrepreneurs' experiences and takes the entrepreneurial context into account, and 3) our results consider design implications alongside stress effects.

Ethical aspects, limitations and future work

Approaching stress from a positive perspective does not come without ethical concerns. First, the line between positive and negative stress is thin: compulsive striving for positive stress or neglecting the need for recovery are likely to have negative consequences. Second, promoting positive stress in one's life needs to be based on one's intrinsic motivation. The use of the Eustress Toolbox could be enabled by the employer, but it cannot be used as a method to increase the external stressors or stressful work of employees. Third, fostering positive stress is intended to be used as a preventive approach – for people who are not suffering from intense negative stress. When experiencing intense negative stress, other stress management tools may be more useful than focusing on the positive aspects of stress.

The target group of this study was entrepreneurs and people having an entrepreneur-like job, which limits the generalizability of the results. However, new methods for finding suitable ways of working without forgetting well-being are relevant for a wider audience as well.

The study participants were selected on a voluntary basis, and thus the study sample included more females than males. Volunteer participants may not fully represent the whole target group. However, the process of fostering positive stress requires the user's intrinsic motivation, which can be best achieved with a group of volunteers who are interested in mental well-being.

The study setting did not exclude the possibility that the participants' stress had been decreased also because of other factors than the use of the Eustress Toolbox. Their stress experiences may have changed during the 6 weeks study period also because of the participation in the study as such, which may have made them think about their lifestyle and choices more - even if they had not used the Eustress Toolbox. Thus, the results

regarding the effects on stress experiences should be considered as preliminary. Future studies could address this issue and repeat the study with a larger sample and with a control group. Furthermore, it would be interesting to test the acceptability and value of the improved service with other populations as well, such as employees, students or job seekers.

One limitation connected to the research setting is that there is no standardized measure for positive stress. Thus, the PSS scale for measuring negative stress and the qualitative reporting of stress experiences were used in this study. Developing a measure for positive stress would be an interesting research aim in the future.

In the future, an interesting holistic service could be one that would combine the means to enhance the stress balance in one's daily life with physiological data on one's bodily states. Our prototype of Eustress Toolbox could also be extended into a more comprehensive service concept with personal coaching, or it could be included as one module of a more general training in occupational well-being.

Conclusions

This article presents the results of a six-week field study on the use of a web service for stimulating positive stress among entrepreneurs and people doing entrepreneur-like work. We studied the usage, user acceptance, user experience, and preliminary effects, combining the approaches of HCI and health interventions. The combination of the approaches proved to be fruitful: it revealed both the preliminary effects on stress and the user experience giving deeper understanding of the fit into the users' life. In the Eustress Toolbox service, the users appreciated especially the off-line and reflection exercises, as well as the quotations from peers, but the design should have supported more active triggering to use the service. The following design implications were identified: *Integrate the service into the daily hassle of entrepreneurs, Provide personal guidance while maintaining a possibility to explore, Recognise the user's progress and accomplishments in a meaningful way* and *Support implicit learning from peer entrepreneurs.* We hope that the findings give insights and inspiration for practitioners designing for well-being of entrepreneurs and encourage researchers to approach stress also from a positive perspective.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12911-019-0909-6.

Additional file 1. Introduction of the Eustress Toolbox web service with screenshots. The screenshots are in the original language, but there are texts in English highlighting the parts of the service and the way the users are supposed to use the service.

Additional file 2. User experience questionnaire 1 developed for this study, translated to English.

Additional file 3. User experience questionnaire 2 developed for this study, translated to English.

Additional file 4. Theme interview questions developed for this study, translated to English.

Abbreviations

HCI: Human–computer interaction; PSS: Perceived Stress Scale; TAMM: Technology Acceptance Model for Mobile Services; UWES: Utrecht Work Engagement scale; UWES-9: 9-item version of the Utrecht Work Engagement scale; UX: User experience

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Authors' contributions

PH, EM and MA designed and conducted the study and co-authored the article together. PH was the main author of the article and was responsible for analysing the qualitative data and deriving design implications. EM was responsible for usage analysis and statistical analysis. All authors have read and approved the manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

All participants signed a written informed consent form. However, an ethical review was not deemed necessary based on the guidelines of the Ethics committee of the Tampere region (where the study was conducted), which follow the guidelines of Finnish National Board on Research Integrity (TENK; https://www.tenk.fi/en/ethical-review-in-finland).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]VTT Technical Research Centre of Finland LTD, P. O. Box 1300, FI-33101 Tampere, Finland. [2]Tampere University, Tampere, Finland.

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Quantified factory worker – expert evaluation and ethical considerations of wearable self-tracking devices

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Quantified Factory Worker - Expert Evaluation and Ethical Considerations of Wearable Self-tracking Devices

Päivi Heikkilä†
VTT Technical Research Centre of Finland Ltd.
Tampere, Finland
paivi.heikkila@vtt.fi

Anita Honka
VTT Technical Research Centre of Finland Ltd.
Tampere, Finland
anita.honka@vtt.fi

Sebastian Mach
Chemnitz University of Technology
Chemnitz, Germany
sebastian.mach@psychologie.tu-chemnitz.de

Franziska Schmalfuß
Chemnitz University of Technology
Chemnitz, Germany
franziska.schmalfuss@psychologie.tu-chemnitz.de

Eija Kaasinen
VTT Technical Research Centre of Finland Ltd.
Tampere, Finland
eija.kaasinen@vtt.fi

Kaisa Väänänen
Tampere University of Technology
Tampere, Finland
kaisa.vaananen@tut.fi

ABSTRACT

Following the Quantified Self trend, everyday self-tracking practices have become common. Still, self-monitoring of people at work is a rather new research topic. Self-tracking of employees' activities, mental state and emotions enables data-based feedback, which could improve the employees' awareness of issues influencing their well-being and performance. We contribute to this topic from two perspectives. First, we explored the potential of wearable self-tracking devices for providing personal feedback to machine operators working in a factory. We used the expert evaluation method to lay ground to the user perspective of self-tracking at work. User experience experts evaluated five tracking devices for their user experience, perceived accuracy and fit to factory workers. Second, we conducted a workshop with the experts to systematically assess the ethical considerations that may arise when adopting self-tracking at work. The results provide insights into the potential of the use of self-tracking devices in a factory context.

CCS CONCEPTS

• Human-centered computing → Human Computer Interaction (HCI) • Ubiquitous and mobile computing

KEYWORDS

Quantified Self, User experience, Ethics, Wearable devices, Expert evaluation, Factory workers

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1 Introduction

Wearable self-tracking devices are becoming increasingly common in everyday use by consumers and employees, especially the wristbands and smartwatches for tracking activity, sleep and heart rate [see e.g. 22]. Recently, the range of wearable self-monitoring devices, on the market, has extended to tracking one's emotions or mental state.

While the number and variety of wearable self-tracking devices have increased, the Quantified Self trend has raised the awareness of ways to practice self-tracking and gain meaningful data-based insights to foster positive behavioural changes. Enthusiastic early adopters have found self-tracking interesting and useful [4,14,23], but less is known about the user experience and usage practices of less technology-savvy users or the use in work contexts.

Extending self-monitoring practices to workplaces or integrating them to corporate wellness programs is a relatively new, but rapidly increasing phenomenon [18]. However, not much scholarly literature exists on the consequences of incorporation of self-tracking at the workplace [2,18]. The potential for true benefits for the worker and the employer depends on a range of issues: ways to adopt self-tracking practices, awareness and consideration of ethical issues and the technical possibilities of the available wearable devices. Furthermore, user experience issues are an important factor in determining whether use feels effortless and pleasant and whether employees accept the new technologies. The boundaries of voluntariness, autonomy of practicing self-

monitoring and the purposes of self-tracking raise important ethical issues, when self-monitoring opportunities are introduced in a work context.

In this paper, we focus on the potential of wearable self-tracking devices for factory workers. Even though factory work may be regarded as rather monotonous and predictable work, the modern factory floor work is assumed to become closer to knowledge work, emphasizing decision-making and problem-solving [8]. When operating a highly automated manufacturing machine, the work already requires process management and problem-solving skills. Compared to typical knowledge work, however, solving problems quickly is more crucial, to avoid or minimize delays in the manufacturing process. A single factory operator may be responsible for a whole machine, and should handle the problem situations without finding it too stressful. In this kind of factory work, self-tracking data may give insights on how one responds to challenging situations physiologically and motivate finding ways to stay calm. Self-tracking may also help to notice the achievements and efforts made during the workday, and thus, create job satisfaction.

The presented study is a part of a wider research project (Factory2Fit), which aims at engaging and empowering factory workers by different means, with one being the opportunity to receive self-tracking feedback, which could improve the workers' awareness of the issues having an impact on their well-being and performance. The gathered self-tracking data will be intended only for the factory workers themselves, not for the employers. The aim of this study was to evaluate the potential of different types of commercially available wearable self-tracking devices, in the context of factory work, and to identify ethical considerations related to self-tracking of factory workers. Before self-tracking devices should be implemented in actual pilots, we wanted to assure that the devices introduced are easy to use and fit the factory context.

Thus, the research questions of this study are:

1) What kind of self-tracking devices have potential to be introduced to factory workers?
2) What ethical considerations need to be taken into account when quantifying the factory worker?

The first research question is studied through an expert evaluation. The expert evaluation method was chosen because it has been proven to be effective in early assessment of potential alternative solutions [27] – experts can systematically evaluate several devices before taking the most appropriate device(s) to the actual users. User experience experts used the selected wearable self-tracking devices as part of their daily life, and evaluated the potential of each device in terms of user experience and perceived accuracy. After this, they evaluated whether the selected devices seem applicable for use by factory workers. As a response to the second research question, ethical considerations were identified in a workshop with the experts, focusing on ethical issues related to the theme of letting the factory workers quantify themselves.

The paper is structured as follows: First, we present related work on wearable devices for tracking well-being and on the potential ethical issues of self-monitoring at work. Second, we describe the study methods and the evaluated devices. Then, the results are presented, first related to the research question 1 and then, to the research question 2. Finally, we discuss the implications and limitations of the results.

2 Related Work

In this section, we first provide background on the expanding range of wearable devices for tracking well-being. Then, we shed light on the potential of self-tracking, especially in work context, and the ethical issues related to adopting self-tracking practices at work.

2.1 Wearable Devices for Tracking Well-being

Commercial wearable devices, for tracking well-being and behaviour, have become popular amongst consumers, with around 25% of Americans owning a wearable wrist device [22]. The most prominent devices include wristbands and smartwatches used to track physical activity and sleep based on accelerometer and heart rate measurements [22], e.g. Fitbit, Samsung, Apple, Polar and Nokia Health, to mention a few of the manufacturers. The advantages of these devices are that they can track objective data round-the-clock, without requiring continuous charging, and they are non-invasive and compact in size. In addition, the accuracy of these devices is sufficient for everyday life contexts for step count [3] and heart rate measurements [24].

Devices monitoring mental well-being, such as negative stress or emotions, are less common in the consumer market, but their popularity is anticipated to increase [25] as the maturity of these devices improves, regarding their user experience and accuracy. Measurements for detecting emotional states that already can, or are foreseen in the future to be recorded with good quality, with off-the-shelf devices, include heart rate variability (HRV), heart rate (HR) and electrodermal activity (EDA) for sensing the functions of the autonomous nervous system, and electroencephalography (EEG) for measuring brain waves [6]. In general, the data tracked with wearables have the potential for providing personalized, immediate and objective feedback [21].

2.2 Quantified Self and Self-tracking at Work

The trend of self-tracking and quantification of oneself has emerged during the last ten years. Quantification of oneself refers to self-tracking of biological, physical, behavioural or environmental data [26]. The term Quantified Self has been used for the practice of self-monitoring, as well as the movement and international community of people practicing self-tracking. The term was coined by Gary Wolf and Kevin Kelly, who created the website (http://quantifiedself.com) for sharing self-tracking practices in 2007. Also, other terms, such as personal informatics [14], personal analytics [17] and lifelogging [see more in 8] have been used to describe practices for gaining self-knowledge, through recording personal data. Most of the research on self-tracking practices has focused on exploring the active members of the Quantified Self community [4,20] or early adopters, for example

using several trackers [23] or attending web forums related to self-tracking [14].

An ultimate goal of the Quantified Self movement is to gain meaningful insights and make positive behavioural changes, based on personal data [4]. Even though this goal is commonly shared by people quantifying themselves and there is optimism towards adopting self-tracking at a workplace [18], the long-lasting impacts have not yet been systematically examined [2,18]. However, the number of trials of self-tracking at work and the inclusion of this to corporate wellness initiatives have expanded during the last years [18].

Although applying the Quantified Self approach to the workplace is a relatively new topic and there is not much research conducted yet, several potential benefits, also applicable to work contexts, have been identified. The potential benefits include reducing the physical and cognitive burden at work [13], earlier detection of health problems [15] and fostering healthy behaviour [1]. Adopting wearable self-tracking technologies may also enable personal recommendations on the sequence of the pending work tasks or practices to reduce stress at work [25]. If the worker can be localized through wearable technologies, the impacts extend to improved safety and the request of immediate help to one's location [13]. Besides all the potential benefits, wearable devices first need to be suitable and provide a solid user experience for the working context. This will be the starting point in the present paper.

2.3 Ethical Issues related to Self-tracking at Work

Adopting self-tracking at the workplace raises a range of ethical issues, as self-monitoring may not be truly voluntary. Lupton [16] has categorized self-tracking at work into five different modes: private, communal, pushed, imposed and exploited. While private self-tracking is initiated for purely personal reasons, pushed self-tracking is externally encouraged or advocated. Inviting workers to voluntarily attend to a corporate wellness program is one example of pushed self-tracking.

The development of ambient intelligent applications, in general, poses a number of ethical concerns. Application design can be guided by different ways of identifying and considering ethical questions, for example, by assessing ethical impacts of information technology [28], identifying the values of the target users and responding to them [6], or following ethical guidelines or principles. The framework of Ikonen et al. [9,12] includes six ethical principles for designing ambient intelligent applications. The identified principles are privacy (ability to control access to one's personal information and protect one's own space), autonomy (right to decide the ways and the purposes for technology use), integrity and dignity (users of technology shall be respected), reliability (sufficient reliability of the technology for its purpose of use), e-inclusion (accessibility for all user groups) and benefit to the society (increases the quality of life and causes no harm).

Regarding the ubiquitous computing at work, Nihan [19] lists values and principles that are frequently used to explain, justify or challenge the development of Ubicomp in the workplace. The listed ten aspects have different meanings and emphases, depending on the stakeholders concerned (e.g. employees vs management). The identified values are privacy, autonomy, health, safety, security, control, responsibility, justice, performance, as well as social interactions and integrations.

Moore and Piwek [18] raise ethical questions specifically related to the context of the emergence of wearable devices and self-tracking technologies in the workplace. They discuss the ethics through four themes: work intensification, the challenges in measuring productivity, stigma and shame for opt-outs and the lack of legal regulation. Fundamental issues, such as "dehumanizing employees" and inadequacy caused by attempts to achieve complete well-being, are discussed. As this is a new area for scholarly research, they call for critical research related to the consequences of incorporating self-tracking technologies in the workplace.

3 Study Design

The study consisted of an expert evaluation of selected wearable devices and an ethics assessment workshop. This section describes the methods and the study procedures.

3.1 Initial User Studies

Before the expert evaluation and the ethics assessment workshop, the experts either participated in or familiarised themselves with the user studies conducted earlier in the research project [10]. Prior starting this study, initial user studies were carried out in the three pilot factories of the research project to understand the factory context of use and the workers' first impressions and thoughts of self-tracking at work. The studies revealed that the workers might welcome positive feedback, enabled by self-tracking, that many are not used to receiving at work. However, the idea of monitoring of oneself at work raised scepticism, as it was regarded as a source of stress or negatively highlighting the differences between workers. This raises the importance of paying attention to ethical issues and the appropriate selection of the self-tracking devices to be used. The results of the initial user studies were used as a basis for understanding factory work and creating scenarios for ethics assessment workshop.

3.2 Expert Evaluation

The first part of the study was conducted by using an expert evaluation method, which has been proven to be efficient in finding user experience issues in a systematic manner [see e.g. 27]. The expert evaluation method was selected, as the project team wanted to gain expertise of the possibilities of the commercially available wearable self-tracking devices and evaluate their potential, to be able to select appropriate devices for the pilots with factory workers. Researchers that had solid experience in user experience design, acceptability of products and/or digital health served as experts. As the devices, especially for tracking mental states, are

still new in the market, experts should evaluate their user experience, perceived accuracy and suitability first, so that factory workers would only use devices that are suitable for real use.

Altogether, nine experts (7 females, 2 males) with a broad age range (average age 38, from 21 to 60 years) tested the selected five devices in their daily life. The usage period of the devices ranged from 9 days to 45 days. The experts used the devices continuously at work and on free time as well as during night, except a headset device that could be used only for short periods, due to practical problems with it. The usage period depended on the schedule of the research project, as all the evaluations needed to be conducted in the early phase of the project. Each device was used and evaluated by four of the experts, one device at a time. An exception to this was a headset device that was immediately found to be unsuitable for factory workers and thus, was only used by two persons. Each expert evaluated 1-3 devices.

3.2.1 Evaluated devices. The devices for the evaluation were chosen based on the following selection criteria: 1) The devices and the related smartphone apps had a consumer-friendly design, regarding their appearance and the expected usability; 2) The self-tracking feedback provided via the apps included advanced data interpretation, instead of presenting the raw data; 3) It seemed possible to transfer time-series data collected by the devices to 3rd party apps or data sheets for research purposes; 4) For tracking mental states, the attempt was to find a variety of different measurement technologies for testing.

The selected devices included a smartwatch and a wristband for self-tracking heart rate, activity and sleep, as well as three device options for mental state detection. The selected devices vary from each other in terms of their form factor and way of wearing them, as well as in terms of the sensors and technologies utilized in the measurements. Three devices for emotion and stress detection were included as less obvious options. The devices are described below.

Figure 1: Devices from left to right, up to down: Samsung Gear S3, Fitbit Charge HR, Spire, Moodmetric, and Emotiv Insight.

The Samsung Gear S3 (www.samsung.com) is a smartwatch with various supporting functionalities, such as managing health and well-being, making phone calls, and messaging. The technical features include an optical heart rate sensor, a 3-axis accelerometer and gyrometer, GPS, an ambient light sensor, a barometer and altimeter as well as a microphone. A large variability of apps is available for the device.

The Fitbit Charge HR (www.fitbit.com) is a wristband for tracking activity, heart rate and sleep. The device includes an optical heart rate sensor, a 3-axis accelerometer and an altimeter sensor. The device monitors several metrics, such as resting heart rate, steps, minutes of activity and stationary hours, as well as duration and quality of sleep. Call, message and calendar notifications can be displayed on the screen of the device. The provided data can be explored through a dashboard app.

The Spire device (www.spire.io) analyses the breathing patterns of the user. Based on the personal average breathing rate, it identifies the mental states of tense, focus and calm. It also monitors sedentary minutes and counts steps, as well as stores location information related to the states. The device notifies different mental states and long periods of inactivity by vibrating. The mobile app displays the current state of the user and gives a detailed summary of the identified states, during each day. The app also includes calming exercises.

The Moodmetric ring (www.moodmetric.com) supports stress management by estimating the intensity of emotions, based on measurements of electrodermal activity (EDA) of the skin. The ring notifies the user of the emotional intensity by a led indicator (high alerts and calm notifications). The mobile app (Moodmetric) displays the current emotional intensity and a summary view of the emotional intensity, during each day and night. The app also shows the step count and offers a feature for practicing calming down.

The Emotiv Insight (www.emotiv.com) is a headset, for monitoring cognitive performance and well-being, based on brainwave (EEG) signals. The device can monitor six cognitive and emotion metrics: focus, stress, excitement, relaxation, interest, and engagement. The mobile app shows the cognitive state of the user in terms of the metrics and an image of the currently activated brain areas.

3.2.2 Data Gathering and Analysis. After each testing period, the experts filled in an evaluation questionnaire. The questionnaire included open questions regarding: 1) the user experience of the device and the accompanying app (e.g. how did you feel using the device?), 2) the perceived accuracy of the self-tracking feedback provided by the apps (e.g. what is your feeling of the accuracy of each parameter monitored?), as well as, 3) the devices' applicability to a factory environment (e.g. do you recommend using the device during work in a factory?). Experts evaluated the first two aspects also quantitatively using a scale from 1 (very poor) to 7 (very good).

The experts' user experience observations were coded and analysed by two researchers, to identify the factors that had an impact on the user experience and perceived accuracy of the evaluated devices. The main categories of the content analysis were: 1) the general user experience, 2) the perceived accuracy of the device, and 3) the applicability for factory workers. Sub-categories for the general user experience and accuracy were retrieved by using guiding questions, based on the dimensions of the Technology Acceptance

Model for Mobile Services (TAMM) [11], i.e. the *ease of adoption, ease of use, trust* and *value.* These aspects were considered as critical factors determining the potential of the devices.

3.3 Ethics Assessment Workshop

As a second part of the study, we organized a workshop for identifying ethical considerations related to the topic. Four of the experts who evaluated the devices participated in the two-hour ethics assessment workshop. All participants had expertise in considering ethical issues, for example when designing digital services or when evaluating e-health solutions.

3.3.1 Scenarios. Before the workshop, two researchers created two scenarios, based on the initial user studies, to illustrate the idea of a quantified factory worker. The scenarios varied in terms of the worker (age, gender, working experience, and mood) and the situation (day vs night work shift, problem solving vs no problems). The imaginary factory was the same in both scenarios, representing the pilot sites of the project and the work contexts that we had observed during the initial user studies. Receiving of both real-time feedback and summarized feedback of the work shift were included in the scenarios. The first scenario concentrates on the work context only, while the second scenario extends the use of the self-tracking device to one's free time (tracking sleep).

The **first scenario** focused on a problem-solving situation:

Matthew, 24, has worked as a machine operator in a sheet metal factory, for three years. He has recently started to use a new multipurpose machine, and finds the work mentally loading, as the machine frequently stops running, which he needs to handle quickly. The problems vary, and thus, there is no clear solution how to get the machine running again.

Matthew starts his work shift, wearing a wearable measurement device on his wrist. Everything goes smoothly until noon, when the machine suddenly stops. He is working alone and feels panicked, as he does not know what to do. His wrist device vibrates to notify him of his increased heartbeat. The device guides him to calm down, breathe deeply and think clearly again. He starts systematically trying options that have helped with problem situations, in the past. The wearable device indicates that he is concentrated, which gives him encouragement to carry on solving the problem. Finally, he gets the machine running again.

After his work shift, he looks over the day's statistics on his phone's app. He sees that he had handled the problem situation quicker than before and realizes that the machine stoppage was only a short one. In addition, he sees that he has already achieved more than half of the recommended step count for the day. He feels satisfied.

The **second scenario** focused on an experienced older worker, who is more sceptical towards wearing a measurement device during a work shift and in free time:

Brenda, 48, has worked in the same factory for 20 years. In general, she finds most renewals and corporate campaigns welcome, but is a bit sceptical towards a new opportunity to wear a measurement device during a work shift and even on free time. She does not want to show others and management that she is reluctant to change, and thus, starts to use the new device.

Brenda starts her work shift, a third night in a row. She finds the second night shift the hardest, while the third one feels easier as she starts to get used to the night rhythm. Still, she feels tired. When starting the shift, she checks the statistics of her wearable device on the operators' computer, especially how she has slept during the past days. She also checks her resting heartbeat and some work performance metrics. During a one-month's use time, she has actually found it interesting to see measures related to herself and her work, and the changes in them, but she does not want to share these results with others. As she feels tired and the measures reinforce her feeling, she starts the work shift with routine tasks that she knows well and that are not likely to result in problems. After sitting for one hour, the wearable device indicates that it is time to walk a bit. This helps Brenda to become more energetic.

After the work shift, Brenda is still a bit tired, but feels better when she checks the statistics of the work shift. She has been able to carry out a decent number of tasks and the machine has been working the whole time. She feels good when heading back home and takes a daytime nap.

In the workshop, participants walked through both scenarios, one at a time, and identified ethical issues. Each participant wrote down relevant ethical issues to post-its, and placed them on the analysis template, including ethical aspects selected for the analysis (listed in the Analysis section). This was done separately for both scenarios. After this, the experts discussed the remarks and added issues raised in the discussion into the template.

3.3.2 Analysis. As a basis for the ethical assessment, we utilised two analysis frameworks: the six ethical guidelines for ambient intelligent applications by Ikonen et al. [9], and a list of ethical values related to ubiquitous computing in the workplace, compiled by Nihan [19]. We utilized the former framework as such, and complemented it with the additional values, listed by Nihan, to include values of particular relevance in the work context. Altogether, our resulting template included ten ethical aspects: *privacy, autonomy, integrity and dignity, reliability, e-inclusion, benefit to society, health and safety, responsibility, justice* and *social interactions.*

4 Findings of Expert Evaluation of the Devices

Table 1 summarizes the results of the expert evaluation as ratings given to the evaluated devices. After that, we describe the results in more detail one by one in terms of the user experience, perceived accuracy, and the fit of each device to factory workers, based on the understanding of the user studies in the project.

Device (what data is tracked)	**User experience** (Rating 1-7 median, range, N=4)	**Perceived accuracy** (Rating 1-7 median, range, N=4)	**Suitability for factory workers**
Samsung Gear S3 smartwatch (activity, heart rate, sleep)	5.5 (4-7)	6.0 (5-6)	Good, except for the big size of the watch.
Fitbit Charge HR wristband (activity, heart rate, sleep)	6.0 (6-7)	5.5 (5-6)	Good. Unobtrusive & fairly good perceived accuracy.
Spire clip (mental states and activity)	6.0 (5-7)	4.5 (3-5)	Maybe. Unobtrusive, but unconvincing accuracy.
Moodmetric ring (emotional intensity)	5.0 (4-5)	6.0 (5-6)	Only for some tasks, cannot be worn for all tasks.
Emotiv Insight, EEG headset (emotions)	1.5 (1-2)	Could not be evaluated	Not suitable.

Table 1. Comparison of the devices by the experts.

4.1 Samsung Gear S3

4.1.1 User Experience and Perceived Accuracy. The experts evaluated the Samsung Gear S3 as easy to adopt and easy to use. The feedback of the smartwatch was evaluated as clear and intuitive. The device appeared to be modest and solid. However, the big size caused problems when pulling one's sleeve over the device and felt disturbing, while running or sleeping. The experts perceived the mobile apps as being intuitive and well structured. The only downsides were irritation of a repeated default reminder to go for a walk and concern caused by the apps' permission requests. However, the content of the apps and the recorded data were considered interesting.

The perceived accuracy of the sensors and the displayed data was rated as good for GPS, heart rate, step count, distances, barometer and sleep tracking, when the device was tightly connected to the wrist. The accuracy of the floor count was estimated as moderate. When compared with another smartwatch, no differences in accuracy were noticed.

4.1.2 Applicability to Factory Workers. The experts regarded the Samsung Gear S3 as suitable for use in a factory, due to its large variety of functions and sensors, and the additional messaging possibilities, which could increase its acceptability. The vibrating alarms can make the workers aware of new messages or notifications in areas with a high noise level. In other contexts, the device is able to provide audible information via speakers. The connection via Wi-Fi allows greater distances than via Bluetooth, and the NFC data connection enables exchanging sensitive data, in close ranges. The wearing position of the device was regarded as practical for doing work tasks with both hands. However, the big size and the resulting potential danger, for example while manually interacting with machines, must be considered.

4.2 Fitbit Charge HR

4.2.1 User Experience and Perceived Accuracy. The experts perceived the device as easy to adopt and connect with the app. It was easy to use, and interpreting the information on the device display was straightforward. Wearing the wristband felt unobtrusive as it was slim, light and fitted well on the wrist. In addition, the experts appreciated the reasonably long battery life, of 4 to 5 days. The dashboard app was perceived as easy to use and the presented metrics were regarded as interesting. The positive indications of achievements and the vibration indication of an arriving call, with the caller's name visible, were liked. However, one of the experts reported the synchronizing of the device data with the dashboard as being rather slow. One of the experts decided to buy a Fitbit device for herself, based on her positive experiences during the testing period.

The daily step count, and the automatic detection of walking, running and cycling were considered as accurate. Two of the experts highlighted that the resting heart rate and sleep quality reflected their perceived stress and tiredness levels well. The experiences regarding the accuracy of sleep detection were mixed. Three of the experts perceived the automatic sleep time detection as being fairly correct, but one expert felt that the device frequently interpreted lying in bed awake as being asleep.

4.2.2 Applicability to Factory Workers. The experts found the Fitbit Charge HR suitable for factory workers. Due to the slim and plain design of the device it was not foreseen to disturb manual work or draw undue attention to itself. The material of the band did not seem particularly sensitive to dirt or dents. However, possible problems in usage with gloves were noted. The accuracy of the monitored metrics seemed to be at a good level.

4.3 Spire

4.3.1 User Experience and Perceived Accuracy. The Spire device was perceived as easy to adopt and easy to use. It was unobtrusive and comfortable to wear, could be hidden under clothes and easily forgotten. Charging the device and connecting it to the phone was easy, but two experts found synchronization with the phone to be slow. In addition, the experts experienced loss of data due to not opening the Spire app frequently enough (as the device can store only 6 hours of data). The experts found the vibration indicator of the mental states and sedentary periods useful, but the vibration patterns were difficult to differentiate from each other. The information provided by the Spire app was easy to understand, and the daily statistics were found interesting. The experts

considered the app views pleasant, especially the main view, with a beautiful background scenery giving a calming feeling.

The detected states were not always in line with the personal feelings. For example, focused moments were occasionally identified as calm, some feelings of tenseness were not detected (possibly because the state needs to last at least 2 minutes to be detected) and light physical activity (e.g. house chores) were often identified as a tense mental state.

4.3.2 Applicability to Factory Workers. As wearing the device was perceived comfortable and unobtrusive, it would fit well in a factory environment. It would not be in the way when performing manufacturing work, and the vibrating feedback could be beneficial for the workers. However, as factory work typically includes physical activity, it could provide wrong results (light physical activity may be identified as mental tenseness). The synchronization of the data might be an issue, as the device can only store 6 hours of data. It should also be noted, that Spire does not provide continuous data, but detects the user state only 30% to 50% of the time it is worn. However, as the feedback from Spire is based on breathing, the acceptability could be higher than with devices that may be perceived as more ambiguous. With Spire, the factor to be measured (breathing) is easy to understand and it is also rather easy to influence (e.g. for calming oneself).

4.4 Moodmetric

4.4.1 User Experience and Perceived Accuracy. Adopting the Moodmetric device was easy, except two experts had problems in finding the most suitable finger for the ring. Use of the ring was mainly easy and effortless, but some problems occurred. One evaluation could not be completed, because the ring stopped measuring. This may have been due to the user's dry hands, during the cold weather, when using the device (around -20 Celsius). Other problems included the difficulty to notice whether the ring was switched on and the low battery indication of it, and problems in everyday use, when washing hands, wearing gloves or doing physical tasks. The ring was felt to be in the way when changing clothes, and holding or lifting items. However, the ring was found durable, since it continued to work regardless of water splashes or accidentally hitting it on items. The experts evaluated the appearance of the ring either as neutral or too bulky. One expert commented that the ring should either look more stylish or clearly indicate that it is a measurement device. The feedback provided by the app was perceived as understandable and interesting, but real-time feedback and more detailed event-related feedback were wished for. The data visualization was liked, but one user found it confusing to follow the daily data, as the day (from 6 am to 6 pm) and night views (from 6 pm to 6 am) did not reflect the real day and night time. One expert experienced connection problems with the phone, but in general, synchronizing the ring with the app was fast.

The experts noticed that most of their emotional reactions were correctly detected and that the device detected both low and high intensity (active/nervous/alert state vs relaxed/calm state). In addition, they reported that the device could detect a rushed feeling, annoyance, stress, uncertainty and multi-tasking. However, the measures also included some false positives, at least partly due to a high body temperature, which seemed to have a clear impact on the measurements. High emotional intensity was shown, for example, after having a sauna or during physical activity. One expert noticed that her tiredness and longer-term stress were reflected in the measurements, during a stressful week.

4.4.2 Applicability to Factory Workers. The experts did not consider the ring as suitable for factory workers. Wearing it can be difficult when doing physical tasks, and it is impossible when wearing gloves. Also taking the ring on and off, when washing hands, could be problematic. Physical tasks and gripping items tightly could also lead to false measurements. Use of the ring could even be prevented by safety regulations. However, as the accuracy of the data seems promising, the data stream is continuous, and the device seems to be reasonably durable, the device might be suitable for some, non-physical tasks in a factory.

4.5 Emotiv Insight

4.5.1 User Experience and Perceived Accuracy. The experts evaluated the user experience for Emotiv Insight device as poor. A proper sensor contact, between the device and the sculpt, was impossible to achieve, and the device itself was uncomfortable to wear. One of the experts reported that after wearing it for an hour, her head began to ache.

The accuracy of the detected metrics could not be evaluated, due to the low usability of the device.

4.5.2 Applicability to Factory Workers. For the above reasons, the device is not suitable for real-life settings.

4.6 Summary of the Expert Evaluation

According to the results, Samsung Gear S3 and Fitbit Charge seemed to be the most suitable devices for factory workers for measuring activity, heart rate, and sleep. Moreover, these devices have additional strengths: Samsung Gear S3 can be also used for communication, while Fitbit Charge HR is compact in size (unobtrusive) and has a reasonably long battery duration, with a continuous heart rate measurement. However, none of the reviewed trackers for emotional state seemed completely suitable for manufacturing work. The Moodmetric ring and the Spire breathing device were the best options, amongst the evaluated emotion trackers, but both have their downsides. The accuracy of the Moodmetric ring is good, but wearing the rather large ring during manufacturing work is foreseen as being impossible or at least inconvenient. The Spire device would fit well in factory environments, in terms of its ease of use, but its accuracy was not perceived as convincing.

5 Ethical Considerations

This section presents the results of the ethical assessment workshop. In the following, the considerations related to each ethical aspect are summarized. Altogether, 47 expert comments

were collected in the workshop. The aspects of privacy (7 comments), autonomy (8 comments), as well as health and safety (8 comments) received the largest number of ethical remarks, which highlights the importance of their role in adopting wearable self-monitoring devices at work.

Privacy is a crucial issue, when adopting this technology at work, due to the personal and sensitive nature of the collected data. The privacy of the user should be guaranteed by ensuring data security and by appropriate design of the wearable devices used. Only data, which is needed for analysis and feedback should be collected. The user's state should not be visible to others, and others should not notice the device's feedback, for example, when indicating a fast heartbeat or calming the user. If the data is used for making anonymous summaries, then the privacy of work teams and the possible cues to identify workers may pose ethical issues.

To support *autonomy*, the employer should guarantee true voluntariness of the adoption of this technology. The line between voluntariness and pressure to start using the device may be thin; the user may feel social pressure or be afraid of negative consequences, such as being stigmatized as a difficult person resistant to changes. The user's autonomy should also be respected, when using the device, by offering the user the possibility to decide what data is collected and how the feedback is given (what device, vibration/sound etc). The feedback should be in the form of recommendations or encouragement, suggesting actions rather than instructing the user.

Any technology should respect the *integrity and dignity* of its users. In this case, dignity needs to be considered when using the wearable device and in the form of the feedback. Is it possible that the device will create a negative image of the user, to herself or others? Could the worker start to consider herself as a nervous person because the device frequently indicates high stress? These possibilities can partly be reduced by giving the feedback in a discrete and appropriate format, by recognizing positive moments and trends, and by giving gentle guidance, and not only indicating the physiological signs. Still, the feedback should be truthful to be valuable to the user.

Reliability of this technology can be approached on several levels. First, it is important to achieve the user's trust in the ways the data is utilized. The user should not have concerns of the employer seeing her personal data, if the data is only collected for the employee's personal use. In addition, the accuracy of the self-monitoring data should be reliable.

E-inclusion was not identified as an issue that would be particularly relevant in the context of factory work. When adopting self-monitoring technologies, however, it would be important to include also older employees in the pilot groups, if possible.

Encouraging self-monitoring at the workplaces is a significant societal issue, which should be implemented to provide *benefit to society and* the workers. Is it possible to truly empower workers and increase their well-being or is it possible that self-tracking creates new pressure, concerns and mental load? Can it create awareness that guides the user towards a healthier life or does it encourage excessive self-monitoring, increasing workers' stress?

Supporting *health and safety* is a crucial issue, as it is one reason for introducing this technology. The wearable devices should be able to meet the individual needs of different users. For example, encouraging the user to collect as many steps as possible may not be a good idea for everyone; sometimes rest would be more essential. It is important to consider whether the device may strengthen the current feeling, such as a feeling of stress, panic or tiredness, when one sees the physiological data related to it. The device should not only remind the user of one's state, but it should also give discreet guidance to change the undesired feeling, for example, by guiding the user in calming down.

The issues of *responsibility* become critical in cases of misuse of the employees' data or accidents related to manufacturing work. Wearing the device and using the accompanied app should not distract the factory worker's attention from the work tasks. Even though use of the device would include gamification features, the user should be able to concentrate on work.

The possibilities to start using self-tracking devices at work or opt out of using them should convey a feeling of *justice.* If the employer offers the opportunity to use the new devices to only some of the employees, others may feel excluded. Feelings of jealousy or inequality may hamper the workplace spirit. On the other hand, some employees may find using the new devices troublesome; - as work becomes increasingly digitalized, they may add to the technological load, by introducing another new technology to learn.

Adoption of self-monitoring devices is likely to have an impact also on *social interactions* at the workplace and raise discussion among workers. Even if the data was not officially shared with others, one may feel social pressure to share it with workmates in a situation where others ask about it or share their data with others. Using self-monitoring devices may also decrease interaction with others in situations where the device is sufficient in assisting the user.

The ethics assessment workshop highlighted several ethical issues to be considered when factory workers are offered an opportunity for self-tracking at work. Some of the ethical issues form ethical dilemmas that need special consideration. For example, due to privacy reasons, the collection of unnecessary data should be avoided. However, to support the user's reflection and thus, to ensure the value of self-tracking, a rich variety of data can prove to be useful.

6 Discussion

Quantified Self research has mainly been focused on self-tracking practices of consumers and early adopters [4,14,20,23], but it has potential also in work context to increase workers' awareness of their well-being and work performance. However, work context raises different requirements and also ethical considerations. This study investigated the potential five different wearable self-tracking devices in a factory context, and ethical issues related to adopting self-tracking on the factory floor.

According to the expert evaluation, the two wrist devices, Fitbit Charge HR and Samsung Gear S3, were evaluated as being the most potential for factory workers. The experts considered them easy to adopt, easy to use, reliable (especially in terms of data

accuracy) and valuable for receiving interesting data. The experts considered the data provided by the emotion trackers interesting. Unfortunately, they did not perceive any of the three evaluated emotion trackers suitable for factory work, due to their restricted usability or perceived inaccuracy.

To be applicable in factory settings, a wearable device needs to be **unobtrusive** during wear, in order to not distract from work tasks, to draw unnecessary attention or to disturb wearing personal safety equipment. **Discrete feedback**, such as vibration feedback, is desirable, due to its practicality in noisy environments and its invisibility for others. The device needs to provide **reliable data**, for example not interpreting physical activity as mental arousal. Both the **immediate feedback and the longer-term trend data** are expected to be valuable. The instant feedback may help, for instance, in staying calm or decreasing long sedentary periods, when needed, while trend data enables personal reflection, which may increase awareness of issues influencing performance and well-being, and thus, lead to positive behavioural changes. To support positive changes and positive user experience, the feedback should not be given as instructions, but rather as notifications or **encouraging suggestions.**

Regarding ethical issues, the experts emphasized the importance of privacy and autonomy, as well as health and safety. The purpose of self-monitoring needs to be clearly defined and the process of collecting and using the data kept as transparent as possible. Special attention should be paid to ensuring the true voluntariness of self-monitoring. As Lupton [16] states, the line between pushed and imposed self-tracking is thin. If self-tracking at work is proposed by the employer, it becomes pushed self-tracking, which may be difficult to refuse. Also, Moore and Piwek have emphasized the same issue; opting out includes the risk of being excluded and stigmatized [18].

Taking ethical considerations into account may require balancing ethical dilemmas. When the purpose for self-monitoring is to increase the opportunities for self-reflection, it is difficult to know, beforehand, which data is relevant to the employees, which may lead to gathering a vast amount of personal data. However, to protect the privacy of the employees, unnecessary information should not be collected. The same kind of balancing is needed with the degree of autonomy provided to the employees. Even though the employees should be provided a possibility to define what information is collected from them, having too many options to decide on may increase their stress and make the adoption of self-monitoring too complicated.

In this study, the scenarios used in ethics assessment workshop naturally had an impact on the findings of the workshop. On the other hand, they helped concretising the topic from different workers' perspective and focusing on aspects identified relevant for the research project. Additional ethical issues may emerge, when involving the actual workers of the pilot sites. In this paper, we focused on the worker's perspective. Expectations of employers or managers should also be studied in the future. If accepted by the workers, anonymous quantification data could provide insights to management or employers.

The expert evaluations gave insight about the potential of different wearable self-tracking devices in factory work. Thus, they created a good basis to continue studies with actual factory workers. In the next phase of the project, we will pilot wearable self-tracking devices at the project pilot sites. The pilots will be carried out as co-designed activities, involving factory workers, as well factory management. In addition to considering user experience and ethical issues, the implementation needs to be adjusted according to the safety regulations of the factories.

7 Conclusion

This article presents an expert evaluation of selected wearable self-tracking devices, which we studied to identify the most suitable device(s) for factory workers. Based on the evaluation, the wearable wrist devices measuring activity, heart rate and sleep were evaluated as being the most suitable devices, while none of the devices measuring the emotional state was considered as suitable, due to the impracticality of the devices in the factory context or the perceived shortcomings in the accuracy of measurements. In addition, the arranged ethics assessment workshop highlighted a variety of ethical issues, especially related to privacy and autonomy of users, as well as their health and safety.

This work contributes to the field of HCI by providing insights into the potential of the use of self-tracking devices in a factory context. Unobtrusiveness of use, as well as reliable and encouraging feedback that is discretely conveyed are expected to be key attributes for the potential of self-tracking devices. As quantifying the worker is a sensitive topic, the paper highlights ethical issues, to be considered when adopting such devices at workplaces.

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PUBLICATION V

Quantified factory worker: designing a worker feedback dashboard

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Quantified Factory Worker: Designing a Worker Feedback Dashboard

Päivi Heikkilä
Technical Research Center of Finland Ltd.
Tampere, Finland
paivi.heikkila@vtt.fi

Anita Honka
Technical Research Center of Finland Ltd.
Tampere, Finland
anita.honka@vtt.fi

Eija Kaasinen
Technical Research Center of Finland Ltd.
Tampere, Finland
eija.kaasinen@vtt.fi

ABSTRACT
Factory work is changing towards knowledge work, demanding problem-solving skills and managing complexity. Providing factory workers the possibility to receive meaningful self-tracking feedback at work, could empower them to cope better with the increasing complexity of their work. We apply the Quantified Self approach to factory work by introducing the concept and prototype of a Worker Feedback Dashboard, which presents various automatically tracked well-being and work performance metrics to workers. Based on user interviews, we created user experience goals for the Dashboard, and identified the following design implications: *Keep positive (but truthful)*, *Give personal feedback*, *Enable reflection*, and *Do not disturb the worker*. After designing the prototype, we studied its user acceptance. Even though the interviewed factory workers' first reactions to tracking personal metrics at work were rather negative, the attitudes became more positive after presenting the prototype. The results encourage implementing the Worker Feedback Dashboard prototype to a functional application.

Author Keywords
well-being; factory workers; Quantified Self; human-centred design, Operator 4.0

ACM Classification Keywords
CCS - Human-centered computing - Human computer interaction (HCI).

INTRODUCTION
The fourth industrial revolution, enabled by advanced digitalization and other technologies, is assumed to change work on factory floor to resemble knowledge work, making the work more interesting and meaningful but also creating demands in terms of managing complexity, abstraction and problem-solving [4]. Already now, operating a highly automated manufacturing machine requires independent problem-solving skills, as a single worker may be responsible for a whole machine, and has to be able to handle problem situations quickly to avoid or minimise idle time in manufacturing.

The changing nature of factory work creates a need to receive feedback on one's performance and consider new aspects of workers' well-being. As one solution, we introduce the concept of a Worker Feedback Dashboard, which aims to empower workers by raising self-awareness of their performance and well-being. Worker Feedback Dashboard is envisioned as a personal digital application, which aggregates and presents automatically tracked personal metrics regarding work performance and well-being for each work shift as feedback to workers, and highlights improvements in personal performance. The concept of the Worker Feedback Dashboard originates from the Quantified Self approach, which promotes self-knowledge and self-improvements through numbers acquired with the help of technology, such as wearables and mobile devices. The ideology aims at providing insightful personal data, which has the potential to lead to positive behavioural changes [3].

Following the Quantified Self trend, wearing self-tracking devices for monitoring personal well-being has become increasingly common in everyday use [see e.g. 22]. Recently, the number of trials of self-tracking well-being metrics at work have also increased, but the impacts have not yet been systematically studied [2, 18]. As self-tracking at work is a relatively new concept and involves a variety of ethical issues [16, 18], it is especially important to involve the workers themselves in the development of new self-tracking solutions. In this study, we first interviewed the factory workers on their initial reactions to our concept idea, and later, we collected their feedback to the designed prototype concretizing the concept. In addition to involving users, paying attention to the user experience (UX) of work systems is important, as a way the user feels about using a system also shapes the image of oneself as a professional [9].

In this paper, the research questions are:

1) What kind of user experience should be targeted to in solutions providing meaningful self-tracking and production feedback for factory workers, and what kinds

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of design implications does the targeted user experience have?
2) What is the user acceptance of the Worker Feedback Dashboard prototype, which provides feedback of the worker's well-being and work performance in a factory context?

The targeted user experience was concretised as UX goals that were created based on the results of user studies with factory workers, discussions with our industrial partner and principles of the Quantified Self approach. They were the basis for design implications that were utilised when designing the Worker Feedback Dashboard prototype. The second research question is addressed by examining the user acceptance of the prototype by engaging factory workers and other key stakeholders in a participatory design process.

This study is a part of a wider research project (Factory2Fit) aiming to create empowering and engaging digital solutions to factory floor workers. The Worker Feedback Dashboard solution specifically aims to empower workers by providing them with new data-based information on their well-being and work performance.

The paper first presents related research and two key concepts: Quantified Self and Operator 4.0. Second, it describes our design process, methods and participants. The results define the central findings related to factory workers needs and concerns regarding the Worker Feedback Dashboard concept, list our UX goals and design implications, and introduce the prototype of the concept. In the discussion section, we highlight the practical implications and ethical questions related to the topic.

RELATED RESEARCH

Quantified Self: From Meaningful Insights to Positive Changes

The term Quantified Self refers to self-monitoring of biological, physical, behavioural, or environmental data [28]. The term became known after Gary Wolf and Kevin Kelly launched the Quantifiedself.com website for sharing self-tracking practices in 2007. The term refers to the practice and trend of self-tracking and to the international community. The website is still in active use, but the trend has expanded. An increasing number of people practice self-tracking, using commercial wearable devices. For example, around 25% of Americans own a wearable wrist device for tracking their well-being and behaviour [22]. The trend of recording personal data for gaining self-knowledge has also been described using other terms such as lifelogging [see more in 5, 27], personal informatics [15] and personal analytics [17].

Even though the Quantified Self trend has become increasingly popular during the last ten years among both consumers and workplaces, most of the studies on self-tracking have only focused on the active members of the Quantified Self community [3, 19], web forums related to self-monitoring [15] or early adopters, for example sport enthusiasts or users of several trackers [24]. Nevertheless, these studies have revealed some user experience-related aspects and usage barriers that are likely to be applicable to a wider group of users.

Based on the analysis of the video posts of quantified selfers, Choe et al. [3] found that the common pitfalls in self-tracking included tracking too many things, which led to tracking fatigue, and not tracking triggers or context, which acted as a barrier to meaningful insights. Oh and Lee [19] studied the user experience issues of self-tracking tools used by quantified selfers based on the content posted on their web forum. The identified user experience issues included the controllability and integration of the data, data accuracy, data visualisations and simplicity of user input. Li et al. [15] identified barriers related to self-tracking based on the survey and interview data of self-trackers. These data showed that the main barriers to self-tracking were lack of time, insufficient motivation and forgetting to self-track. The barriers to reflection on the data included lack of time, lack of visualisations, scattered data, and missing context information.

The studies of early adopters emphasise the need for visualisations and the data's context information. Pantzar and Ruckenstein [20] also found in their study that data visualisations made the data more meaningful for the study participants, by proving the impressions they had had before, or demonstrating non-anticipated findings. Seeing graphs was motivating and gratifying. For example, the participants felt that housework activities gained a new value because they contributed positively to the exercise and heart rate data. Data visualisations proved and supported this, evoking satisfaction and a sense of accomplishment.

The goal of the Quantified Self movement is to gain meaningful insights based on personal data, which then lead to positive changes in behaviour [3]. Recording everyday life offers 'a possibility of breaking bad habits and turning one's life for the better' [27]. The goal is the same, whether self-tracking is practised during one's free time or at work. In general, the data tracked by wearable devices have the potential to provide personalised, immediate and objective feedback [21]. According to a study by Rooksby et al. [24], the motivations for self-tracking can vary from goal-driven tracking to documentary and diagnostic tracking, or to collecting rewards or fetishised tracking. Even though the number of experiments related to self-tracking at work has expanded during the last years [18], long-lasting impacts of the trials have not been reported [2, 18].

For gaining meaningful insights and even positive behavioural changes, the design of the self-tracking devices and applications plays a critical role. In this study, we aim to design an acceptable, interesting and useful solution to self-tracking in a factory context.

Operator 4.0

The fourth industrial revolution, often referred to as Industry 4.0, is already on its way, enabled by advanced digitalisation,

the industrial internet and novel interaction tools such as augmented and virtual reality [12]. For factory floor workers the industrial change brings opportunities to make work more interesting and meaningful but also creates demands in terms of managing complexity, abstraction and problem-solving [4]. Operator 4.0 refers to smart and skilled operators of the future, who are assisted by automated systems that provide sustainable relief from physical and mental stress and let the operators utilise and develop their creative, innovative and improvisational skills without compromising production objectives [23].

Operator 4.0 factory work will be qualitatively enriched and flexible and will require new qualifications to master the digital technology invading factories. Future factories should support current workers in learning new skills as well as tempt new workers who are already familiar with digital solutions. Operators' physical, sensory and cognitive capabilities evolve over time, but these capabilities may also vary according to the work context [23]. According to Hackman and Oldham [6], one important factor influencing job motivation is keeping employees aware of how well they perform in their work. Thus, for work motivation, it would be important to receive feedback on personal performance and competence development, but in work, which is becoming increasingly automated, this kind of feedback is not readily available.

DESIGN PROCESS, METHODS AND PARTICIPANTS

Participatory Design Process

Our design process followed a human-centred design approach [8], and the principles of the participatory design process, in which users and possibly other stakeholders are involved in the design [14, 25]. The design process began by gaining an understanding of factory work, the working context and the workers' initial attitudes towards self-tracking. In addition to the factory workers, the process also involved the management of the factories in terms of their expectations, potential concerns and practical issues.

Based on the knowledge gained, we created the first version of the Worker Feedback Dashboard concept. The concept design was based on UX goals, that concretise the intended emotions or experiences that the solution is targeted to awake. Concrete, focused and shared UX goals help creating and maintaining UX mindset within the design team [9]. Kaasinen et al. [9] propose UX goals to guide the design of industrial systems. UX goal setting integrates the viewpoints of different stakeholders, thus committing them to the defined UX goals and emphasizing user experience as a strategic design decision. In our study, we defined the UX goals based on the results of the user studies, discussions with our industrial partner and principles of the Quantified Self approach. UX goals were used to concretise the targeted user experience, and they were interpreted into design implications as suggested by Roto et al. [25]. The derived design implications guided our design of the Dashboard prototype.

The user acceptance of the Worker Feedback Dashboard was studied by introducing the designed prototype to factory workers, who could express their feedback and further improvement ideas to it. After this, the prototype was revised according to the feedback.

Data Collection Methods and Participants

The first part of the study was conducted as individual factory worker interviews including several themes. The relevant theme for this paper was the workers' initial attitudes towards wearing a self-tracking fitness device and receiving well-being and performance metrics as feedback during the workday. In addition, we asked the interviewees what kind of feedback they currently receive of their work. The 1–1.5 hours of semi-structured interviews were conducted in a meeting room at the factory by two researchers; one mainly led the interview and the other made notes and posed additional questions. The interviews were audio recorded. The interviews were complemented with observations, where the researchers visited the actual workplace of the interviewees and observed their work, to obtain a contextual understanding of their tasks, work practices, the problem situations that occur, and the factory environment [see more about the context information in 10].

In this first part of the study, we interviewed altogether 13 factory workers from two factories of metal industry (referred to Factory A and Factory B). The interviewees were working in different roles: 6 as machine operators, 4 in managerial positions and 3 as development engineers. All the machine operators used a modern, highly automated, multipurpose manufacturing machine, which required problem-solving skills and managing the complex production process. The two factories were customers of our industrial partner, and this partner proposed these factories to the study. The interviewees were chosen to the interview based on their availability during our factory visits.

The involved factory workers can be seen as early representatives of the Operator 4.0 vision [23]. Even though also the managerial personnel were interviewed to gain an overall picture of the manufacturing process and factory work, the interviews of the machine operators provided the main material for the user requirements related to the concept development.

In the second part of the study, after creating the first prototype of the Worker Feedback Dashboard concept, we introduced the first draft to five machine operators of the same two factories who worked with the same machinery (one was also interviewed in the earlier theme interview). To three operators, the concept was explained as part of a wider 1.5-hour interview, and to two operators, it was elaborated in more detail in a one-hour feedback/co-design session dedicated to the concept. We also introduced the draft to a production manager and a development engineer of Factory A, where the management also wanted to participate in the design process.

The second part of the study focused on the participant's overall feelings towards the concept, their view on the relevant/irrelevant and potentially missing metrics, and their ideas for improvements. In addition, we studied user acceptance with a five-scale numeric feedback questionnaire. The questionnaire included five statements measuring 1) whether the content was easy to understand, 2) whether it is was interesting, 3) whether the data seemed personally valuable, 4) whether the appearance of the views was pleasant, and 5) whether the use of this kind of app raised any doubts. The evaluated aspects were based on the dimensions of the Technology Acceptance Model for Mobile Services (TAMM) [11]. The dimensions indicating acceptability were *ease of adoption and use* (S1)*, value* (S2-3) *and trust* (S5).In addition, we had a UX question about the pleasantness of the appearance of the main view, as it is easy to evaluate already before using the solution.

In both phases of the study, the participants were emphasized that the participation is truly voluntary, and they signed the informed consent form. The personal data was treated confidentially in all research phases, and anonymised after the data collection.

Data Analysis

The data from the first interviews and observations were analysed qualitatively. To form a common understanding of the findings, two researchers first separately read through the interview data, and then jointly analysed them. The relevant pieces of data were identified and organised to form data-driven themes. The analysis of the wider interviews followed the principles of creating an affinity diagram, an analysis phase of the contextual design method [1]. The initial attitudes towards self-tracking at work and receiving feedback on it, as well as the comments on current feedback of one's work were analysed. In the second part of the study, the findings of the feedback/co-design sessions were jointly analysed by two researchers. The quantitative data of feedback questionnaires were used to complement the qualitative analysis.

RESULTS

In the following, we first describe the factory workers' initial reactions to the idea of practising self-tracking at work and receiving feedback on it. Then, we present the identified UX goals and design implications, the design of the Worker Feedback Dashboard concept, the feedback received from the factory workers, and the revisions made to the design on the basis of the feedback.

Workers' Initial Reactions towards Tracking Personal Metrics at Work

When the interviewed factory workers were introduced to the idea of self-tracking at work, they had mixed, but mainly negative initial reactions towards it. They associated the personal feedback based on self-tracking with the workplace's current measurements related to the effectiveness of their manufacturing work. In their work, performance is typically reported in negative measures, such as the number of errors or the waiting time of the machine, and thus they associated also self-tracking with receiving negative feedback. The first comment of one operator was: *'Uhh. You get enough [negative] feedback already now'.*

Despite the mainly negative first impressions, obtaining data on one's stress level at work (e.g. based on heart rate) was seen as a somewhat interesting. However, the majority did not see the value of self-monitoring for themselves, and seemed to be worried about why the data was to be collected. One of the workers pointed out that the form of the feedback is also important: *'If you are frustrated and get a notification that you need to relax, you'll get even more frustrated'.*

When the workers told about factors having an impact on their job satisfaction, the key factor seemed to be high productivity of the work, which was appreciated also by the management. The operators explained that they enjoy their work most when the machinery works without disturbances: *'The best thing is when the machine rocks'.* This provides direct feedback on the productivity of work. Even though the workers made efforts to avoid interruptions to the manufacturing process, they felt that the management did not acknowledge or appreciate their efforts. They remarked that it was not typical to receive positive feedback: *'You never get to hear thanks from others, but when you make a mistake, you hear it right away'.*

Some of the workers were in the habit of checking the statistics related to machine usage time in the reports produced of the machine flow, but these data were not interesting to all workers. It seemed that the information on the reports was more relevant for the management, as it offered an overall picture of the manufacturing and highlighted any problems. For workers, more personal and encouraging information would have more potential to be beneficial and interesting.

Designing the First Prototype of the Worker Feedback Dashboard

Based on the understanding of the factory workers' working context and their initial reactions towards self-tracking at work, we designed the first prototype of the Worker Feedback Dashboard. The ideology of Quantified Self movement and the Operator 4.0 vision were also applied in designing the prototype.

Based on the results of the user interviews, we first set the following UX goals for the Worker Feedback Dashboard.

1) *Being empowered and encouraged.* The workers felt that they did not get much positive feedback on their efforts, and were afraid that self-tracking would lead to increased negative feedback. To encourage and empower workers, the dashboard should highlight the positive changes and accomplishments of the workday. To be valuable to the workers, this feedback still needs to be truthful.
2) *Getting personal feedback.* To enable striving for positive changes in one's work practices or in factors

related to one's well-being, the feedback needs to be based on personal data. This offers the possibility to have an impact on the factors tracked and the possibility to see one's development in work tasks. Personal feedback means also that only the workers themselves can access the data, which is in accordance with the Quantified Self approach.

We also defined two additional UX goals based on the key principle of the Quantified Self approach and the nature of factory floor work.

3) *Getting meaningful insight.* According to the Quantified Self approach, meaningful insights require personal reflection on the data. Different types of data may be valuable and interesting to different users. The design should offer the possibility to combine different types of data to enable the discovery of meaningful connections and trends. The user should feel making self-discoveries by linking different types of data to each other.
4) *Being undisturbed.* The solution needs to be quickly interpreted and must not take too much time from working or distract from work tasks. This is important for any kind of work, but factory work specifically requires attentive monitoring of machinery and quick reaction to problems. This is important for both productive manufacturing as well as for ensuring safety at the factory. The user should feel being fully able to concentrate on the workflow.

The UX goals were interpreted to four design implications: 1) *Keep positive (but truthful)*, 2) *Give personal feedback*, 3) *Enable personal reflection*, and 4) *Do not disturb the worker*. In the next section, we describe how these implications influenced the design.

Overview of the First Prototype

The Worker Feedback Dashboard was designed to include both well-being and production metrics, and to provide the user with the possibility to discover connections between these, such as the relation between sleep, mood and achievements at work. The feedback is intended for the personal use of the worker, and not to be shared with management or other employees. The feedback is presented visually via various graphs and charts, and it is based on data that would be collected automatically by a commercial wearable with an open application interface, and by the manufacturing production system. Well-being data would be collected through a wearable fitness tracker used by the factory worker and the performance metrics would involve manufacturing production data that are collected inside the factory into its ERP (Enterprise Resource Planning) system.

Figure 1 shows the contents of the main view of the first prototype of the Worker Feedback Dashboard. This view presents an illustration of the data from one day or work shift, including well-being metrics, production metrics and a time series graph that presents selected well-being metrics together with certain work performance outcomes. By selecting a specific metric, the user can see its evolvement as a trend view.

The well-being metrics include parameters that can be automatically tracked by commercial wearable fitness trackers and the mood during the work day, as a self-reported measure. The mood information was included to enable a general evaluation of the user's feelings and to encourage users engage with the Dashboard. Step count at work, sleep duration of the previous sleeping period and the resting heart rate for the day were selected as other well-being metrics to be shown in the Dashboard.

The production metrics selected include the machine running time (utilisation rate of the machine), the longest continuous running period during the work shift, the recovery time after failures (the time taken to resolve the error situation), and achievements (number of finished orders and manufactured parts) during the shift. The time series graph shows the state of the machine (running, idle/waiting or failure) together with the data on the user's heart rate and steps. We selected these production metrics as they mirror the importance of the manufacturing without interruptions and quick solving of problems, which are the key objectives of the operators.

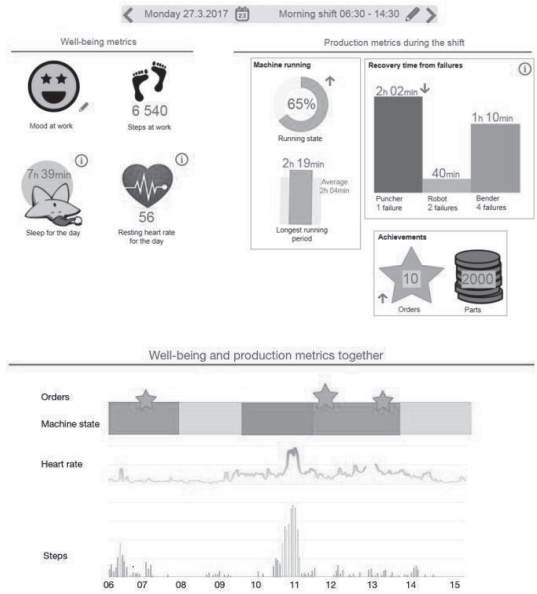

Figure 1. Main view of the first prototype of Worker Feedback Dashboard.

The design implications influenced the design in the following way:

1) *Keep positive (but truthful).* The production metrics of the work are designed to highlight the positive aspects and achievements of the workday. Instead of the

machine idle time or the number or duration of failures, the data highlights the periods of fluent work. The number of finished orders and manufactured parts may enhance the worker's feeling of achievement. The positive development of the metrics is indicated to the user with small arrows besides the metric.

2) *Give personal feedback.* The feedback is intended to be such that the workers can have an impact on it, and see their development related to their work tasks. Thus, it demonstrates the development in one's work competence. The feedback may also include more sensitive well-being related data, as they are not accessible by the employer or managers. Still, the employees will be offered a possibility to select which data is shown in the Dashboard and exclude data that they find too sensitive or irrelevant.
3) *Enable personal reflection.* The Dashboard shows the selected data and highlights positive accomplishments, but the user needs to discover the personally relevant relations between the metrics. After longer use of the Dashboard, the trend data (not visible in the main view) supports finding meaningful relationships related to one's behaviour and the metrics. In addition to automatically collected data, self-reporting of one's mood may drive the user to think about one's overall feelings at least once a day, and thus foster personal reflection.
4) *Do not disturb the worker.* The daily data are shown in the main view in such a way that they can be interpreted quickly. The idea is that the worker checks the data after or at the end of each work shift, or alternatively, during breaks at work. The first version shows only the summary of data, and does not give any real-time notifications of the user's state or the machine that could disturb the worker. If the worker wants to explore the data in more detail, it can be done via any device whenever the user wants, as the Dashboard is intended to be accessible as a web service.

Feedback and Revisions to the First Prototype

When the first prototype of the Worker Feedback Dashboard was introduced to the factory workers, most of them perceived the idea of wearing a self-monitoring device and receiving feedback through the dashboard rather positively. Four of the five interviewed workers perceived the concept as at least somewhat interesting, especially the data related to heart rate and step count. One interviewee was more critical towards the idea and claimed that it is *'everyone's own business how they live, sleep and eat'*, and not the employer's. This may have related to a desire to keep work and free time apart. Even if it was emphasized that the measures are for the worker's personal use only, he seemed to have an impression that the data was accessible for the employer. This emphasized the need to ensure data protection and communicate it to the users clearly. The users should have a true freedom to choose not to participate in self-tracking and if possible, to select which metrics are tracked. Even though the reactions were not solely positive, the first impressions were clearly more favourable than in the first round of interviews.

In the co-design/feedback sessions, the factory workers highlighted which parameters they regarded as the most and least interesting. Of the well-being parameters, the participants were interested in the data related to their heart rate and step count. These users did not perceive the data on sleep and mood as very interesting, as they felt that it offered no new information. Especially, self-reporting of mood information was not seen as being worth the effort.

Of the production parameters, the participants perceived the machine operating time as the most relevant, as this was the most important parameter in production in these factories. The time for recovering from errors was also seen as interesting, as the current production reports did not directly give this parameter. The number of produced orders and items were not considered very relevant, as the workers felt they could not personally influence these metrics. The workers at Factory A also discussed the possibility of including the utilisation percentage of the metal sheets in the production metrics, as the production manager followed this. However, it was not a personally relevant metric for the workers, as the utilisation percentage realised during one's work shift was often determined during the previous work shift by a fellow worker. The production manager also highlighted that including this parameter on the Dashboard might encourage workers to prioritise this issue over the machine running time, which should not happen.

According to the numerical feedback (Table 1), the factory workers perceived the Dashboard prototype rather positively. The content was considered easy to understand and relatively interesting, and most of the respondents regarded it as personally valuable. The question of whether the use of this kind of solution raised doubts produced mixed responses: two of the five respondents had no doubts about the usage, but three saw its use as not completely indubious.

Feedback item	Evaluation median	Range of evaluations
Dashboard concept in general	4	3-4
Clarity of content	5	4-5
Interestingness of content	4	3-4
Perceived value of content	4	2-5
No doubts about usage	3	2-5
Pleasantness of appearance	4	3-5

Table 1. Numeric feedback regarding the user acceptance of the Dashboard prototype provided by five factory workers. Evaluation scale: from 1 = negative to 5 = positive.

Based on the interviews, the idea of the dashboard seemed promising, and we identified no need for major changes in

the design. However, as the self-reported mood information was not considered interesting, we decided to change the question related to the user's mood to a question on their attention ('How effortless did concentrating on your work tasks feel today?', see Figure 2). In the factory work context, the workers' perceived attention may be a relevant parameter to follow, and the users may find reflection on the sleep data, for example, interesting. Even though sleep data was not felt specifically interesting, we decided to include it in the design, as the personal value of it may be revealed later when linking it to other data. Furthermore, as working in a night shift is typical in factory work, the sleep information may prove to be interesting.

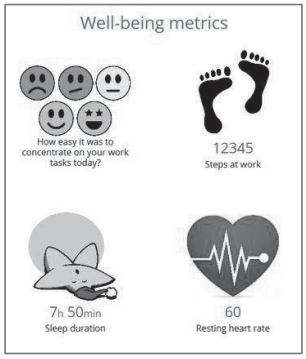

Figure 2. Revised view of well-being metrics.

Four of the five interviewees were interested in testing the Worker Feedback Dashboard as part of their daily work if they had the opportunity to participate. In Factory A, the production management was also willing to participate in the pilot. In Factory B, the management was not willing to participate, as the manufacturing work had urgent problems that the company needed to solve before undertaking new development projects.

DISCUSSION

This study explored the user acceptance of the Worker Feedback Dashboard concept in a factory context. Through a participatory design process, we first created UX goals and design implications and then the design solutions for the concept. The idea of the Worker Feedback Dashboard is in line with the Quantified Self trend, as it provides data-based feedback to factory workers to increase their awareness of the issues that influence their work performance and well-being. The study contributes to the existing literature by increasing the understanding of the acceptability of self-tracking at work, especially in a factory floor environment. As many studies have focused on the early adopters and active members of Quantified Self community [3, 15, 19, 24], it is important to extend the understanding to less tech-savvy users and employees who are offered the opportunity of self-tracking without being familiar with the idea in advance. Operator 4.0 factory work [23] offers an interesting context for applying quantification data, as it is assumed that the work of factory operators will involve an increasing number of problem-solving situations and complexity in the future.

Our first research question aimed to identify the UX goals and design implications for a concept that provides meaningful self-tracking and production feedback to factory workers. Based on the user and context requirements as well as the Quantified Self trend, we ended up in four key design implications. The first, *Keep positive (but truthful)* highlights the importance of positive feedback. The second design implication, *Give personal feedback*, emphasises the opportunity to offer personal feedback, and thus enable workers to see their development at work. The third implication, *Enable reflection*, refers to providing an opportunity for the user to find the personally meaningful connections of the data. Finally, the fourth implication, *Do not disturb the worker*, reminds us of the factory work context, in which it is important that the technical solution does not distract the worker from actual work tasks. These design implications complement the current understanding of important user experience issues related to self-tracking, such as the benefit of visualisations [15, 19] and context information [3, 15], which foster obtaining meaningful insight of the data.

The second research question focused on the user acceptance of the Worker Feedback Dashboard. During the design process, the factory workers first perceived the idea of measuring workers negatively, but this perception became more positive when they could see the actual design and the purpose and content of the concept. There may be several reasons for this. Generally, it is often easier to accept less ambiguous and more concrete ideas, and engaging with the idea may make it more acceptable. However, the result also indicates that the design solutions as such were perceived as acceptable, and the workers also regarded most of the features of the concept as interesting and valuable for themselves.

Despite the rather positive feedback, not all the study participants considered using the Worker Feedback Dashboard as completely indubious. As the topic of personal measurements at the workplace is a sensitive one, the ethical aspects will be considered in the design and evaluation of the solution throughout the research project. We will use the proactive Ethics by Design approach [7, 13] to create an ethically sustainable solution. In addition, the ethical issues and the expected impacts of the solution will be discussed with the ethical advisory board of the project.

This study provides an initial understanding of the acceptability of self-tracking concepts in a factory context. In our research project, we will further develop the concept using the identified design implications, to create a prototype with the key features. The usage of the prototype will be studied in a study with approximately twenty machine operators in several factories including Factory A of this study. When recruiting the study participants, we will pay

specific attention to the ethical issues, such as the true voluntariness of participation and protecting the privacy of the user data.

The limitations of this study derive from its explorative and initial nature and the small number of participants. However, we expect the qualitative data of the thoughts of the factory workers, the identified design implications and the suggested design solutions to provide value to the HCI (human-computer interaction) community. Even though this study focuses on factory work, the design implications and a part of the design solutions are applicable to other occupations as well. As the quantification of the workers is a new and significant topic, we hope that in the future, other studies will also focus on the ethical aspects, design alternatives and user perspective of this subject.

CONCLUSION

This study sheds light on the acceptability of a concept for providing personal production and self-tracking feedback to factory floor workers. The results encourage implementing the introduced Worker Feedback Dashboard prototype to a functional application. In broader scope, the results encourage the design of self-tracking systems for workers and involving workers in the design process. We hope that the identified UX goals and design implications provide useful guidance for practitioners and inspire the HCI community members working on the area of quantification or self-tracking at workplaces.

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PUBLICATION VI

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Heikkilä, P., Honka, A., Kaasinen, E., & Väänänen, K.

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